

Response of winter wheat to mineral and organic fertilization and liming on pseudogley soil of Western Serbia

Original Article

Abstract:

The tests were performed on the property of the Agricultural and Chemical School "Dr. Đorđe Radić" in Kraljevo. A trial involving the wheat cultivars Pobeda and NS 40S was conducted to evaluate the effect of different variants of mineral nutrients with lower and higher doses of phosphorus tested, as well as combinations of the same with lime and manure on the productive characteristics of winter wheat. The study was performed as an experiment based on extremely acidic pseudogley soil (pH <5.0). Trials were arranged according to a randomized scheme in five repetitions. Grain yield, 1000-grain weight and test weight in winter wheat grain were analysed. The highest yield was obtained was achieved with variant T5 fertilized with 120 kg/ha N, 100 kg/ha P₂O₅, 60 kg/ha K₂O, with 5 t/ha CaCO₃ and 20 t/ha manure in both cultivars (5.625 t/ha in Pobeda and 5.458 t/ha in NS 40S). The maximum 1000-grain weight was recorded in Pobeda under treatment 2 (43.84 g), while the highest test weight was found in Pobeda under treatment 3 (79.70 kg hl⁻¹) and in the control (79.58 kg hl⁻¹), and in NS 40S under treatment 4 (75.73 kg hl⁻¹). Analysis of variance revealed a highly significant effect of cultivar on 1000-grain weight and test weight, and a highly significant effect of fertilization treatments on grain yield. The results confirm the potential for achieving higher and more stable wheat yields on acidic soils through the application of different fertilization treatments, emphasizing the importance of combining mineral and organic fertilizers with lime.

Key words:

grain yield, test weight, wheat, yield components

Apstrakt:

Uticaj mineralnog i organskog đubrenja i kalcizacije na ozimu pšenicu gajenu na pseudogleju zapadne Srbije

Istraživanja su izvedena na oglednom dobru Poljoprivredno-hemijske škole „Dr Đorđe Radić“ u Kraljevu. Ogled sa sortama pšenice Pobeda i NS 40S postavljen je radi ispitivanja uticaja različitih varijanti mineralnog đubrenja sa nižim i višim dozama fosfora, kao i njihovih kombinacija sa krečom i stajnjakom, na proizvodne osobine ozime pšenice. Istraživanje je sprovedeno na izrazito kiselom pseudoglejnom zemljištu (pH < 5,0). Ogled je postavljen po slučajnom blok sistemu u pet ponavljanja. Analizirani su prinos zrna, masa 1000 zrna i hektolitarska masa zrna ozime pšenice. Najveći prinos ostvaren je u varijanti T5 đubrenoj sa 120 kg/ha N, 100 kg/ha P₂O₅ i 60 kg/ha K₂O, uz primenu 5 t/ha CaCO₃ i 20 t/ha stajnjaka kod obe sorte (5,625 t/ha kod sorte Pobeda i 5,458 t/ha kod sorte NS 40S). Najveća masa 1000 zrna zabeležena je kod sorte Pobeda u tretmanu 2 (43,84 g), dok je najveća hektolitarska masa utvrđena kod sorte Pobeda u tretmanu 3 (79,70 kg hl⁻¹) i u kontroli (79,58 kg hl⁻¹), kao i kod sorte NS 40S u tretmanu 4 (75,73 kg hl⁻¹). Analiza varijanse pokazala je visoko značajan uticaj sorte na masu 1000 zrna i hektolitarsku masu, kao i visoko značajan uticaj tretmana đubrenja na prinos zrna. Dobijeni rezultati potvrđuju mogućnost ostvarivanja većih i stabilnijih prinosa pšenice na kiselim zemljištima primenom različitih sistema đubrenja, pri čemu se posebno ističe značaj kombinovane primene mineralnih i organskih đubriva sa kalcizacijom.

