



Genetic Architecture and Physiological Strategies in Canola: Multivariate Analysis Reveals Distinct Water-Use Efficiency Mechanisms for Targeted Breeding

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Abstract

This study analyzed genetic variation in photosynthetic efficiency and water use among nine canola genotypes using PCA and hierarchical clustering. PCA identified two main systems: photosynthetic-stomatal regulation and growth-yield allocation, explaining 66.87% of the variation. Hierarchical clustering classified genotypes into four groups: balanced efficiency (G1, G2, G8, G9), high efficiency (G3), high photosynthesis (G4, G6, G7), and high transpiration (G5). Genotype G3, with high photosynthetic efficiency and low water loss, emerged as a strong candidate for drought-tolerant breeding. This multivariate approach helps clarify genotype-phenotype relationships for environment-specific breeding strategies.

Introduction

Canola (*Brassica napus* L.) is a key oilseed crop, but its productivity is limited by water scarcity and climate variability (Rauf et al., 2007). Improving drought tolerance and yield stability requires understanding the genetic basis of key traits. Since drought tolerance involves complex interactions, single-trait selection is often insufficient (Blum, 2009). Multivariate methods like principal component analysis (PCA) and hierarchical clustering integrate multiple traits, reduce dimensionality, and reveal genetic structure (Jolliffe & Cadima, 2016). This study used PCA and clustering to analyze physiological diversity in canola, identify key axes of variation, define genetic groups, and select superior germplasm for targeted, environment-specific breeding.

Materials and methods

The study evaluated nine canola genotypes under optimal conditions at Shahid Chamran University of Ahvaz, Iran, measuring nine physiological and morphological traits. PCA and hierarchical clustering were used to assess genetic diversity and identify genotype groups. Standardized data were analyzed to enable trait comparison, and hierarchical clustering grouped genotypes based on similarities. Statistical analyses in R helped identify genotypes with unique genetic characteristics for breeding.

Results and discussion

This study used PCA and hierarchical clustering to analyze genetic diversity in canola genotypes, identifying four groups: Balanced Efficiency (G1, G2, G8, G9), High Efficiency (G3), High Photosynthesis (G4, G6, G7), and High Transpiration (G5). G3, with high photosynthetic efficiency and low water loss, was highlighted as an ideal candidate for breeding drought-tolerant cultivars. The study recommends hybridization strategies for improving performance in variable environments.

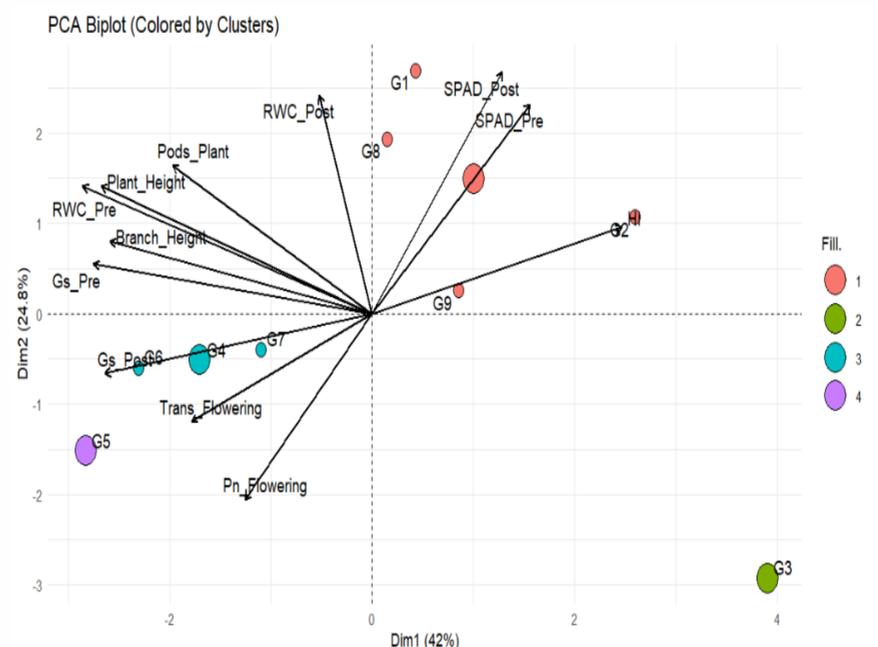


Figure 1. PCA-based ordination of canola genotypes across two principal components. Color-coded groupings correspond to the four distinct clusters (C1–C4), illustrating the physiological basis of genetic differentiation among the studied genotypes.

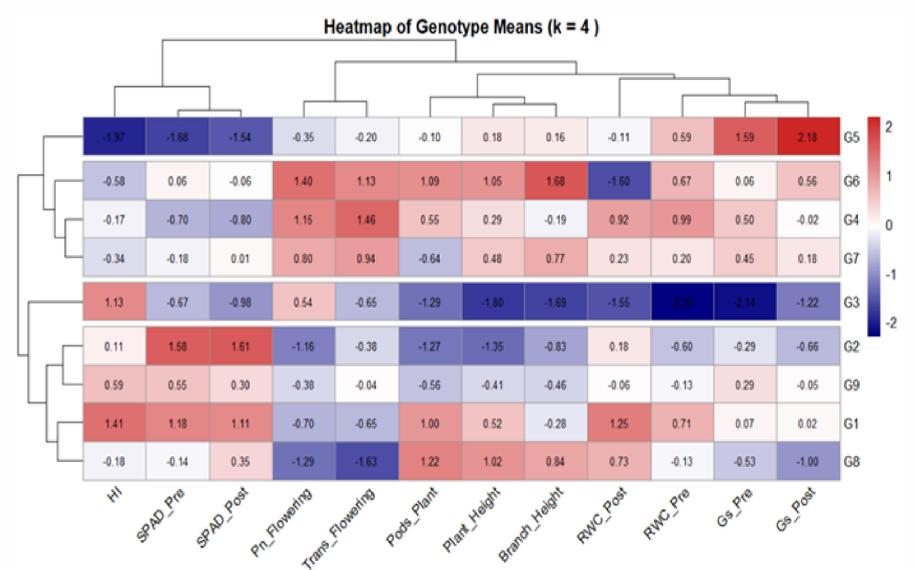


Figure 2. Hierarchical clustering heatmap and dendrogram of canola genotypes based on physiological and agromorphological traits before and after anthesis (K=4).

References

- Jolliffe, I. T., & Cadima, J. (2016). Principal component analysis: a review and recent developments. *Philosophical Transactions of the Royal Society A*, 374(2065), 20150202.
- Passioura, J. B. (2007). The drought environment: physical, biological and agricultural perspectives. *Journal of Experimental Botany*, 58(2), 113-117.