

CORRELATIONS BETWEEN MORPHOLOGICAL, QUALITY, AND PRODUCTION TRAITS IN WHEAT

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Abstract: Climate change and the increasing demand for wheat are major factors that could influence the breeding program to accelerate the process of introducing new varieties to the market. However, the long time required for the development of new wheat varieties blocks the cycle of introducing new genotypes adapted to new climatic conditions. In this study, we evaluated 10 commercial wheat varieties in two seasons, 2025 and 2026, at the Institute for Agricultural Research and Development (SCDA) Lovrin. We evaluated several morphological, quality and yield traits in wheat to find a correlation model in the selection of new wheat. According to our results, plant height ($p < 0.05$), protein content ($p < 0.001$) and starch content ($p < 0.01$) recorded a significant involvement of the genotype factor. On the other hand, the genotype factor did not influence grain yield ($p > 0.05$), spike length ($p > 0.05$), hectoliter weight ($p > 0.05$) or thousand-grain weight ($p > 0.05$). Furthermore, correlation analysis revealed a strong negative correlation between protein content and starch content ($r = -0.96$), a negative correlation between protein content and hectoliter weight ($r = -0.72$) and a positive correlation between hectoliter weight and starch content ($r = 0.68$). The results provide a perspective for further studies, with more genotypes involved and more locations, to reveal a more pronounced pattern of correlation, which may be beneficial for breeding programs in selection processes.

Keywords: wheat breeding; traits correlation analysis; principal component analysis (PCA);

INTRODUCTION

Wheat (*Triticum aestivum* L.) is one of the most important cereal crops worldwide. According to the Food and Agriculture Organization (FAO), global wheat production exceeds 770 million tons annually, placing it among the most widely cultivated crops. There are 220 million hectares cultivated worldwide (FILIP et al., 2023). Currently is estimated that global demand for wheat by 2050 is predicted to increase by approximately 50%. Therefore, developing new varieties of wheat of better adaptability is a crucial factor in the breeding process.

Climate change has become one of the biggest factors affecting wheat yields and grain quality globally. Also, increasing temperature and irregular precipitation patterns may negatively the wheat cultivation. Therefore, developing wheat cultivars capable of maintaining stable performance under variable environmental conditions is the major objective for every breeding program. Studies revealed the by using biotechnology, such markers assisted selection, gene editing or haploids could be a beneficial application for the breeding programs

(CIPRIAN et al., 2024; ONISAN et al., 2023; ONISAN et al., 2025). However, this may not be the case in conventional breeding programs. The conventional strategy could be to introduce selection through salt exposure. It is well known that salt has been shown to be like drought tolerance, therefore, by evaluating in this way, selections in breeding programs could be shortened. Also, finding correlated partners in terms of yield, quality and mobility could be a very feasible conventional indicator for breeders and does not require investment (FILIP et al., 2023; GORINOIU et al., 2025).

Wheat quality as well as production capacity are the most important quality of any wheat varieties. Studies have demonstrated significant relationships among grain yield, protein content, and starch accumulation (GORINOIU et al., 2025). Numerous studies show that genotype significantly influences grain protein content and other quality traits. Therefore, understanding the relationships among yield components, grain quality parameters, and morphological traits is essential for selection in the breeding programs.

In this study, our objectives were (1) to identify the influences and correlations between morphological, qualitative and production traits in wheat (2) to evaluate the influence of traits, be they morphological, qualitative or production parameters, and (3) to evaluate the influence of genotypes and environments of 2025 and 2026 on the variables included in the study.

MATERIAL AND METHODS

For the experiment, ten commercial varieties were used over a two-year period. The experiment took place at the Lovrin Agricultural Research and Development Station, where the evaluation also took place. In order to evaluate different characteristic of the varieties, selection included varieties known for productivity, quality and specific morphological aspects.

The experiment was conducted over two-year period from 2025 and 2026. The experimental design included three repetitions each year. Microplot covered an area of 12 m² covering plant density of 500 plants/m². Each year, wheat received 150 kg/ha NPK (15-15-15), 150 kg/ha ammonium nitrate in spring, and Axial herbicide for weed control during the vegetative stage. In order to do quality analyses, grain samples from the ten wheat varieties were collected over two years from each replications. In order to analyze starch and protein we used an Inframatic NIR 9200 analyzer based on calibrated near-infrared absorption spectra (HAKIM et al., 2012).

Furthermore, grain yield, plant height (cm), spike length (cm), protein content (%), starch content (%), hectoliter weight (kg hL⁻¹), and thousand-kernel weight (g) were recorded and evaluated. Grain yield was determined for each 12 m² microplot and subsequently converted to a hectare basis (t ha⁻¹) (CHACHAR et al., 2024). All obtained data were subjected to statistical analysis. Analysis of variance (ANOVA) was performed to assess significant differences among wheat varieties (KIM, 2017). Pearson correlation analysis was used to examine relationships among agronomic and quality traits. In addition, principal component analysis (PCA) was conducted to investigate multivariate relationships among the evaluated parameters. All statistical analyses, graphical representations, dendrogram construction, and correlation coefficient calculations were performed using RStudio software (DEGE & BRÜGGEMANN, 2024).

