UDC 633.11:631.95:575.22
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GENOTYPE COMPONENT OF GRAIN YIELD VARIATION OF MODERN WINTER WHEAT VARIETIES

The AMMI approach (Additive Main Effects and Multiplicative Interaction) is one of the most informative tools for studying genotype performance in multi-environment trials because it integrates two complementary statistical principles within a single framework. The additive component, represented by analysis of variance (ANOVA), allows the researcher to partition the total variation into genotype and environment main effects, whereas the multiplicative component, represented by principal component analysis (PCA), reveals the internal structure of genotype × environment interaction (GEI).

The objective of the present research was to determine how strongly genotype (G), environment (E), and their interaction (G×E) contributed to grain yield variation in winter wheat and, on this basis, to identify genotypes capable of combining high productivity with stable performance under contrasting growing conditions. The experimental design included a net plot area of 10 m^2, three replications, and three growing seasons spanning 2022 to 2024. The evaluation of genotype × environment interaction was carried out using the AMMI model, in which the additive main effects were examined through ANOVA and the interaction structure was decomposed using PCA. The testing network comprised 20 varieties assessed across 17 environments.

When cultivars are judged exclusively by their multi-year mean yield across all environments, without considering stability or the pattern of response to environmental change, the most productive entries in the dataset were LG Orlis (82.41), Bosporus (82.09), CHIKO (81.83), Khvylia Dnipra (79.93), LG Kvadrant (78.72), MV Nador (78.59), and Pozytsiia Odeska (77.30). The composition of the top-yielding group is itself informative. These leaders originated from several breeding systems, including French, German, Hungarian, and Ukrainian programs, indicating that the study captured a broad eco-genetic spectrum. This diversity makes it difficult to support the idea that one breeding center or one breeding philosophy has a universally superior outcome. Instead, the results suggest that successful cultivars can be produced within different scientific and breeding traditions, provided that they combine strong productivity potential with an adaptive response appropriate for variable growing conditions. In this sense, contemporary breeding appears capable of supplying materials suitable for different agroecological zones and technological backgrounds rather than converging on a single dominant type.

To overcome the limitations of ranking by productivity alone, an integrated assessment of yield and stability was performed using the Yield Stability Index (YSI), calculated as the sum of the rank for yield and the rank for stability. According to YSI, the most promising broadly adapted cultivars in the present dataset were LG Orlis, LG Kvadrant, CHIKO, and MIP Roksolana. LG Orlis combined the highest mean yield (82.41) with strong stability (ASV 17.08), making it the clearest example of a high-performing and well-balanced genotype. LG Kvadrant also showed a favorable combination of substantial productivity (78.72) and very good stability (ASV 16.16), placing it among the most reliable broadly adapted entries. CHIKO maintained high productivity (81.83) together with satisfactory stability (ASV 18.70), which supports its suitability for extensive cultivation across zones. MIP Roksolana, although not the top-yielding genotype, was distinguished by the best stability score (ASV 14.44) and an acceptable mean yield level (76.09), making it especially valuable where yield predictability is a primary objective.

Taken together, these results identify LG Orlis, CHIKO, LG Kvadrant, and MIP Roksolana as the most universally valuable genotypes in the trial, because they combine relatively high mean yield with a comparatively stable response to environmental variation. In practical agriculture, this means they are likely to provide not only competitive productivity but also greater consistency under fluctuating growing conditions.

Each of these cultivars occupies a somewhat different functional position. LG Orlis may be regarded as the leading all-around genotype because it joins the highest average productivity with a strong stability profile. CHIKO stands out for maintaining elevated yield across multiple zones, which increases its relevance for wider cultivation. LG Kvadrant represents a particularly balanced type, combining good performance with dependable stability. MIP Roksolana, in turn, serves as a model of environmental buffering, showing minimal specific interaction and therefore offering valuable risk reduction where stable production is more important than attaining the absolute maximum yield. From a practical deployment perspective, combinations such as LG Kvadrant + MIP Roksolana may be especially effective where reliability is required, while LG Orlis + CHIKO may be more suitable where the goal is to capitalize on favorable conditions and maximize yield expression.

