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Evaluating Drought Tolerance in Ascorbic Acid-Rich and Poor Chickpea Genotypes: Insights for Breeding Resilient Varieties

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Abstract:

Drought stress is a significant challenge in agriculture, particularly for staple crops like chickpea, where water availability can dramatically affect seed yield. Present study revealed vital insights into how different ascorbic acid (AsA)-rich and AsA-poor chickpea genotypes respond under well-watered (WW) and water-stressed (WS) conditions. By deriving drought tolerance indices, researchers have identified genotypes that excel under stress and others that falter. Here, we unpack these findings to understand their implications for drought-tolerant breeding programs.

The Metrics of Drought Resilience

To evaluate the drought resilience of chickpea genotypes, we employed a series of indices, each capturing a unique aspect of stress response.

These included:

- **Tolerance (TOL):** The difference in yield between WW and WS conditions.
- **Stress Susceptibility Index (SSI):** A measure of yield reduction under stress relative to WW conditions.
- **Yield Reduction Ratio (YRR) and Percent Yield Reduction (PYR):** Indicators of how much yield declined under WS conditions.
- **Other indices:** Stress Tolerance Index (STI), Drought Resistance Index (DRI), Geometric Mean Productivity (GM) and Harmonic Mean (HM).

  These metrics helped classify genotypes into drought-tolerant and drought-intolerant categories based on their performance.

The Champions and the Challenged

AsA-rich genotypes had consistently low values for indices like TOL, SSI, YRR, PYR, and high values for STI, GM, DRI, and others, showcasing their ability to maintain seed yield even under water-limited conditions. Conversely, AsA-poor genotypes demonstrated higher susceptibility to drought, with high values for TOL, SSI, YRR, and related indices, signaling poor performance under water stress.

Breaking it Down with Principal Component Analysis (PCA)

A multivariate analysis approach, specifically PCA, provided further clarity by grouping genotypes based on their drought response characteristics. Remarkably, the first two principal components captured 99.8% of the variability in the dataset, offering a clear visualization of how AsA-rich and AsA-poor genotypes diverged under WW and WS conditions.

Key Findings from PCA:

- **AsA-Poor Genotypes:** These clustered together with higher values for susceptibility indices like SSI, TOL, and YRR, reflecting poor drought adaptation.
- **AsA-Rich Genotypes:** These were distinctly separate, indicating stronger drought resilience.

Implications for Drought-Tolerant Breeding

The results of this study are a beacon for breeding programs aiming to develop drought-resistant chickpea varieties. The indices and PCA analysis together illuminate not only the best-performing genotypes but also the physiological traits and stress-response strategies that underlie their success. AsA-rich genotypes represent a genetic resource pool for future breeding efforts.

Conclusion

The study underscores the potential of AsA-rich chickpea genotypes as a genetic resource for enhancing drought tolerance in chickpea breeding programs. Through a comprehensive evaluation of drought tolerance indices, it was evident that AsA-rich genotypes exhibit superior resilience under water-stressed conditions compared to AsA-poor genotypes, maintaining higher yield stability and lower susceptibility to stress. PCA further validated these distinctions, revealing clear divergence in drought response characteristics between the two groups. The findings highlight the significance of leveraging AsA-rich genotypes in developing chickpea varieties better equipped to cope with water-limited environments, paving the way for more robust and sustainable agricultural practices in the face of climate change.