Variance of Variables: Shoot vs. Root Phenotypes for Explaining Class Differences in Maize

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Introduction

- Maize is a globally important food, feed, and biofuel crop that serves as a model organism in agricultural science.
- Roots are laborious to study leaving a gap in our understanding of this important food crop.
- Because **roots are understudied**, it is unclear if you get the same information from using roots as you would using shoots.
- **GOAL**: **Compare variance** in shoot versus root traits that are most correlated with genetic background, in order to **identify significant traits to focus on in future classification studies**

Data Collection

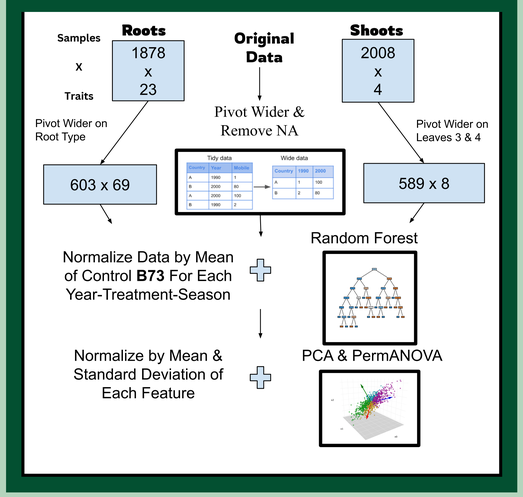
- Collected morphological data from 20 diverse maize genotypes.

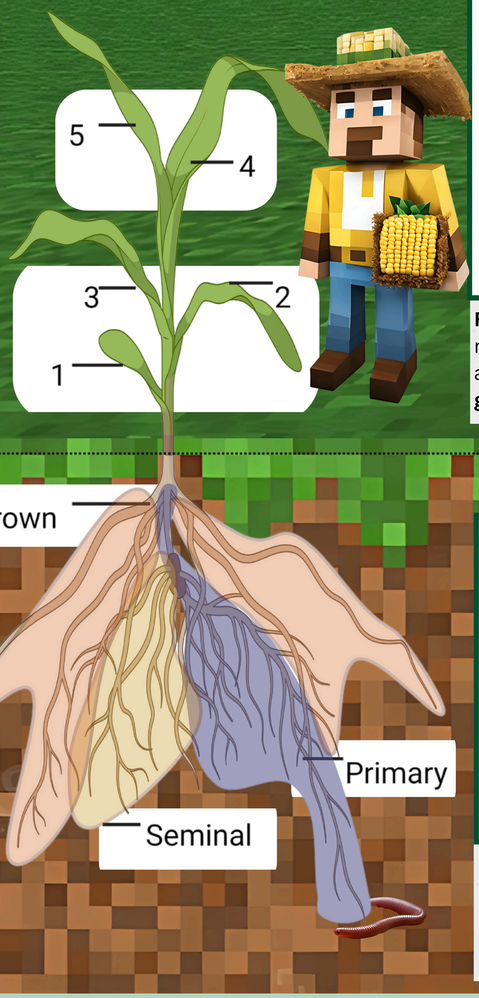
Genotypes Grouped by Genetic Background

Genetic Background	Genotypes
Mixed	Mo18W, Tx303, M37W
Non-Stiff-Stalk	M162W, OH7B, Ky21, Ms71
Popcorn	HP301
Stiff-Stalk	B73, B97
Subtropical	NC350, CML277, CML247, Ki11, CML333, CML103, CML322, CML228, CML52, CML69

- Image analysis was conducted on **root architecture** and **shoot morphological traits.**

Data Analysis





SHOOTS

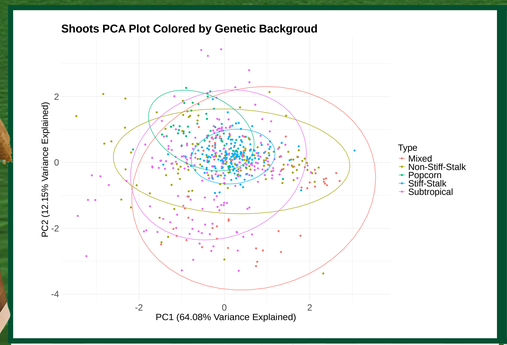


Fig. 1A - PCA results of **shoot data** after Varimax rotation with 95% confidence ellipses. Centroids appear to be **more spread out** and **dispersion is greater** than in the root data.

Pairwise Permanova Results on Shoot Data (95% Confidence Interval P-values)

	Mixed	Non-Stiff-Stalk	Popcorn	Stiff-Stalk
Non-Stiff-Stalk	0.0017*	-	-	-
Popcorn	0.0017*	0.0057*	-	-
Stiff-Stalk	0.0017*	0.012*	0.0017*	-
Subtropical	0.0075*	0.01*	0.0017*	0.0017*

Red cells indicate p-values where the assumption of homogeneity is violated.