Ključne reči:

prinos zrna, hektolitarska masa, pšenica, komponente prinosa

Introduction

By knowing the agrotechnical requirements of a specific variety and meeting them, it is possible to achieve yields that are close to those corresponding

to the maximum genetic potential for yield (Jevtić & Đekić, 2018; Terzić et al., 2018; Đekić et al., 2019; Đurić et al., 2020; Rajčić et al., 2021; Sekulić et al., 2022). All over the world, there are current

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experiments in which the influence of the amount and type of fertilizer on the yield and grain quality is being investigated, all to determine the optimal amounts of fertilizers that ensure optimal production (Iftikar et al., 2012; Zafaranaderi et al., 2013; Temneanu & Margitas, 2019; Zhang et al., 2022). In Serbia, the most common amounts of applied nitrogen range from 80 to 120 kg/ha depending on the agrochemical properties of the soil (Jaćimović et al., 2011; Živanović et al., 2017).

The full effect of NPK nutrients can only be realized if other factors that model yield are optimized (Biberdžić et al., 2014; Jelic et al., 2015). This especially applies to nitrogen due to its influence on grain yield and quality, but also due to its high mobility in the soil (Jelić et al., 2016; Rajičić et al., 2019). Of all the macroelements, nitrogen, phosphorus and potassium have the greatest influence on the normal growth and development of small grains. However, the effect of nitrogen on grain yield significantly decreases without other nutrients, especially phosphorus (Rajičić et al., 2020; Tmušić et al., 2021). Hence, there is increasing emphasis on the application of larger amounts of phosphorus fertilizers, i.e. NPK-fertilizers with a higher proportion of phosphorus, because the influence of phosphorus nutrition is particularly pronounced in both acidic, and most other degraded soils (Jelić et al., 2014; Terzić et al., 2025a). Acidity, alkalinity, salinity, monoculture, wind, water and erosion are the main factors in the degradation of agricultural soils (Đekić et al., 2013; Hristovet et al., 2013; Djuric et al., 2018; Luković et al., 2020; Biberdžić et al., 2021). On acid soils, the application of mineral fertilizers in combination with lime and manure reduces the acidity of the soil, resulting in an increase in the yield of cultivated crops (Biberdžić et al., 2014; Jelic et al., 2015). This kind of production of cereals on acid soils is more expensive, due to the high price of mineral, lime and organic fertilizers, so there is the issue of its profitability (Babić et al., 2023).

Organic and microbiological fertilizers play a significant role in modern agriculture by improving plant access to nutrients such as nitrogen and phosphorus and increasing resistance to abiotic stresses caused by climate change. These fertilizers facilitate symbiotic relationships between plants and beneficial microorganisms in the rhizosphere, leading to the exchange of bioactive compounds that improve crop growth, yield and quality (Cvijanović et al., 2022; Rakašćan et al., 2021; Popović et al., 2022; Ljubičić et al., 2023; Rajičić et al., 2025; Terzić et al., 2025b, 2026). Manure is an organic fertilizer that has multiple roles, as it contains the necessary nutrients for plant nutrition, improves soil structure, increases the soil's ability

to retain water by preventing nutrient leaching, and improves long-term soil fertility and increases yield (Jelić et al., 2015; Babić et al., 2023).

Acidic soils limit plant growth through a chain of interrelated processes that simultaneously affect the soil's chemical, physical, and biological functions. On acidic soils, phosphorus becomes more soluble and becomes practically unavailable to plants, which is why the plant appears weak, yellow, and slow growing. Acidic soils act as an invisible limiting factor. The soil may have sufficient water and nutrients, but the plant cannot access them, resulting in yield decreases. Calcification has far more effects than just neutralizing acidity, because it reduces the toxicity of aluminum and manganese, provides calcium and magnesium, increases the availability of phosphorus and molybdenum, increases microbiological activity, and increases aggregate stability (Jelic et al., 2015). Calcification application improves plant roots, enhances soil structure, and significantly increases plants' resistance to drought, thereby reducing soil acidity and increasing the yield (Biberdžić et al., 2014).

