




GENOTYPE AND ENVIRONMENT INTERACTION IN GENOMIC SELECTION

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OVERVIEW OF GENOMIC SELECTION (GS) AND ITS SIGNIFICANCE IN BREEDING



Genomic Selection (GS) is a breeding methodology that utilizes genomic data to predict the breeding values of individuals, enhancing selection accuracy.

- Mechanism:

GS relies on a training population with known phenotypes and genotypes to develop predictive models. These models estimate the genetic potential of untested individuals based solely on their genomic markers.

- Significance in Breeding:

- Increased Accuracy: GS improves the precision of selecting desirable traits, particularly for complex traits controlled by multiple genes.

- Reduced Phenotyping Costs: By predicting traits genetically, it minimizes the need for extensive field trials.

- Accelerated Breeding Cycles: GS shortens the time required to develop new varieties, crucial for adapting to environmental changes and increasing food production.

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INTRODUCTION



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IMPORTANCE OF GEI IN PLANT AND ANIMAL BREEDING

Importance in Breeding:

- Phenotypic Variation: GxE is essential for assessing the stability of genotypes across various environments, aiding in the selection of superior cultivars.
- Resource Allocation: It informs breeding strategies by identifying optimal testing environments and germplasm choices.
- Yield Prediction: Understanding GxE helps predict performance variability, optimizing breeding outcomes in agriculture.



WHAT SHOULD BE PRESERVED?



- Overview of Conventional GS Models

Traditional genomic selection (GS) models often struggle to accurately predict phenotypes across varying environments due to their inability to effectively incorporate genotype x environment interaction (GEI) .

- Key Limitations

- Predictive Power: Standard models have low power to model complex GEI, leading to poor predictions in unobserved environments.

- Correlated Environmental Covariates: Many known environmental factors are highly correlated, explaining only a small fraction of GEI variability .

- Computational Challenges: Fitting appropriate variance models for intercepts and slopes is computationally intensive, limiting practical applications .

INTRODUCTION TO IMPROVED MODELS LIKE 3GS



- Overview of 3GS Model

The 3GS model integrates Genotype \times Environment (GE) interaction with genomic selection (GS) by employing GGE analysis to enhance prediction accuracy.

- Key Features of 3GS

- Higher Prediction Accuracy: Significantly improves predictions in environments with low correlations to others, particularly in extreme conditions.
- Unobserved Environments: Capable of accurately predicting performance for new genotypes in unobserved environments.
- Computational Efficiency: Linear increase in complexity with more environments and larger populations, making it much faster than traditional models.

- Applications

Useful in modern breeding programs that utilize high-throughput techniques to gather multi-environment phenotypes, allowing for better resource management and improved selection outcomes.

IMPORTANCE OF MULTI-ENVIRONMENT TRIALS IN ASSESSING GEI

- **Definition:** Multi-environment trials (METs) evaluate genotypes across various environments to assess genotype x environment interaction (GEI).

- Purpose: Identify stable and high-performing genotypes under diverse conditions.

- **Advantages:**

- Increases prediction accuracy of genomic selection models.

- Provides insights into genotype adaptability and performance variability.

- Facilitates efficient resource allocation in breeding programs.



WHAT SHOULD BE PRESERVED?



- Introduction to GxE Models

GxE interaction is crucial in understanding how different genotypes perform across varying environmental conditions.

- Key Statistical Approaches:

- AMMI Model: Combines additive main effects and multiplicative interaction effects to analyze GxE.
- GGE Biplot: Visualizes genotype and environment interactions, identifying ideal genotypes for specific environments.
- Reaction Norm Models: Captures how genotypes respond to environmental changes, offering insights into stability and adaptability.

- Advancements in Modeling:

Recent models like the 3GS integrate GGE analysis with genomic selection, enhancing prediction accuracy and computational efficiency in diverse environments.

