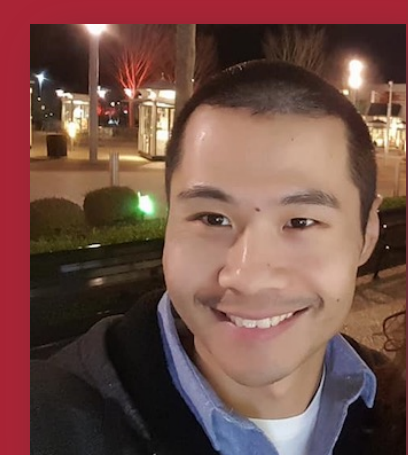




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Abstract

Challenge:

Digital Imaging of root traits 3D (DIRT/3D) [1] is a software to measure 3D root traits on excavated roots crowns from the field. However, quantifying 3D root traits remains a challenge due to the unknown tradeoff between 3D root-model quality and 3D root-trait accuracy [2].

Questions:

1. Can the 3D root model reconstruction be improved while reducing the image-capturing effort?
2. Does improved 3D root model quality increase the accuracy of trait measurements?

Evaluation:

1. Compare reconstruction performance of **five open-source 3D model reconstruction pipelines** on 12 architecturally contrasting genotypes [1] of field-grown maize roots.
2. Evaluate the accuracy of 3D root traits between the original implementation of DIRT/3D based on VisualSFM with an implementation based on COLMAP.

Conclusion:

The updated DIRT/3D (COLMAP) pipeline enables quicker image collection by reducing the number of images needed and reducing the human factor during image collection. The results demonstrate that the accuracy of 3D root-trait measurements remained uncompromised.