Wheat production in Serbia depends to a large extent on the environmental factors. Climate change poses significant challenges for wheat production, frequent and intense weather extremes, including droughts and irregular distribution of precipitation, negatively affect grain yield and quality (Luković et al., 2014; Biberdžić et al., 2020; Sekulić et al., 2022; Rajičić et al., 2023). Climatic conditions (temperature and precipitation) and fertilization are the two main factors that affect the yield and quality of wheat grains (Đekić et al., 2015; Đurić et al., 2016; Popović et al., 2020; Ljubičić et al., 2021; Rajičić et al., 2025; Terzić et al., 2025b, 2026).

While the general benefits of combined fertilization on acidic soils are documented, there is a lack of precise data on how specific, widely cultivated winter wheat genotypes (such as Pobeda and NS 40S) respond to integrated nutrient management under the highly unstable climatic conditions of Western Serbia. This study fills this gap by investigating the combined effects of mineral fertilizers, lime, and manure on an extremely acidic pseudogley soil during a growing season characterized by irregular rainfall pattern.

Material and Methods

Materials and field trials

The tests were performed on the property of the Agricultural and Chemical School "Dr. Đorđe Radić" in Kraljevo (43°43'00"N, 20°40'60"E, 198 m above sea level), on pseudogley soil during the 2017/2018 growing season in dry crop conditions,

with the aim of analysing the yield and quality of winter wheat grains in Western Serbia. The experiments were set up according to a randomized block system with a plot size of 5 x 10 m² in five replicates. The experiment included five treatments of fertilizers and their combinations (T1-control; T2-120 kg/ha N, 80 kg/ha P₂O₅ and 60 kg/ha K₂O; T3-120 kg/ha N, 100 kg/ha P₂O₅ and 60 kg/ha K₂O; T4-120 kg/ha N, 80 kg/ha P₂O₅ and 60 kg/ha K₂O and 5 t/ha lime and 20 t/ha manure and T5-120 kg/ha N, 100 kg/ha P₂O₅ and 60 kg/ha K₂O and 5 t/ha lime and 20 t/ha manure). Fertilization with the stated amounts of nutrients was performed regularly according to the established schedule. The total amount of phosphorus, potassium, lime and manure fertilizers was applied before sowing together with half of the nitrogen fertilizer, while the other half of the nitrogen was applied in one supplementation in the phase of full rooting, at the end of winter or at the beginning of spring.

The winter wheat varieties Pobeda and NS 40S originating from the Institute of field and vegetable crops, Novi Sad was selected as the material for the experiment. Sowing was done in the second decade of October. Other care measures implemented during the vegetation period were standard.

The following properties were analyzed: grain yield (t/ha), 1000-grain weight (g) and test weight (kg/hl). Grain yield was measured for each plot and converted to grain yield in t/ha based on 14% grain moisture, after which a sample was taken for analysis of 1000 grain weight and test weight of the wheat.

Soil conditions

The trial at the secondary agricultural-chemical school “Dr. Đorđe Radić” in Kraljevo was performed on pseudogley soil of unfavourable physical characteristics and of poor water-air regime with frequent water or air deficiencies. According to the results of agrochemical analysis, the soil is

acidic (pH in H₂O 5.42 and pH in KCl 4.46), poor in humus (2.19%), poor in available phosphorus (<10 mg/100 g of soil) and provided with a medium quantity of readily available potassium (13-18 mg/100 g of soil). The soil was analysed using chemical methods: soil pH value was determined in a 1:2.5 soil-to-1 M KCl suspension after a half-hour equilibration period; hydrolytic acidity by Ca acetate extraction using Kappen’s method; the sum of exchangeable basic cations by Kappen’s method; humus content by Kotzmann’s method; total nitrogen by Kjeldahl, and available P₂O₅ and K₂O levels by the Egner-Riehm Al method.

