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Inheritance of Grain Yield and Protein Concentration in Recombinant Wheat Lines from a Cross between Contrasting Parents

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ABSTRACT

The development of productive wheat genotypes that combine high yield with high grain protein content represents a key objective for wheat breeders worldwide. In this study, two parental lines showing contrasting characteristics for these traits - grain yield and protein concentration - were selected: Unitar and FDL Amurg. The Unitar line, serving as the high-yield parent, is an advanced Romanian breeding line derived from a cross between mutants of cultivar Izvor and the breeding line 00628G34 (M1 Izvor/M1 00628G34). FDL Amurg, originates from the cross Murga/F03124G//Pitar, where Murga, developed in Mexico, carries genetic material introgressed from *Aegilops tauschii*, while Pitar is a Romanian variety known for its outstanding bread-making quality. The high protein content in FDL Amurg may be attributed to the genes introduced from *Aegilops tauschii* via Murga, possibly complemented by favorable alleles from the Pitar cultivar. A total of 140 F5-3 lines were randomly selected from the Unitar × FDL Amurg cross and evaluated during two successive growing seasons (2023-2024 and 2024-2025), along with the parental lines replicated five times, as controls. The results indicated a significant negative correlation between grain yield and protein content among the parents: FDL Amurg line consistently produced grain with higher protein concentration, but lower yield compared to Unitar line. In contrast, among the derived lines, no significant correlation between the two traits was observed. Several progeny lines exceeded Unitar in grain yield; however, none surpassed FDL Amurg in grain protein percentage We identified wheat lines that combined improved yield potential with enhanced grain protein content, achieving a better balance between productivity and grain quality than either parent alone.

Keywords: wheat recombinant lines, protein %, yield, regression GY/GPC, deviations.

INTRODUCTION

Wheat remains one of the most cultivated cereals of the world and plays an important role in maintaining food security.

Two of the main objectives of all breeding programs are grain yield and grain protein concentration.

Despite significant breeding progress, yield levels in wheat have remained relatively low and stagnant under marginally growing environments. There is a need for genetic improvement of wheat using yield-promoting morpho-physiological attributes and desired genotypes under the target production environments to meet the demand for food and feed (Tshikunde et al., 2019).

Protein content is a critical quality indicator, but its importance differs significantly between producers (farmers) and processors (bakers), influencing both the selling price and the technological process. For farmers, the protein content of wheat is directly related to profitability and selling price, while for bakers, it is essential for the functional quality of the flour and the success of the finished product.

This high protein requirement means that farmers often must apply more nitrogen fertilizer, which leads to higher production costs, increased energy requirement for fertilizer production and the potential environmental footprint. Although it may be possible to reduce the protein requirement for breadmaking by modifying the breadmaking process, this has proved to be difficult to achieve, and attention has focused on increasing GPC at lower nitrogen fertilization (Richard et al., 2025).

Carbon and nitrogen management in plants is closely linked at the physical and biochemical levels (Bogard et al., 2010). This

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is reflected in negative correlation between grain yield and grain protein content, observed in different various cereals (Monaghan et al., 2001; Oury et al., 2003; Oury and Godin, 2007; Bogard et al., 2010) but over the time, the breeders tried to identify wheat genotypes that deviated from the regression between the two traits. Positive deviations reflect greater nitrogen use efficiency and is an important target for breeders to develop more sustainable types of wheat (Richard et al., 2025).

Marinciu et al. (2018) found that Profund (having the same genealogy as FDL Amurg line) line had highest deviation from the regression of protein % on grain yield (+1.24%) and highest protein concentration (13.9%) at an average yield of 6012 kg/ha. This was attributed by Marinciu et al. (2020) to higher post-anthesis Nitrogen uptake. In contrast, Unitar line showed negative deviation of -0.29% and a protein concentration of 11.7% at an average yield of 6689 kg/ha.