Visual comparison of five 3D reconstruction pipelines

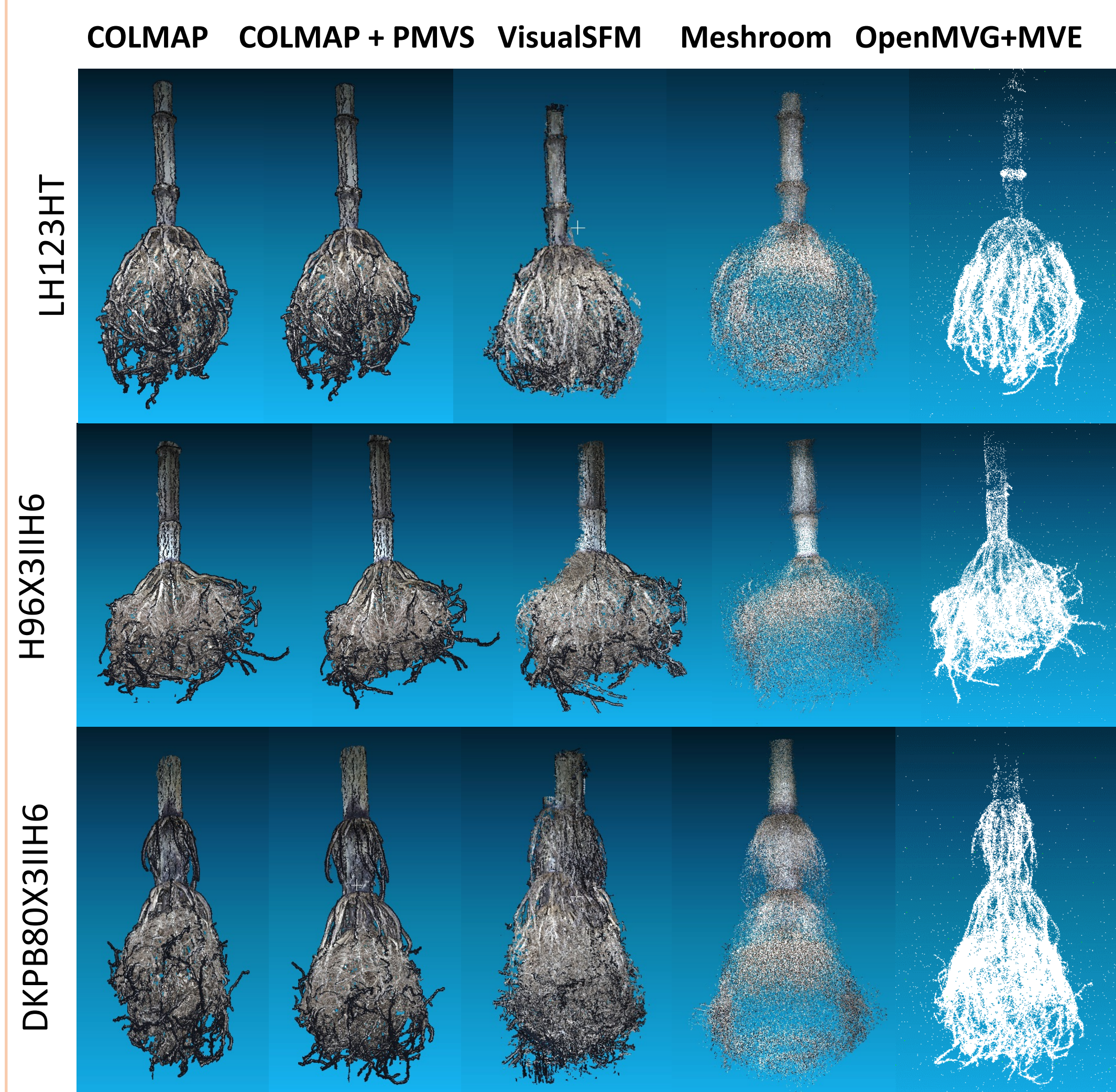


Figure 1. Visual comparison of three reconstructed maize genotypes. The 3D root models in each row compare the same genotype across different 3D reconstruction pipelines. The 3D root models in each column compare a 3D reconstruction pipeline across different genotypes.