RESULTS AND DISCUSSIONS

According to the results, significance levels differed depending on the trait analyzed, whether it was a yield, quality, or morphological trait (Table 1). From the varieties point of view, plant height ($p < 0.05$), protein content ($p < 0.001$), and starch content ($p < 0.01$) registered significant involvement of the genotype factor. On the other hand, genotype factor did not influence the grain yield ($p > 0.05$), spike length ($p > 0.05$), hectoliter weight ($p > 0.05$), or thousand-kernel weight ($p > 0.05$). Furthermore, the influence of the year was significant for grain yield ($p < 0.05$). This indicates that environmental conditions and the varieties used had different adaptations depending on the year of testing. Year also influences the height of the genotypes used ($p < 0.001$) and hectoliter weight ($p < 0.001$). Year did not significantly affect spike length, protein content, starch content, or thousand-kernel weight ($p > 0.05$) (Table 1).

Table 1.

ANOVA test among grain yield, morphological, and quality traits.				
Trait	Genotype (F)	Genotype (p)	Year (F)	Year (p)
Yield	2.21	0.1265	4.50	< 0.05 *
Plant Height	2.42	< 0.05 *	156.31	< 0.001 ***
Spike Length	1.24	0.3769	1.34	0.277
Protein	5.25	< 0.001 ***	1.59	0.239
Starch	3.81	< 0.01 **	1.26	0.291
Hectoliter Weight	0.77	0.6487	80.18	< 0.001 ***
Thousand Kernel Weight (TKW)	1.35	0.3307	0.07	0.80

Note: ns = non-significant ($p > 0.05$); * = significant at $p < 0.05$; ** = significant at $p < 0.01$; *** = significant at $p < 0.001$.

Regarding correlation analysis, results can be visualized in Figure 1. The analysis revealed different relationships among grain yield, morphological traits, and quality traits. Strong negative correlation was observed between protein content and starch content ($r = -0.96$). Therefore, the increase of the protein content influences inversely proportionately the starch content. The results were expected, as they are in line with many research reports (CHOI et al., 2025; GORINOIU et al., 2025; HAKIM et al., 2012; KINDRED et al., 2008). Furthermore, research report indicate a decrease of yield when the starch content increases (GORINOIU et al., 2025). Conversely, a yield decrease is registered when the protein content increases (ASSENG et al., 2019; WAN et al., 2022). Regarding protein content, hectoliter weight showed a strong negative correlation ($r = -0.72$). Also, a strong positive correlation with starch content ($r = 0.68$). Therefore, denser grains with greater hectoliter weight, increased protein levels may be associated with lower grain density (Figure 1). Yield revealed weak positive correlations with plant height ($r = 0.33$) and thousand-kernel weight (TKW) ($r = 0.36$). Furthermore, no other notable correlations were observed among the evaluated traits.

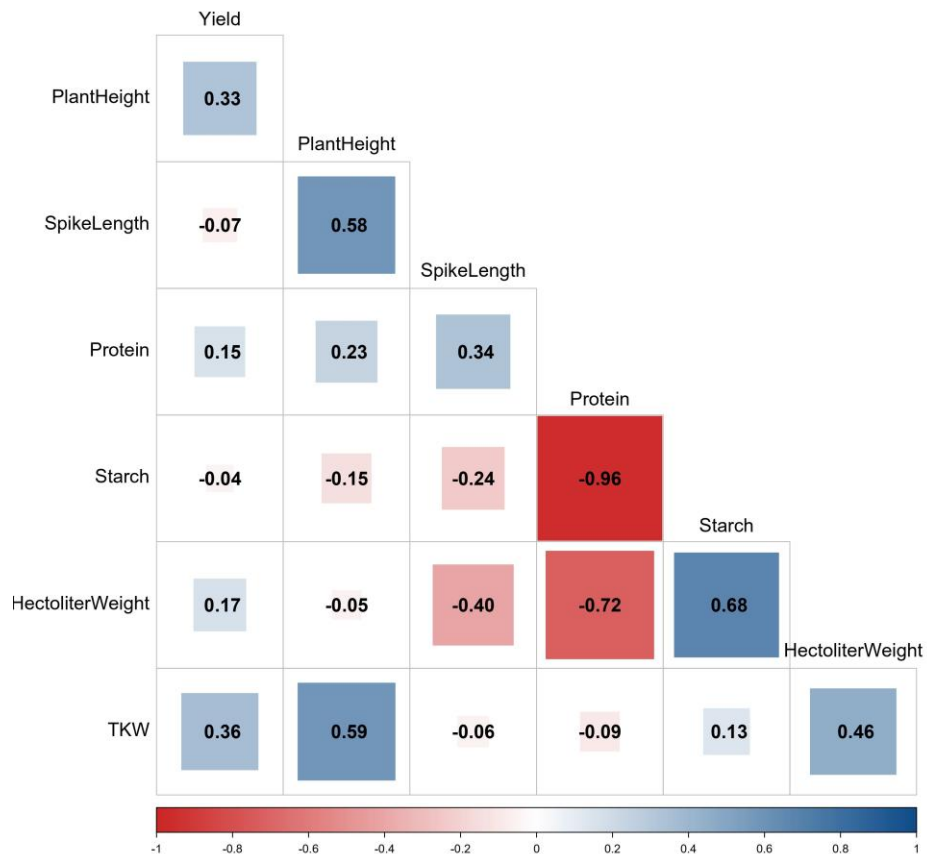


Figure 1. Correlation among grain yield, morphological, and quality traits.

