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"Genetic Synergy: How Genetics and Environment Shape Livestock"

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Abstract

The genotype-environment correlation and interaction are vital for optimizing animal performance and welfare. Genotype-environment correlation refers to the way an animal's genetic makeup influences its exposure to specific environments, which can affect its development and performance. This correlation can be passive, where genetics affect environmental exposure; evocative, where genetic traits elicit particular environmental responses; or active, where animals seek out environments that match their genetic predispositions. Genotype-environment interaction involves the differential effect of genetic variants on traits depending on environmental conditions, or the influence of environmental factors on the expression of genetic traits. These interactions highlight the complex interplay between genetics and environment, informing breeding and management strategies aimed at optimizing animal health, productivity, and adaptability.

Key words: Genotype, Environment, Correlation, Livestock

Genotype – Environment Correlation (G X E Correlation):

Typically, it is assumed that genotypic values and environmental deviations are independent, meaning there is no correlation between them. However, in some cases, a correlation can exist between genotypic values and environmental deviations. For instance, in dairy cattle husbandry, higher-yielding cows are often given better feed, which introduces a correlation between phenotypic values and environmental conditions. This, in turn, creates a correlation between genotypic values and environmental deviations. When such a genotype-environment (G x E) correlation is present, the phenotypic variance increases by twice the covariance of genotypic values and environmental deviations, and the equation becomes $\mathbf{V_P = V_G + V_E + 2\ cov_{GE}}$.If V_G and V_E are estimated, the G x E correlation component $2cov_{GE}$ can be estimated as $\mathbf{2cov_{GE} = V_P - (V_G + V_E)}$. In practice, however, the value of the covariance is often unknown. Therefore, it is often considered part of the genetic variance because the non-random

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aspects of the environment are influenced by the genotype, making the environment a component of the genotype. In experimental populations, where randomization is a key objective, the correlation between genotype and environment is rarely a significant issue and is overlooked.

Genotype – Environment Interaction (G x E INTERACTION):

The phenotype of an individual animal results from both its genotype and the environment it experiences. For animal breeders, the phenotype is the primary data used to assess the breeding values of animals, whether based on measurements from individuals or their relatives. Ideally, evaluating breeding values would be straightforward if the effects of genotype and environment on phenotype were purely additive(*i.e.* P = G + E). . However, the relationship between genotype and environment can also be non-additive. Statistically, this is represented as linear relationships for additive effects and non-linear relationships for non-additive effects, often referred to as genotype-environment interactions. In practical terms, this means that the impact of an environment on different genotypes can vary; the effect of a genotype on phenotype may differ across environments. Consequently, the phenotypic difference between two genotypes can change depending on the environment, highlighting a differential response of genotypes to varying environmental conditions

In genotype-environment (G × E) interaction, the phenotype is not simply the sum of the genotype and environment effects (i.e., it can be either less than or greater than i.e., P < (G + E) or P > (G + E). . When there is no interaction, the phenotype equals the sum of genotype and environment, P = (G + E).When G × E interaction is present, the relative performance of different genotypes can vary depending on the environment. This means that the best genotype in one environment may not be the best in another. G × E interaction is defined as the variation in performance of genotypes across different environments, reflecting how different genotypes perform differently under various conditions. These genotypes can include breeds, strains, or lines, while the environments can vary in terms of nutrition, climate, housing, and management practices.

For example, genotype A might outperform genotype B in environment 1 but perform worse in environment 2, illustrating the presence of G × E interaction.

Each genotype exhibits specific adaptability, which is influenced by genotype-environment (G × E) interactions. When G × E interactions are absent, the top-performing genotype in one environment will consistently be the best across all environments. However, when G × E interactions are present, the phenotypic value of an individual is not merely **P = G + E**; it also includes an interaction component, resulting in $\mathbf{P = G + E + I_{GE}}$. This interaction component introduces an additional source of variation, $\mathbf{V_{GE}}$ into the phenotypic variance. In genetically uniform groups, any variance observed is attributed to environmental differences

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among individuals, with interaction variance being combined with environmental variance. Adaptability is a crucial concept in animal breeding related to G × E interaction. For instance, zebu cattle (Bos indicus) may be less suited than various European breeds (Bos taurus) in temperate climates but excel in tropical climates. This illustrates how the performance ranking of breeds can change depending on the climate in which they are evaluated, with the ranking of bulls varying based on the country where their daughters' performance is measured.

Types of Genotype-Environment Interactions:

Linear Relationship (Additive Relationship)

In a linear relationship, the phenotypic differences between two genotypes (G1 and G2) remain consistent across different environments (E1 and E2). This means that if the phenotypic values of the two genotypes change in response to the environment, the changes are equal and in the same direction. Consequently, the rank order of the genotypes does not shift between environments. For example, if both G1 and G2 increase or decrease by the same amount when moving from E1 to E2, the linear relationship is indicated.

Non-Linear Relationship (Non-Additive Relationship)

A. Same Direction, Unequal Magnitude: When the phenotypic values of two genotypes change in the same direction but by different amounts in response to environmental changes, this causes a shift in the rank order of the genotypes. For instance, if genotype G1's performance increases more than G2's when moving to a new environment, their relative ranking changes.
B. Opposite Direction, Same Rank Order: When the phenotypic values of two genotypes change in opposite directions with the environment, but the rank order remains the same, this represents a non-linear relationship without rank reversal. For example, if G1's performance decreases while G2's increases, but G1 remains better than G2, the rank order is unchanged.
C. Opposite Direction, Changing Rank Order: When the change in phenotypic values occurs in opposite directions and leads to a change in the rank order of the genotypes across environments, this indicates a non-linear relationship with a shift in rankings. For example, if G1's performance improves while G2's declines, G2 might surpass G1 in the new environment.

Genetic Slippage

Genotype-environment interactions can lead to decreased performance when a population selected in one environment is exposed to a new environment, a phenomenon known as genetic slippage. This occurs when the phenotypic or breeding value of an individual decreases due to the mismatch between the selected genotype and the new environmental conditions.

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Importance of G×E interaction

The genotype-environment (G × E) interaction becomes particularly significant when individuals in a population are raised under varying conditions that cannot be controlled. Experimental findings indicate that the top breeding bulls from dairy breeds in temperate regions may not perform as well in tropical climates. Similarly, differences in performance have been observed between countries that utilize high levels of concentrate feeding and those that rely on pasture-based feeding systems. As a result, the best sires in low-environment conditions may not be the best in high-environment conditions.This variability underscores the necessity of considering G × E interactions when selecting breeding stock. Breeders must focus on identifying animals with general adaptability to multiple environmental conditions or those specifically suited for targeted environments to ensure optimal performance.

Conclusion

Genotype-environment (G × E) correlation and interaction are vital in livestock breeding, influencing how animals perform under different environmental conditions. These interactions highlight the need for selecting livestock that are not only genetically superior but also well-adapted to specific environments. Understanding G × E interactions is key to optimizing breeding programs, ensuring that livestock can consistently perform well across diverse or targeted environments, ultimately contributing to sustainable and resilient livestock production.

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