3D root models & computed root structures

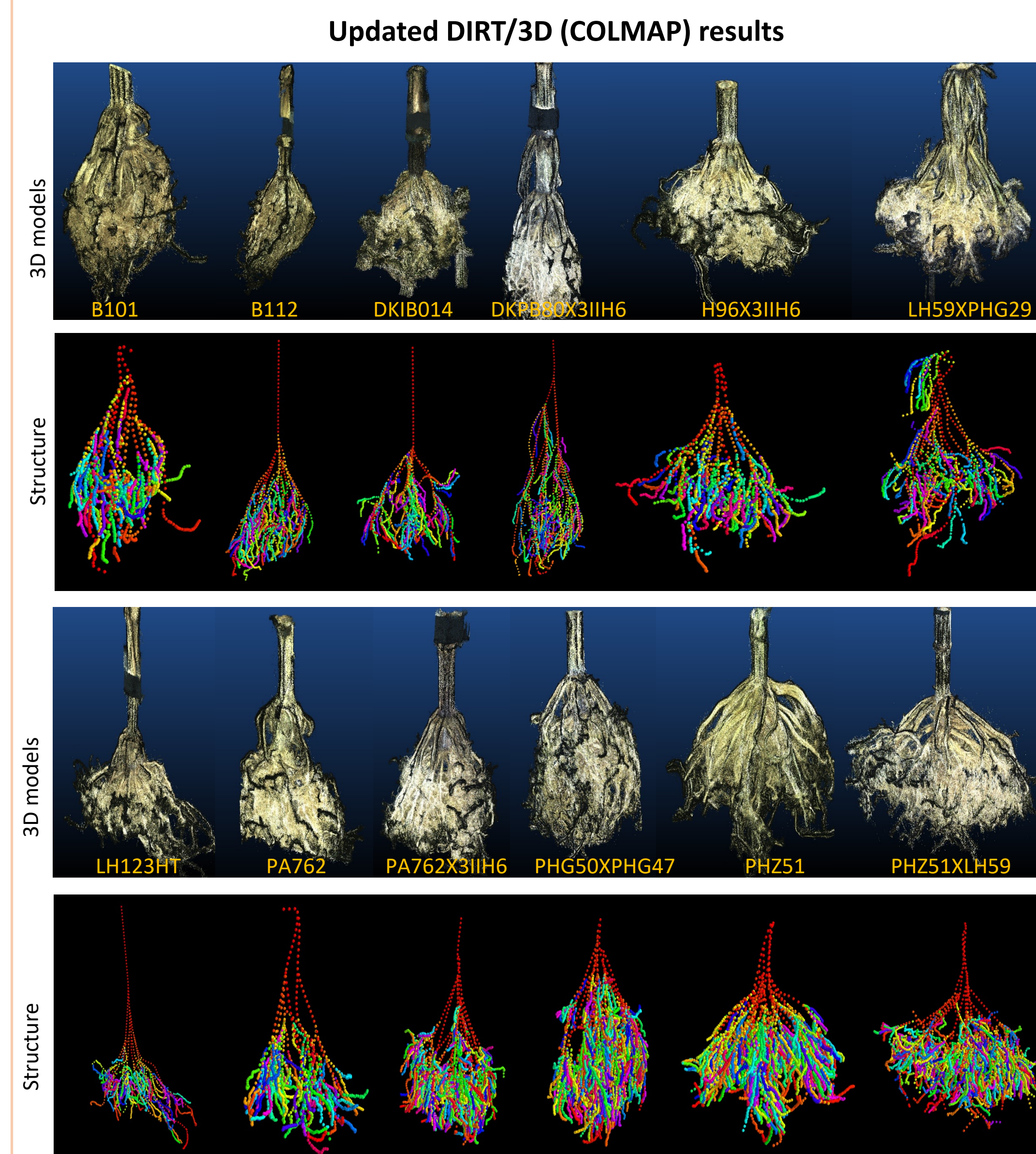


Figure 2. 12 sample 3D root models and their related computed root structure.

Test 1 : Comparison of five 3D reconstruction pipelines

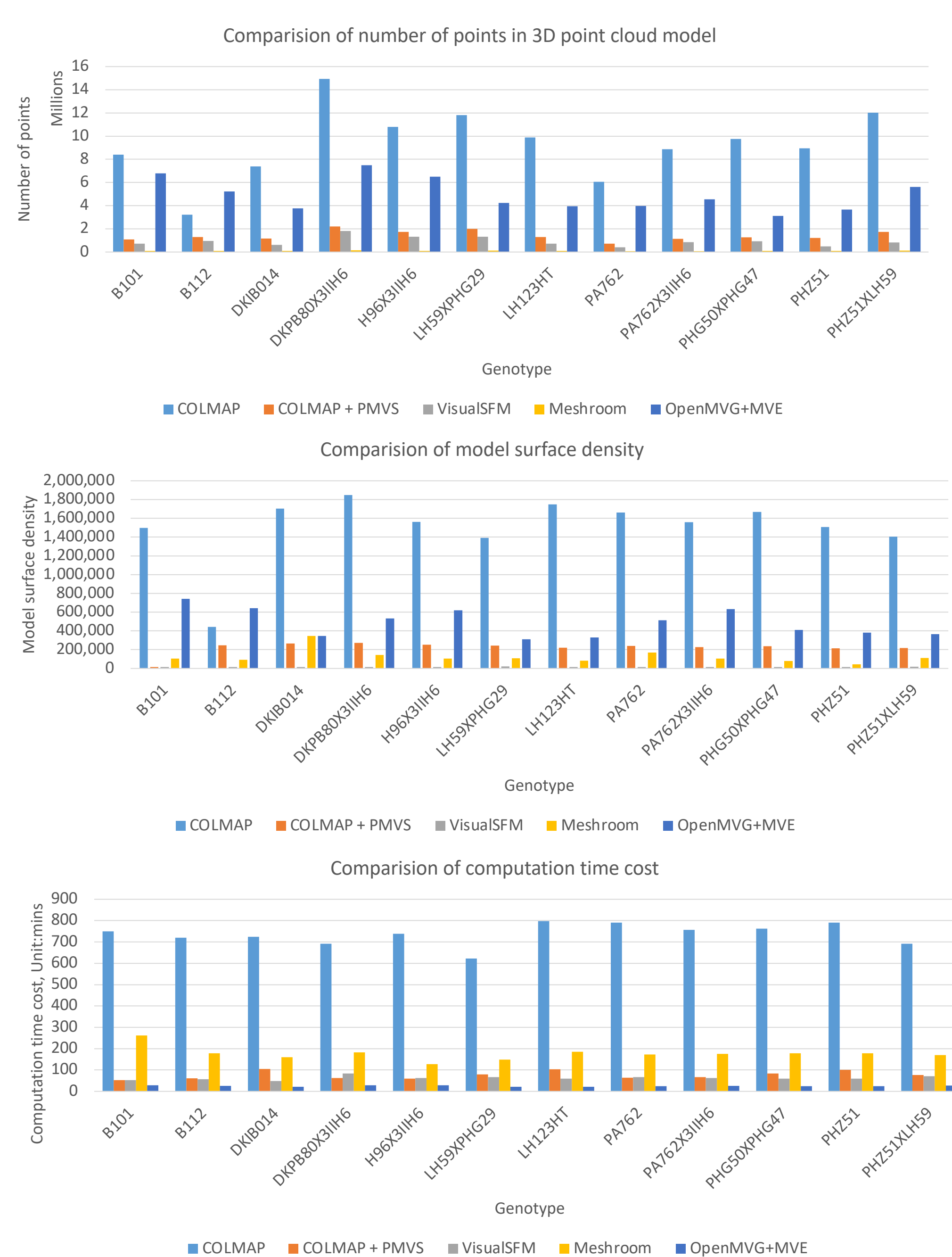


Figure 3. Comparison of 3D model quality (number of points & surface density) and computation time using one representative root per genotype.