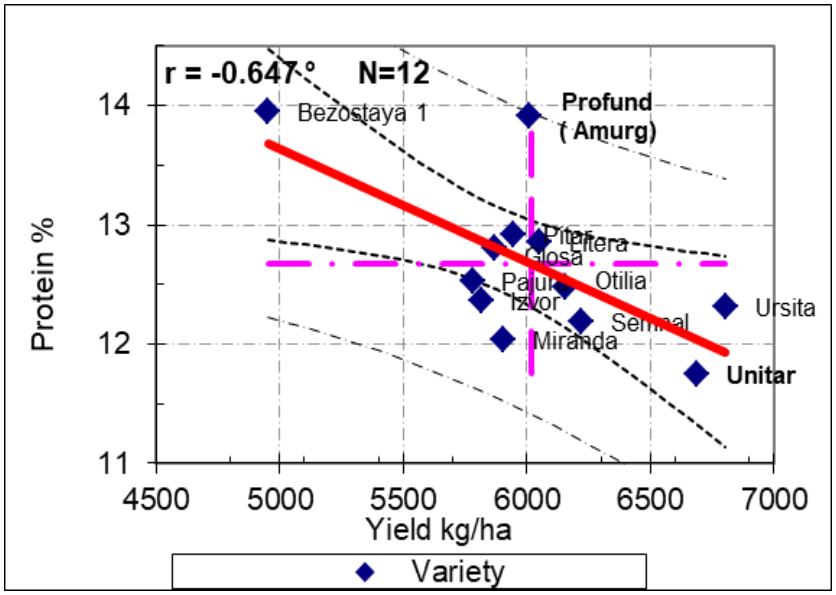

Figure 1. Relationship between average grain yield and grain protein concentration in 25 yield trials performed in 2016 and 2017 (r = -0.62*) (Marinciu et al., 2018)

Under organic agriculture conditions, the line FDL Amurg had on average a grain protein content more than 1% higher than expected based on the regression (Marinciu et al., 2022) and Şerban et al. (2022) found that this high grain protein concentration was associated with good bread making quality indices.

The aim of this research was to identify wheat recombinant lines with higher grain yield than the highest-yielding parent, Unitar, while having improved protein concentration.

MATERIAL AND METHODS

Testing conditions

The testing field was placed at National Agricultural Research and Development Institute Fundulea (NARDI Fundulea), Lat. 44°30`N, Long. 26°51`E, on chernozem soil with pH=5.8 and humus content 3.4%, during two seasons, 2023-2024 and 2024-2025.

Weather conditions

In both seasons the temperatures were higher than the multiannual average temperature (calculated for the last 60 years), so the average temperature in the 2023-2024 season exceeded the r[illegible]nual average temperature by 4.4°C [illegible] the average temperature in the 2024-2025 season exceeded the multiannual average temperature by 2.1°C, which means that global warming was also manifested in this area.

The rainfall in these two seasons was lower than the average multiannual rainfall for this area, being unevenly distributed; the 2023-2024 season was characterized by drought conditions during winter and grain

filling; the amount of rainfall during the season was 308.8 l/m^2 (106.2 l/m^2 less than the average multiannual rainfall) while the amount of rainfall during the 2024-2025 season was 328.8 l/m^2 (86.2 l/m^2 less than average multiannual rainfall).

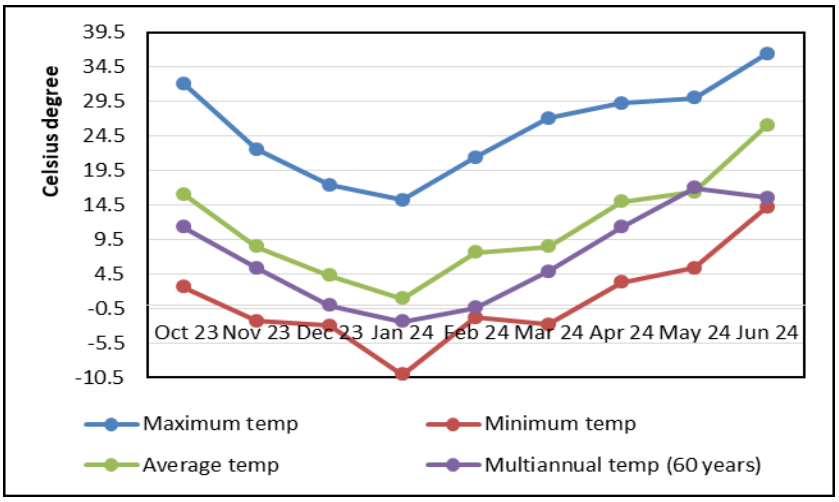

Figure 2. Temperatures registered during 2023-2024 season, compared to average multiannual temperature