Meteorological conditions

The research was conducted during 2017/2018 consecutive season in the Raška district, Central Serbia, on pseudogley soil, in the secondary agricultural school “Dr. Đorđe Radić”, in Kraljevo (43° 43’00’’N, 20° 40’60’’E). The study area is Kraljevo, located at an altitude of 192 to 217 m in the zone of temperate continental climate, with an average annual temperature of 11.5 °C and the amount of precipitation of about 580 to 790 mm.

The data (Tab. 1) for the investigated period indicate that the average air temperature was higher than the annual average by 0.8 °C. The data clearly shows differences in weather conditions between the year of the study and the long-term mean for the region the wheat growing season analyzed. The total amount of precipitation in the vegetation in 2017/18 was 758.7 mm. The total amounts of rainfall were above the perennial average in the surveyed growing season (2017/18), with a rather uneven monthly distribution. Weather conditions in the growing period in 2017/18 were marked by high rainfall during March, while rainfall in April was significantly lower. Variable and moderately warm weather, with less precipitation than average, marked May 2017/18. During the run of the experiment, the differences between the mean

Table 1. Mean monthly air temperatures and precipitations in Kraljevo, Serbia (2017/2018), in relation to many years average

Interval	Months									
	X	XI	XII	I	II	III	IV	V	VI	Average
Mean monthly air temperature (°C)										
2017/18	11.9	6.8	4.0	2.7	2.0	6.5	16.6	19.1	20.9	10.0
Average	11.6	7.7	2.0	0.6	3.3	7.9	12.5	16.3	20.9	9.2
The amount of precipitation (mm)										
2017/18	133.3	32.4	55.6	51.0	80.9	111.2	40.6	84.4	169.3	758.7
Average	73.4	37.8	56.0	48.6	51.5	80.8	80.3	112.1	82.4	622.9

precipitation values and the perennial average in the year of the study were the highest in March and June. Higher precipitation and their better distribution in 2017/18, especially in October, March and June, contributed to better fertilizer decomposition and higher wheat grain yield.

It was found that newly created high-yielding varieties of wheat are less responsive to temperature deviations (except extremes) than is the case with precipitation (Milovanović et al., 2012; Luković et al., 2016; Đurić et al., 2018; Đekić et al., 2019; Terzić et al., 2022). Namely, the total amount of precipitation is reflected in the multi-year average, but the schedule, especially in the critical phases of development, is significantly disturbed. It has been determined that winter precipitation significantly affects the realization of the production potential of wheat (Dimitrijević et al., 2011; Hristov et al., 2014; Jocković et al., 2014; Perišić et al., 2016; Terzić et al., 2018; Rajičić et al., 2021). In addition to the necessary reserves for the spring part of the vegetation, winter precipitation greatly affects the distribution of easily accessible nitrogen in the soil (Jelić et al., 2015; Đekić et al., 2018; Rajičić et al., 2025; Terzić et al., 2025a).

Statistical analysis

Experimental data were analysed using descriptive and analytical statistics in GenStat (2013). A two-way analysis of variance (ANOVA) was applied, with genotype (cultivar) and fertilisation treatments modelled as fixed factors, and replicates (blocks) as random effects. The significance of differences between means was evaluated using the LSD test at $p < 0.05$ and $p < 0.01$ probability levels.

Results and Discussion

Grain yield and yield components

The average values of productive grain yield and yield components of the investigated winter wheat varieties grown in the secondary agricultural-chemical school “Dr. Đorđe Radić” in Kraljevo are shown in **Tab. 2**. The integration of mineral NPK with lime and organic manure (T5) resulted in the highest grain yield across both cultivars. Interestingly, while the absolute yield was highest in T5, the relative response to soil amelioration differed between cultivars. Pobeda exhibited greater adaptability to acidic soil than NS 40S, particularly when organic matter was combined with lime. This suggests that the “Pobeda” variety better utilises the improved nutrient availability following the reduction of hydrolytic acidity. Chemical changes in the rhizosphere justify the highly significant effect of the treatment on grain yield. The application of