CASE STUDIES IN GENOTYPE X ENVIRONMENT INTERACTION



- Chickpea Breeding:

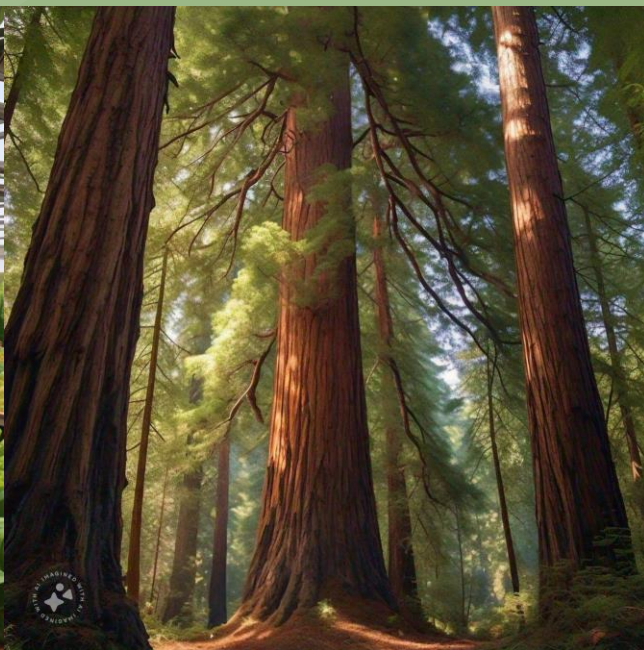
Genomic selection (GS) effectively improved resilience in chickpeas through GxE interactions, enhancing yield under varying environmental conditions. For instance, GS models demonstrated increased accuracy in predicting performance across diverse climates, leading to better adaptation strategies.

- Coast Redwood Study:

A common garden experiment revealed minimal GxE effects on growth traits like diameter at breast height (DBH), emphasizing the need for tailored genetic approaches based on specific environmental factors to optimize productivity.

- Douglas-Fir Research:

Significant GxE interactions were observed in Douglas-fir, with family performance varying across different sites, highlighting the complexity of genetic responses to environmental conditions and the necessity for adaptive breeding strategies.



COMPUTATIONAL EFFICIENCY IN GxE MODELS

- Key Points:
 - Traditional Models: Often struggle with high computational demands, especially in multi-environment trials. They may overlook GxE interactions, leading to reduced prediction accuracy.
 - Modern Approaches: Utilize reaction norm (RN) models and advanced statistical techniques, improving accuracy and efficiency. For instance, RN models can yield up to 319 times greater response in environmental sensitivity than traditional methods.
 - Benefits of Genomic Selection: Incorporating large reference populations enhances computational efficiency and accuracy, allowing for better exploitation of GxE interactions.



FUTURE DIRECTIONS IN GENOMIC SELECTION ✓ METHODOLOGIES

- Advancements in GxE Modeling:

The integration of Genotype x Environment (GxE) interactions into genomic selection (GS) models is crucial for enhancing prediction accuracy. Recent models like 3GS combine GGE analysis with GS, improving computational efficiency and accuracy, especially in untested environments

- Use of Environmental Data:

Incorporating environmental variables (e.g., temperature, soil moisture) into GS models allows for better predictions across diverse conditions. This enhances the ability to select genotypes suited for specific environments

- Nonlinear Models and Deep Learning:

The application of nonlinear genomic kernels and deep learning techniques is emerging as a promising direction. These methods can capture complex interactions and improve prediction capabilities significantly



CONCLUSION



: Conclusion: Importance of Adapting Genomic Selection to Varying Environmental Conditions

- Genotype x Environment (GxE) interactions significantly influence plant and animal performance, affecting breeding outcomes and genetic progress.
- Adapting genomic selection (GS) to account for GxE enhances prediction accuracy, leading to improved resilience and productivity across diverse environments.
- Incorporating GxE in GS models allows breeders to identify genotypes that perform optimally under specific environmental conditions, reducing yield losses and improving adaptation.
- Emphasizing GxE interactions can foster the development of robust genotypes, crucial for sustainable agricultural practices in the face of climate change.



*Thank
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