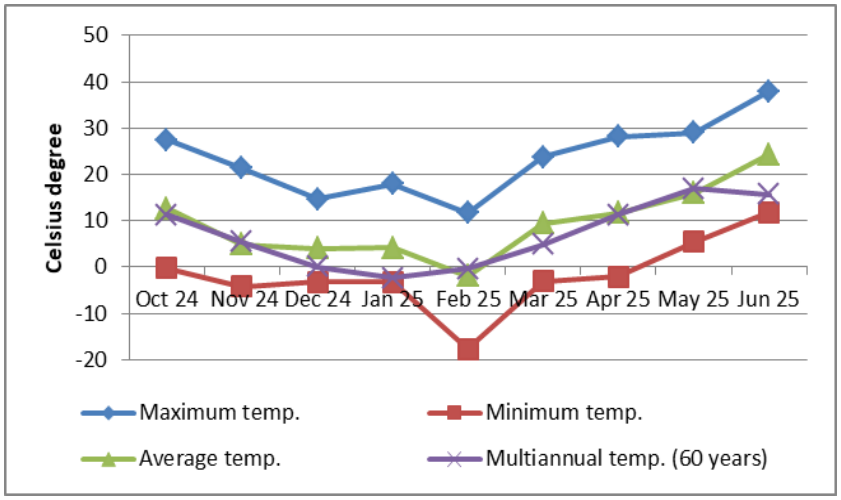

Figure 3. Temperatures registered during 2024-2025 season, compared to average multiannual temperature

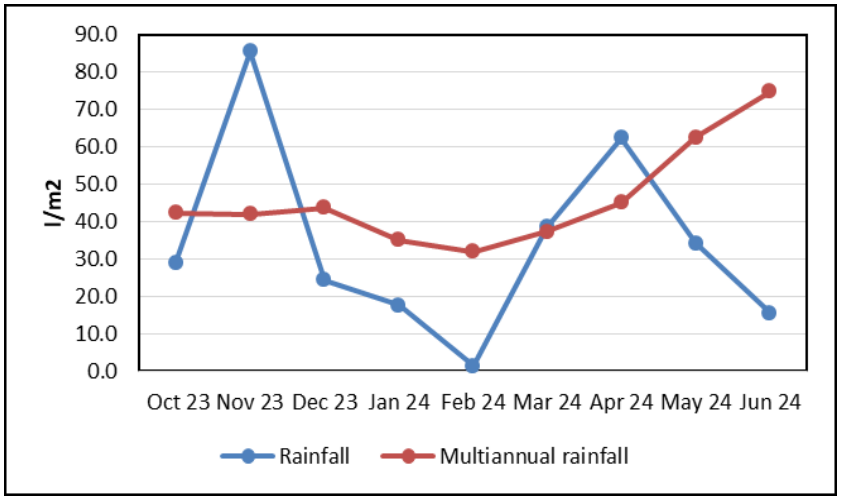

Figure 4. Rainfall during 2023-2024 season compared to multiannual rainfall

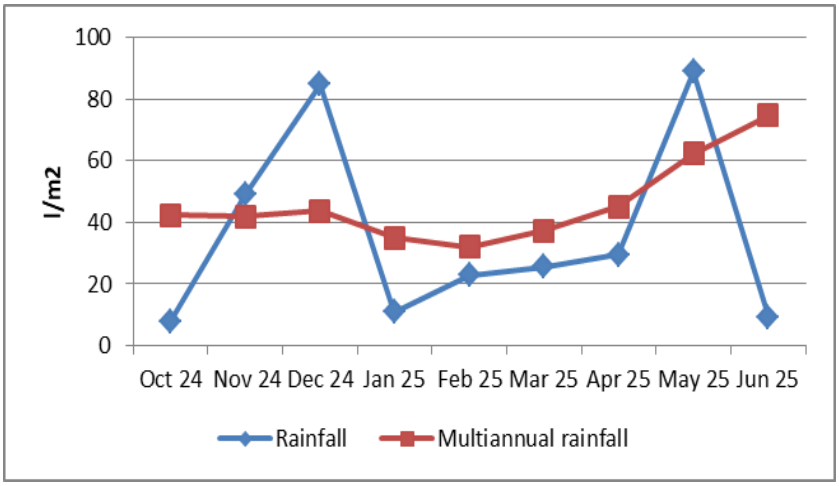

Figure 5. Rainfall during 2024-2025 season compared to multiannual rainfall

Tested materials

One hundred-forty F5-3 lines randomly extracted from the cross Unitar/FDL Amurg were tested on six m^{-2} plots, along with the two parents replicated five times. Unitar is an advanced breeding line, obtained from two Romanian mutant lines, M1 Izvor/M1 00628G34 and was used as higher yielding parent, while FDL Amurg is an advanced breeding line obtained from the cross Murga/F03124G//Pitar which was used as highest quality parent. Murga is a Mexican cultivar derived from a cross with *Aegilops tauschii* and Pitar is a Romanian variety with very good quality properties.