lime and manure reduces hydrolytic acidity, thereby increasing the availability of bound phosphorus and activating soil microbial activity. The pronounced genotypic specificity and the significance of the genotype $\times$ treatment interaction for grain yield confirm that the Pobeda variety has a higher degree of adaptability and stability on acidic soils compared to the NS 40S variety. This variability is consistent with previous research. Terzić et al. (2018) highlight average wheat yields of 5,091 t/ha with significant annual fluctuations, while Đekić et al. (2019) also highlight genotypic adaptability (Kruna variety) as a crucial factor in a wide range of yield variations (3,743 to 6,275 t/ha). Biberdžić et al. (2020) and Terzić et al. (2022) confirm that yield varies widely depending on genotype and pedoclimatic conditions (ranging from 3,464 to 6,865 t/ha). Similar to our results, Rajičić et al. (2025) state that on acidic soils, the application of a complex treatment that includes manure, limestone and mineral fertilizers creates the highest yields (in the Ikona genotype, up to 7.37 t/ha), while on control variants without fertilization, yields decrease drastically (up to 3.12 t/ha), which is in accordance with research. ANOVA revealed that fertilisation treatments did not exert a statistically significant effect on either 1000-grain weight or test weight ($p > 0.05$). This indicates that these physical grain characteristics are primarily under tight genetic control in the genotypes investigated, as further supported by the highly significant cultivar effect ($p < 0.01$). Cultivar Pobeda maintained higher values for both traits compared to NS 40S across all environments. Although minor numerical fluctuations were observed among treatments (e.g., maximum 1000-grain weight of 43.84 g in Pobeda under T2), these differences lack statistical support and should not be over-interpreted as biological responses to fertilisation. This aligns with the findings of Perišić (2016), who notes that grain dimensions are predominantly varietal traits and are relatively cushioned against minor nutrient fluctuations. Analysis of variance showed that the applied fertilisation treatments had no statistically significant direct effect on 1000-grain weight and hectoliter weight. From an agronomic point of view, this indicates that the grain's physical characteristics are primarily under strong genetic control, confirming the highly significant influence of the genotype. Previous research (Terzić et al., 2018; Rajičić et al., 2023) also confirms that the weight of 1000 grains is a hereditary trait. In earlier studies by Jelić et al. (2015), Tmusic et al. (2021), and Terzić et al. (2025a), a positive effect of intensive nitrogen fertilisation on increases in 1000-grain weight and hectoliter weight was observed. In this experiment, the absence of a direct, statistically significant effect

Table 2. Average values of investigated winter wheat varieties traits

Treatments	Pobeda			NS 40S			Average		
	x	Sd	Sx	x	Sd	Sx	x	Sd	Sx
Yield, t/ha									
T1	2.975	0.094	0.042	2.927	0.176	0.079	2.951	0.135	0.043
T2	3.873	0.414	0.185	3.304	0.429	0.192	3.589	0.498	0.157
T3	4.486	0.528	0.236	4.472	0.266	0.119	4.479	0.394	0.125
T4	5.203	0.089	0.040	5.096	0.206	0.092	5.149	0.160	0.050
T5	5.625	0.179	0.080	5.458	0.364	0.163	5.541	0.285	0.090
Average	4.432	1.006	0.201	4.252	1.045	0.209	4.342	1.019	0.144
1000 grain weight, g									
T1	41.17	1.356	0.606	35.26	1.359	0.608	38.22	3.371	1.066
T2	43.84	1.427	0.638	34.70	0.704	0.315	39.27	4.936	1.561
T3	40.98	0.655	0.293	30.22	0.372	0.166	35.60	5.693	1.800
T4	40.82	1.192	0.533	34.45	0.636	0.284	37.64	3.479	1.100
T5	39.53	0.576	0.258	33.30	0.563	0.252	36.42	3.327	1.052
Average	41.27	1.755	0.351	33.58	1.977	0.395	37.43	4.300	0.608
Test weight, kg/hl									
T1	79.58	0.303	0.136	74.05	0.245	0.109	76.81	2.926	0.925
T2	78.81	0.431	0.193	74.77	0.228	0.102	76.79	2.154	0.681
T3	79.70	0.316	0.141	72.85	0.316	0.141	76.27	3.623	1.146
T4	78.86	0.261	0.117	75.73	0.228	0.102	77.29	1.666	0.527
T5	79.14	0.261	0.117	75.05	0.490	0.219	77.09	2.187	0.692
Average	79.22	0.473	0.095	74.49	1.042	0.208	76.85	2.519	0.356