Fig. 2A - PermANOVA and Tukey test results on the Principal Components. **Mixed** is the most significantly different centroid-wise. **Stiff-stalk** was the most different **dispersion-wise**.

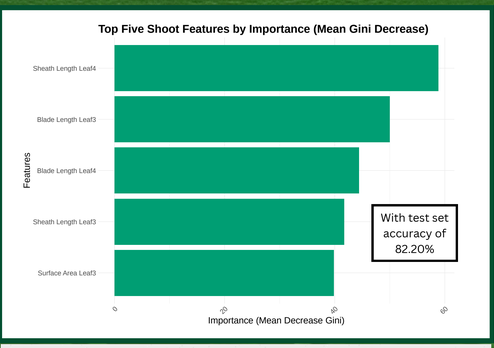


Fig. 3A - Best features to split on in the final model by Mean Gini Decrease (MGD). **Shoots dataset** had a **prediction accuracy** of **82.20%** on Genetic Background which is greater than **roots (70.83%)**

ROOTS

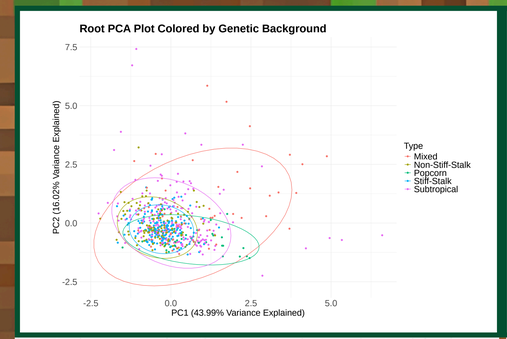


Fig. 1B - Displays PCA results of **root data** after Varimax rotation with 95% confidence ellipses. Centroids appear to be **more clustered** and **dispersion is less** than in the shoot data.

Pairwise Permanova Results on Root Data (95% Confidence Interval P-values)

	Mixed	Non-Stiff-Stalk	Popcorn	Stiff-Stalk
Non-Stiff-Stalk	0.0011*	-	-	-
Popcorn	0.0011*	0.0011*	-	-
Stiff-Stalk	0.0011*	0.002*	0.0011*	-
Subtropical	0.0011*	0.0011*	0.0011*	0.0011*

Red cells indicate p-values where the assumption of homogeneity is violated.

Fig. 2B - PermANOVA and Tukey test results on the Principal Components. **Popcorn** was the most different centroid-wise. **Mixed** was the only class that was not different from any other class centroid-wise.

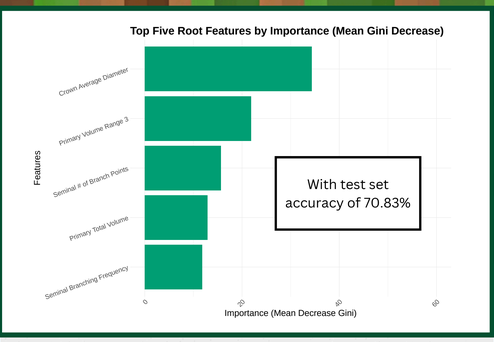


Fig. 3B - Best features to split on in the final model by Mean Gini Decrease (MGD). **Root phenotypes** were **worse at reducing variance** among classes in child nodes possibly due to high number of features in the root dataset.

RF Training Results

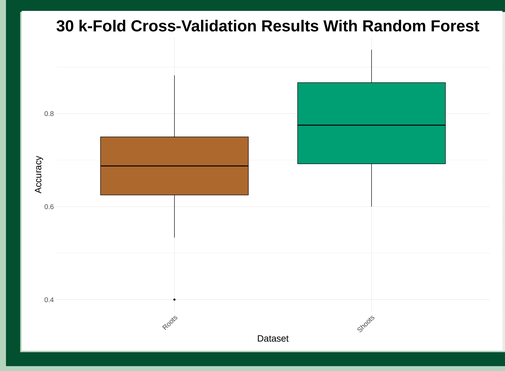


Fig. 4 - Random forest training with 500 trees and 30 k-folds Shoots (n=471) had a higher average accuracy than roots (n=483) along with larger variation.

Conclusions

- **Shoots** are a better discriminator of Genetic Background using **Random Forest**.
- The best features were Leaf 4 sheath length and Crown root average diameter.
- **Mixed** was the standout class in the **shoots** while **Popcorn** was the standout in **roots.**
- Scientists can **leverage this information** to reduce labor in the data collection process by **focusing on** only shoots or only **key traits**.

Future Studies

- More samples needed so that genetic origin classes are balanced.
- Possible interactions between Root and Shoot features were not accounted for.
- Variation during reproductive stage.

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