Quality parameters (grain protein content and dough strength - W) were determined with a FOSS Infratec 1241 Grain Analyzer.

Linear regression was utilized to describe the relationship between grain yield and grain protein content, as well as between yield and dough strength (W).

RESULTS AND DISCUSSION

The correlation between grain yield and grain protein content in the two parents was significantly negative, with all FDL Amurg plots having higher grain protein but lower yields than Unitar plots (Figure 6).

Grain protein content varied between 13.5-15.7% in Unitar line with an average value of 14.6% and between 14.9-16.8% in FDL Amurg line with an average value of 16.0 %. Grain yield varied between 4630-6381 kg/ha in Unitar with an average value of 5391 kg/ha and between 4198-5976 kg/ha in FDL Amurg line with an average value of 4997 kg/ha.

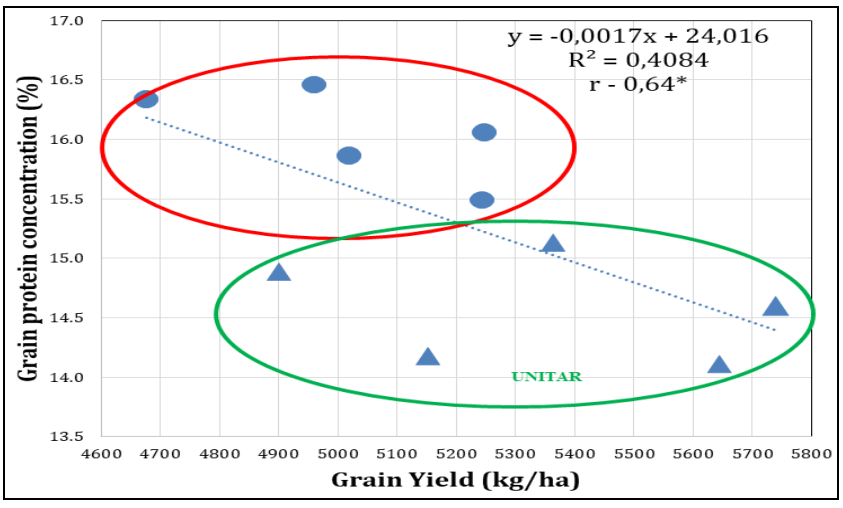

Figure 6. Relationship of protein concentration on grain yield in plots with the parents Unitar and FDL Amurg

Grain protein content varied between 13.1-16.7% in F5-3 recombinant lines with an average value of 14.8%. Grain yield varied between 3762-6867 kg/ha in F5-3 recombinant lines with an average value of 5243 kg/ha.

There was no correlation between grain yield and protein concentration in lines randomly extracted from the cross Unitar/FDL Amurg (Figure 7). Many lines over yielded the higher yielding parent Unitar, but no line had higher protein concentration than FDL Amurg. Many recombinant lines from the cross Unitar/FDL Amurg, over yielded the highest yielding parent Unitar, suggesting that FDL Amurg line contributed with favorable alleles for yield, despite being lower yielding itself.

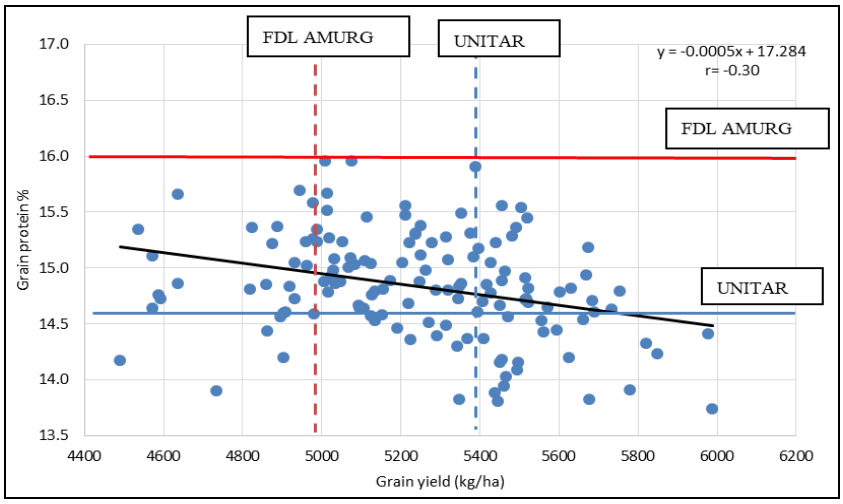

Figure 7. Relationship of protein concentration on grain yield in random recombinant lines from the cross Unitar/FDL Amurg

Deviations from regression of grain protein % on grain yield have been suggested as a way of identifying genotypic differences in nitrogen storage efficiency (Monaghan et al., 2001; Oury and Godin, 2007, Marinciu and Săulescu, 2008). There was a very large genetic variation between the recombinant lines, regarding the deviations from regression, ranging from -1.17 +1.13 %. Seventy-one recombinant lines presented positive deviations from the regression, twenty of them over 0.5 % (Figure 8). Five recombinant lines with positive deviations over 0.5% registered yields over the highest-yielding parent Unitar.