of fertilisation on these parameters is explained by the fact that the stresses due to the lack of moisture and nutrients in acidic soil limited grain filling during the critical stages.

Test weight

The test weight of winter wheat varied significantly across genotypes and treatments (**Tab.2**). The test weight varied across treatments from 76.27 kg/hL in the T3 to 77.09 kg/hL (T5) and 77.29 kg/hL (T4) in treatments where a combination of NPK was applied with higher and lower content of phosphorus, lime and organic fertilizers. In the genotype Pobeda, the test weight varied across treatments from 78.81 kg/hL in the variant T2 to 79.70 kg/hL in the fertilizer variant T3, where a combination of NPK was applied with increased content of phosphorus. In the genotype Ns 40S, the test weight varied across treatments from 72.05 kg/hL in the variant T3 to 75.73 kg/hL in the fertilizer variant T4, where a combination of NPK

was applied with lower content of phosphorus, lime and organic fertilizers.

During the two-year study, Jevtić and Đekić (2018) point out that the test weight, of the tested wheat varieties, ranged from 69.5 to 71.03 kg/hL. Biberdžić et al. (2020), regarding the optimal wheat sowing date, have found that the hectolitre weight of grain was 71.42 kg/hL, while in the case of later sowing it was 69.96 kg/hL, which does not represent a statistically significant difference.

According to the authors Terzić et al. (2022) the average value of test weight during the two-year research was 75.60 kg/hL, ranging from 73.73 kg/hL to 78.18 kg/hL. The same authors emphasize that the highest value of hectoliter weight in both examined years was achieved by the variety Zvezdana (77.35 kg/hL and 79.00 kg/hL). Rajičić et al. (2025) point out that the highest average test weight values were measured in the genotype Ikona during the first year of investigation for treatments F4 (76.60 kg/hL) with NPK, lime, manure and

microbiological fertilizer and F2 (76.03 kg/hl) with NPK and microbiological fertilizer.

Analysis of variance between observed traits of wheat

Analysis of variance for grain yield, 1000-grain weight and test weight of winter wheat genotypes with the application of different fertilization treatments, are shown in **Tab. 3**.

Analysis of variance in winter wheat cultivars tested showed statistically highly significant differences in 1000-grain weight and test weight in relation to the genotype ($p < 0.01$). Fertilization treatments had a highly significant impact on wheat grain yield, whereas it was not statistically significant concerning the average values of the 1000-grain weight and test weight among the tested wheat genotypes. The interaction between genotype and treatments showed a statistically significant impact in the average values of the yield, 1000-grain weight and test weight among the two wheat genotypes, are shown in **Tab. 2**.

Jelić et al. (2015) found significant impacts of weather conditions on the yield and quality of winter wheat grain. The combined use of NPK fertilizers, lime, and manure positively influenced the grain yield of winter wheat. According to Rajičić et al. (2020) and Tmušić et al. (2021), the response of wheat to fertilization with 80 and 120 kg/ha N compared to unfertilized treatments was significantly more pronounced in unfavourable years. The same

authors emphasize that wheat grown on acidic soils has significantly higher productivity when fertilized with NPK fertilizers compared to soils that are not acidic. According to the findings of Cvijanović et al. (2022), significant influences on yield were attributed to varieties and the interaction of density x variety, while treatments during fertilization had a notable impact. Previous research results indicate the need for continuous determination of the quantities and ratios of nutrients required under specific agro-ecological conditions, especially since the amount of applied nitrogen interacts with soil reaction and agro-meteorological conditions. Rajičić et al. (2025) determined that different fertilization regimes, annual climatic conditions and genotype significantly affected wheat yield. However, the interaction among these factors did not show statistically significant differences in the achieved average grain yields, except for the interaction between year and treatment, which demonstrated a statistically very significant effect on the obtained average grain yield.