Overall, the study demonstrated that genotype × environment interaction represented the dominant source of variation in winter wheat grain yield within this multi-environment testing system. The cultivars with the highest yield potential included LG Orlis, CHIKO, Bosporus, Khvylia Dnipra, and LG Kvadrant, whereas MIP Roksolana emerged as the most stable genotype because of its minimal environmental sensitivity. When productivity and stability were considered jointly, LG Orlis, CHIKO, and LG Kvadrant appeared to be the most valuable broadly adapted cultivars.

At the same time, the results revealed clear zonal differentiation in adaptation. In the Steppe, the most favorable performers were CHIKO, LG Orlis, and Khvylia Dnipra. In the Forest-Steppe, Bosporus, Khvylia Dnipra, LG Orlis, and CHIKO showed the greatest suitability. In Polissia, the leading cultivars were LG Orlis, CHIKO, and Bosporus. In addition, several varieties, including Khvylia Dnipra, Tika Taka, Tenor, LG Litopys, Bosporus, and MIP Nika, displayed pronounced specific adaptation to particular environmental conditions. Such genotypes should not be overlooked merely because they are less universal; rather, they should be considered important material for zone-specific recommendations and targeted breeding strategies.

UDC 633.11:631.95:575.22

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YIELD VARIATION OF NEW WINTER WHEAT VARIETIES UNDER DIFFERENCE ENVIRONMENTAL CONDITIONS

A range of statistical tools is used in plant breeding to quantify genotype × environment interaction and to assess the stability of yield expression. These methods include regression-based models, nonparametric approaches, and multivariate techniques. Regression procedures are useful for describing the way a genotype responds to environmental change through the slope of its response curve and the magnitude of deviation from that trend. Nonparametric methods are particularly valuable when the assumptions required for classical parametric statistics, such as normality of distribution or homogeneity of variance, are not fully satisfied. At the same time, multivariate approaches offer a broader analytical perspective, because they are able to reveal complex interaction structures that cannot be adequately represented by a single statistic, especially when many test environments are included.

According to the average productivity background, the most favorable environments in the present trial were Chernivtsi, Ternopil, Lviv, Rivne and Vinnytsia. However, productivity alone was not sufficient to characterize the analytical role of these environments. When evaluated by vector length in the IPC1–IPC2 space, the most representative sites were Volyn, Zakarpattia, Ternopil, Kharkiv and Lviv, because their shorter vectors indicated a closer approximation to the average response of the genotype set. By contrast, Dnipropetrovsk, Khmelnytskyi, Sumy, Vinnytsia and Kirovohrad showed the greatest discriminating capacity, indicating stronger ability to differentiate among genotypes. This pattern highlights the importance of maintaining both reference-type and strongly contrasting environments within the cultivar testing network.

The zonal structure of the results was especially informative. Within the Steppe, no single dominant variety was observed across all locations. DARYNA ranked first in Dnipropetrovsk, ZU Shamal in Kirovohrad, and HIMALAYA in Odesa. Such variation among only three Steppe sites demonstrates that even within one natural zone, environmental contrasts are sufficiently strong to alter varietal ranking. This makes local recommendation particularly important in the Steppe, where cultivar superiority cannot be generalized without reservation.

The Forest-Steppe showed an intermediate pattern between the highly contrasting Steppe and the more consistent Polissia zone. In this group of environments, STK21G, Zoloto Stepu, Atrybut, and ZU Willem appeared more frequently among the leaders, although their exact ranking differed considerably from one region to another. This indicates that the Forest-Steppe combines relatively high productivity with substantial internal heterogeneity, meaning that the specific agroecological background of each testing point must be taken into account when interpreting varietal performance.

In Polissia, the results were characterized by a greater recurrence of the same leading genotypes. Pamiati Horlacha ranked first four times, while STK21G, Atrybut, Dnistrianka Odeska, and ZU Willem repeatedly appeared among the top three. Compared with the Steppe, this suggests a somewhat more homogeneous environmental pattern and a more predictable response of the genotypes. At the same time, the presence of some contrasting sites shows that even within Polissia, local differentiation remains relevant.

For breeding practice, several practical conclusions follow from these results. First, no single environment can replace a properly constructed multi-location network, because different sites perform different analytical functions. Some are valuable for obtaining a generalized estimate of cultivar response, while others are essential for exposing specific adaptation. Second, varieties that repeatedly appear among the top-ranked entries across different zones should be treated as material with broad adaptive value and as sources of favorable stability components. Third, genotypes that dominate only in individual environments should not be underestimated, because their local superiority may reflect useful specific adaptation to particular agroeco-