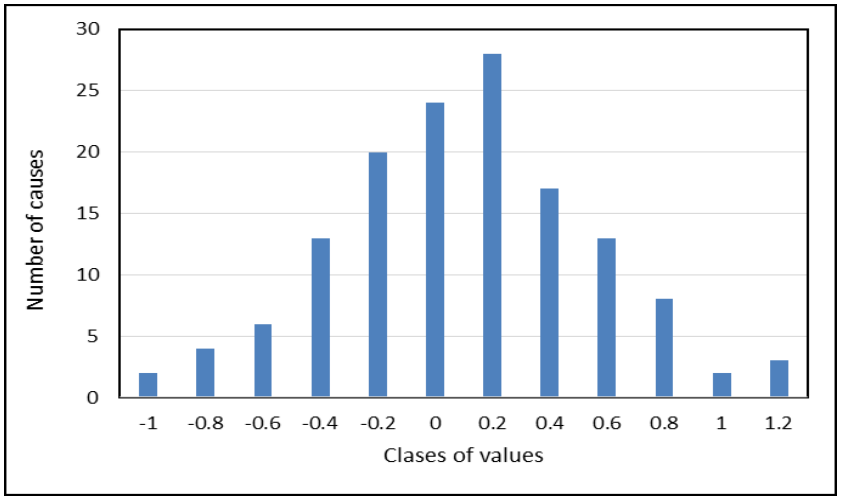

Figure 8. Histogram of deviations from GPC/GY regression

No recombinant F5-3 recombinant line reached the dough strength (W) level of the best parent FDL Amurg, but many lines had both better W and better yield than Unitar.

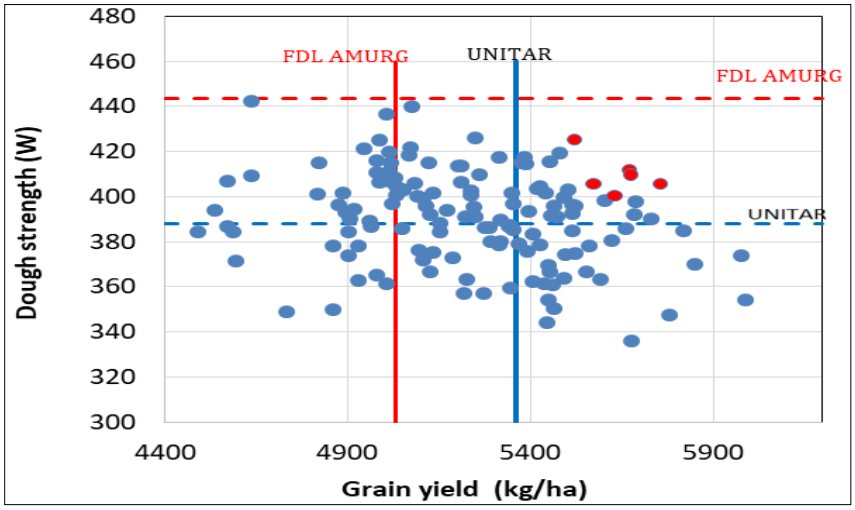

Figure 9. Relationship of dough strength (W) on grain yield in random recombinant lines from the cross Unitar/FDL Amurg

CONCLUSIONS

In our study, several recombinant wheat lines over yielded the highest yielding parent, Unitar, while having improved protein concentration. These results suggest that the parent FDL Amurg contributed with favorable alleles for grain yield, despite its lower yield performance.

In contrast, no recombinant line was better than FDL Amurg for protein concentration or dough strength, confirming the difficulty of simultaneously improving yield and end-use quality traits. Lines combining high values for yield and protein concentration will be useful in the wheat breeding program at National Agricultural Research and Development Institute Fundulea (Fundulea), hoping that they will break the well-known negative relationship between grain yield and grain protein content, leading to breeding cultivars with these traits within the desired parameters.

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