The variance analysis conducted by Rajičić et al. (2020) identified a statistically significant difference in the 1000-grain weight between growing seasons and fertilization treatments, as well as the interaction between fertilization treatments and growing seasons. The findings align with those of other researchers who assert that the 1000-grain weight is genetically determined; however, this trait is influenced by the growing season and fertilization methods (Terzić

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

Effect of genotype on the traits analyzed				
Traits	Mean sqr Effect	Mean sqr Error	F (1. 48)	p-level
Grain yield (t/ha)	0.408	1.051	0.388	0.536 ^{ns}
1000-grain weight (g)	738.356	3.495	211.280	0.000**
Test weight (kg/hl)	279.425	0.655	426.407	0.000**
Effect of treatments on the traits analyzed				
Traits	Mean sqr Effect	Mean sqr Error	F (4. 45)	p-level
Grain yield (t/ha)	11.528	0.106	109.147	0.000**
1000-grain weight (g)	21.080	18.262	1.154	0.344 ^{ns}
Test weight (kg/hl)	1.484	6.777	0.219	0.926 ^{ns}
Effect of the treatments x genotype interaction				
Traits	Mean sqr Effect	Mean sqr Error	F (9. 40)	p-level
Grain yield (t/ha)	5.225	0.096	54.409	0.000**
1000-grain weight (g)	96.561	0.926	104.248	0.000**
Test weight (kg/hl)	34.090	0.102	335.036	0.000**

*Statistically significant ($p < 0.05$); **Statistically high significant ($p < 0.01$)

et al., 2018; Rajičić et al., 2023). Cvijanović et al. (2022) found a highly significant difference in the interaction between years and treatments.

The test weight of grains is significantly influenced not only by genotype but also by the growing environment and the type and amount of fertilizer applied, which is a key factor affecting yield quantity and quality. However, it must be aligned with climatic and soil conditions and the requirements of the variety (Rajičić et al., 2020; Cvijanović et al., 2022; Terzić et al., 2026). Tmušić et al. (2021) point out that genotype, environment, and the interaction of genotype x environment influence test weight. The data obtained from Rajičić et al. (2025) indicate a statistically significant influence of the year, genotype and treatments on test weight was statistically very significant, and the interaction of all three factors demonstrated a statistically significant effect on test weight. It is important to acknowledge that the current study is based on a single growing season (2017/2018), which limits the generalisation of the conclusions regarding long-term climatic stability. Inter-annual weather variability in Western Serbia is often high, which heavily influences wheat responsiveness to fertilisation. This specific hydrometeorological regime, characterised by alternating periods of drought and excessive moisture during the critical stages of plant development and grain filling, further exacerbated the poor physicochemical properties of the pseudogley soil, namely its tendency toward waterlogging and surface crusting. However, from an ecological standpoint, this season represents an exceptionally representative model for testing fertilisation efficiency under environmental stress. The 2017/2018 growing season was characterised by average temperatures 0.8 °C higher than the long-term average and a total precipitation of as much as 758.7 mm, which was highly unevenly distributed (marked by extreme cycles of surplus in March and June and a severe deficit in April). Therefore, these results, although spanning only a single year, accurately reflect the functional value of ameliorative fertilisation (T5) as an agrotechnical buffer under pronounced climatic extremes.

Conclusion

The application of integrated fertilization (NPK + Lime + Manure) is essential for achieving yields above 5.5 t/ha on acidic pseudogley. While grain yield is highly responsive to fertilization, 1000-grain weight and test weight are more dependent on the choice of cultivar. This study confirms that for sustainable production on marginal soils, the selection of an adaptable genotype is as crucial as

the amelioration of soil acidity.

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