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Maize and Climate Change: Breeding Resilient Varieties for Tomorrow

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Maize (*Zea mays* L.) is a cornerstone of global food and feed security, cultivated across diverse agro-ecological zones. However, the escalating impacts of climate change—including rising temperatures, shifting rainfall patterns, drought, flooding, and increased pest and disease pressures—pose significant threats to maize productivity and stability. To sustain yields and nutritional value, the development of climate-resilient maize varieties has become a strategic priority.

Climate Change and Its Impacts on Maize

- Heat stress: Increases sterility, reduces pollen viability, and accelerates leaf senescence.
- Drought stress: Limits photosynthesis, elongates anthesis-silking interval (ASI), and reduces kernel set.
- Flooding/waterlogging: Reduces root oxygenation, disrupts nutrient uptake, and weakens plant stands.
- Emerging pests and pathogens: Climate shifts expand the range and severity of threats like fall armyworm (*Spodoptera frugiperda*) and maize lethal necrosis virus.
- Nutrient-use inefficiency: Reduced soil fertility under stress-prone systems further lowers yields.

Breeding Strategies for Climate-Resilient Maize

1. Conventional Breeding Approaches

- Selection for drought tolerance (stay-green, ASI reduction).
- Introgression of stress-tolerant germplasm from tropical and subtropical pools.
- Participatory breeding for locally adapted varieties.

2. Molecular and Genomic Tools

- Marker-Assisted Selection (MAS): Exploitation of QTLs for drought, heat, and disease resistance.

- Genomic Selection (GS): Predictive breeding for complex stress traits using genome-wide marker data.
 - Genome-Wide Association Studies (GWAS): Discovery of novel alleles and loci linked to stress adaptation.
 - CRISPR/Cas genome editing: Precision modification of key genes regulating stress tolerance (e.g., ABA signaling, heat shock proteins).
- 3. High-Throughput Phenotyping (HTP)**
- UAV-based imaging for canopy temperature, greenness, and stress indices.
 - Root architecture assessment using shovelomics and imaging platforms.
 - Automated platforms for multi-environment stress phenotyping.
- 4. Integrated Approaches**
- Multi-stress breeding: Developing varieties tolerant to drought, heat, and pests simultaneously.
 - Biofortification: Coupling resilience with nutritional quality (e.g., provitamin A maize, QPM).
 - Climate-smart hybrid development: Exploiting heterosis for yield stability across environments.

Case Studies and Success Stories

- Drought Tolerant Maize for Africa (DTMA): Delivered hybrids with 20–30% higher yields under drought, benefiting millions of smallholders.
- Heat-tolerant maize hybrids in South Asia: Developed through CIMMYT and national collaborations, enabling stable yields under >35°C environments.
- Fall armyworm-resistant breeding efforts: Combining native resistance with genomic tools for durable defense.

Future Perspectives

- Pan-genomics and haplotype-based breeding to capture untapped genetic diversity for resilience.
- Systems biology approaches integrating transcriptomics, metabolomics, and phenomics to unravel complex stress networks.
- Artificial Intelligence (AI) and machine learning for predictive modeling and decision support in breeding pipelines.
- Farmer- and climate-centric breeding programs that incorporate local adaptation, socio-economic factors, and gender-sensitive preferences.

Conclusion

Climate change poses unprecedented challenges to maize cultivation worldwide. However, by integrating traditional breeding wisdom with modern genomic and phenotyping innovations, breeders can accelerate the development of resilient maize varieties. These climate-smart varieties will secure food systems, enhance farmer livelihoods, and prepare agriculture for the uncertainties of tomorrow.