Further analyses of PCA revealed that the first two principal components explained 59.3% of variation. According to the results, PC1 accounting for 32.1% and PC2 for 27.2%. The analysis revealed that genotype significantly influenced plant height, protein content, and starch content. Also The grain yield, plant height, and hectoliter weight was effected by environmental factors. Similar research reported influence on grain yield and certain morphological characteristics (MUQADDASI et al., 2020; TANIN et al., 2022).

PC1 (32.1%) was mainly associated with plant height, protein content, starch content, and hectoliter weight. Additionally, PC2 (27.2%) was primarily influenced by starch content, protein content, and hectoliter weight. The distribution of varieties across the PCA plot highlighted considerable variability among the analyzed genotypes in both agronomic and quality-related traits (Figure 2).

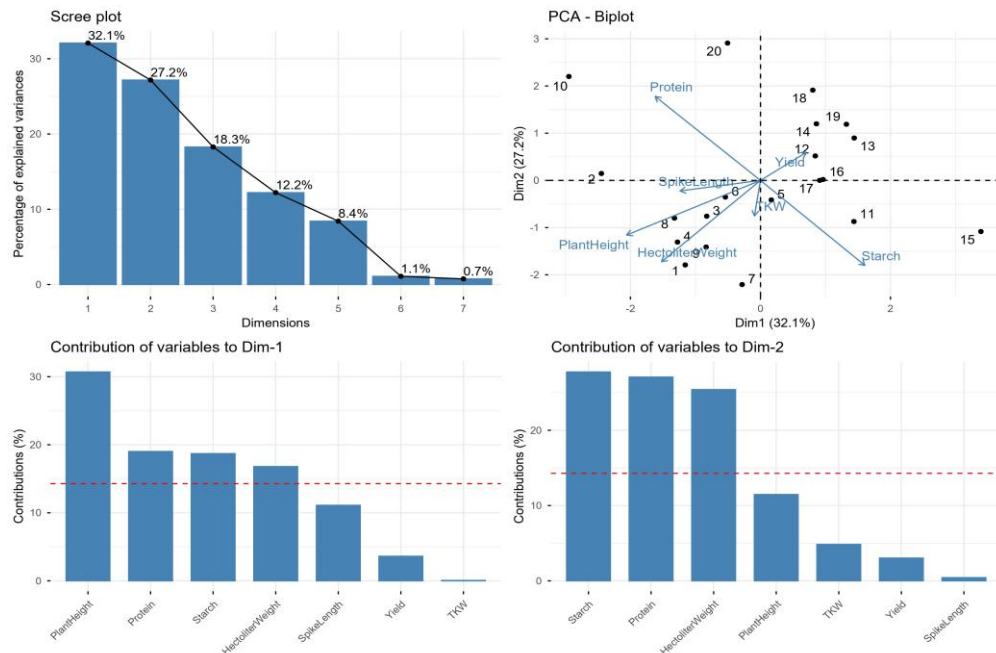


Figure 2. Principal component analysis (PCA) of grain yield, morphological, and grain quality traits in wheat genotypes.

Significant genotypic effects were observed for plant height, protein content, and starch content ($p < 0.05$). However, no significant differences among genotypes were detected for grain yield, spike length, hectoliter weight, or thousand-kernel weight ($p > 0.05$). In contrast, several studies have reported significant genotypic variation in wheat yield and quality-related traits under different environmental conditions (KONDIC-SPIKA et al., 2019; MUQADDASI et al., 2020; TANIN et al., 2022; UROSEVIC et al., 2023).

The discrepancy between the findings of previous studies and the present results may be attributed to the limitations of the current experiment, including the relatively small number of evaluated genotypes, the assessment over only two growing seasons, and the use of a single experimental location. Future research should expand the experimental framework by incorporating a larger set of wheat genotypes evaluated across multiple locations and growing seasons to better capture genotype \times environment interactions and improve the robustness of the conclusions.

CONCLUSIONS

From the experiment, it is revealed that genotype significantly influenced plant height, protein content, and starch content, while grain yield. Also, mainly affected by environmental conditions of the two testing seasons. Negative correlation was observed between protein and starch content ($r = -0.96$). Revealing that once the protein content increases the starch content decreases. Principal component analysis (PCA) explained 59.3% of the total variability.

Demonstrating that protein content, starch content, plant height, and hectoliter weight as the main traits contributing to genotype variations. Results indicate that grain quality traits are more strongly controlled by genetic factors, whereas grain yield is more dependent on environmental conditions. However, further study should be done in order to conclude this aspect with more number of genotypes evaluated and more locations.

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