Test 2 : Comparison of 3D root model quality between DIRT/3D using COLMAP and VisualSFM

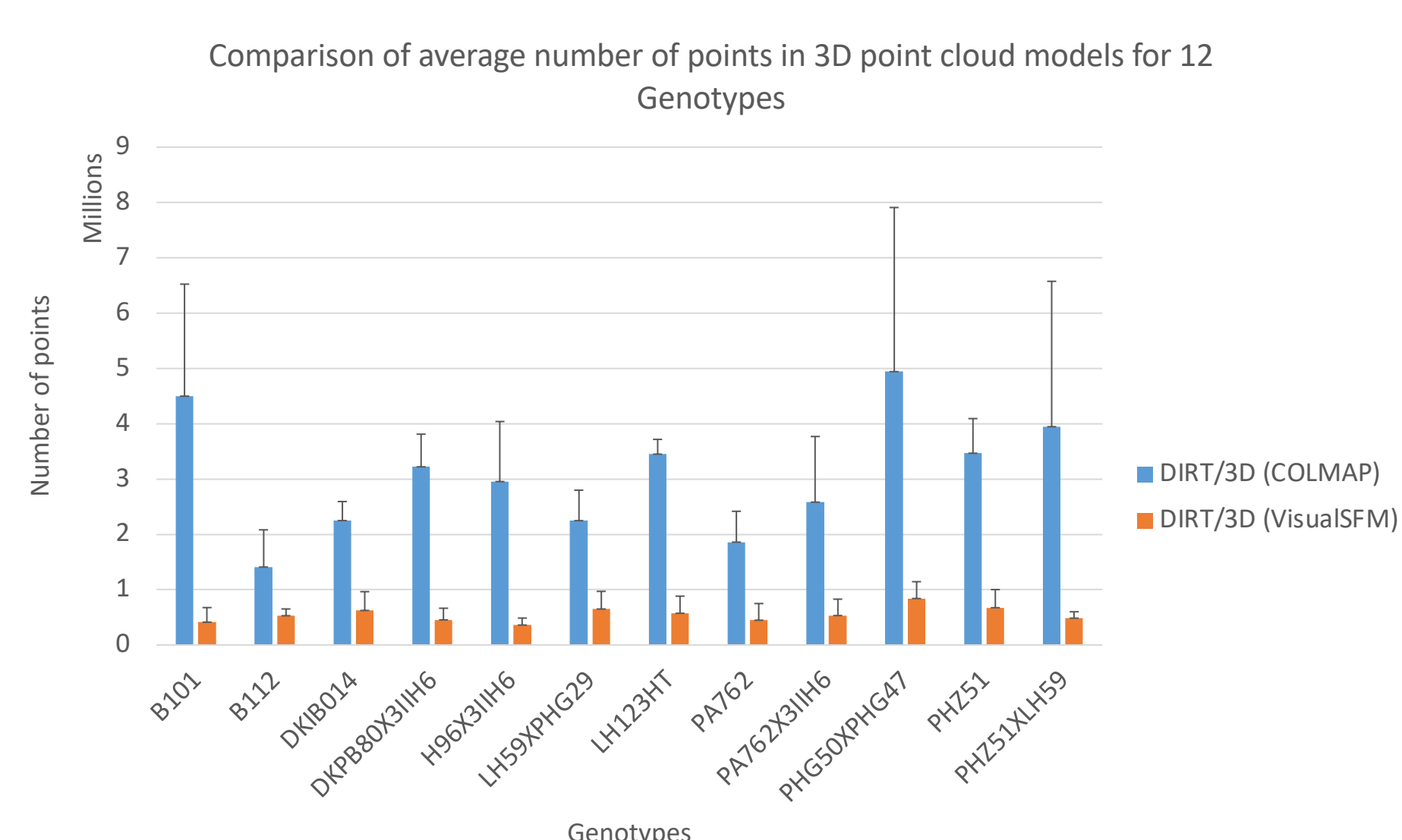


Figure 4. Comparison of the number of points between models generated with DIRT/3D (COLMAP) and DIRT/3D (VisualSFM) using 5-10 replicates per genotype.

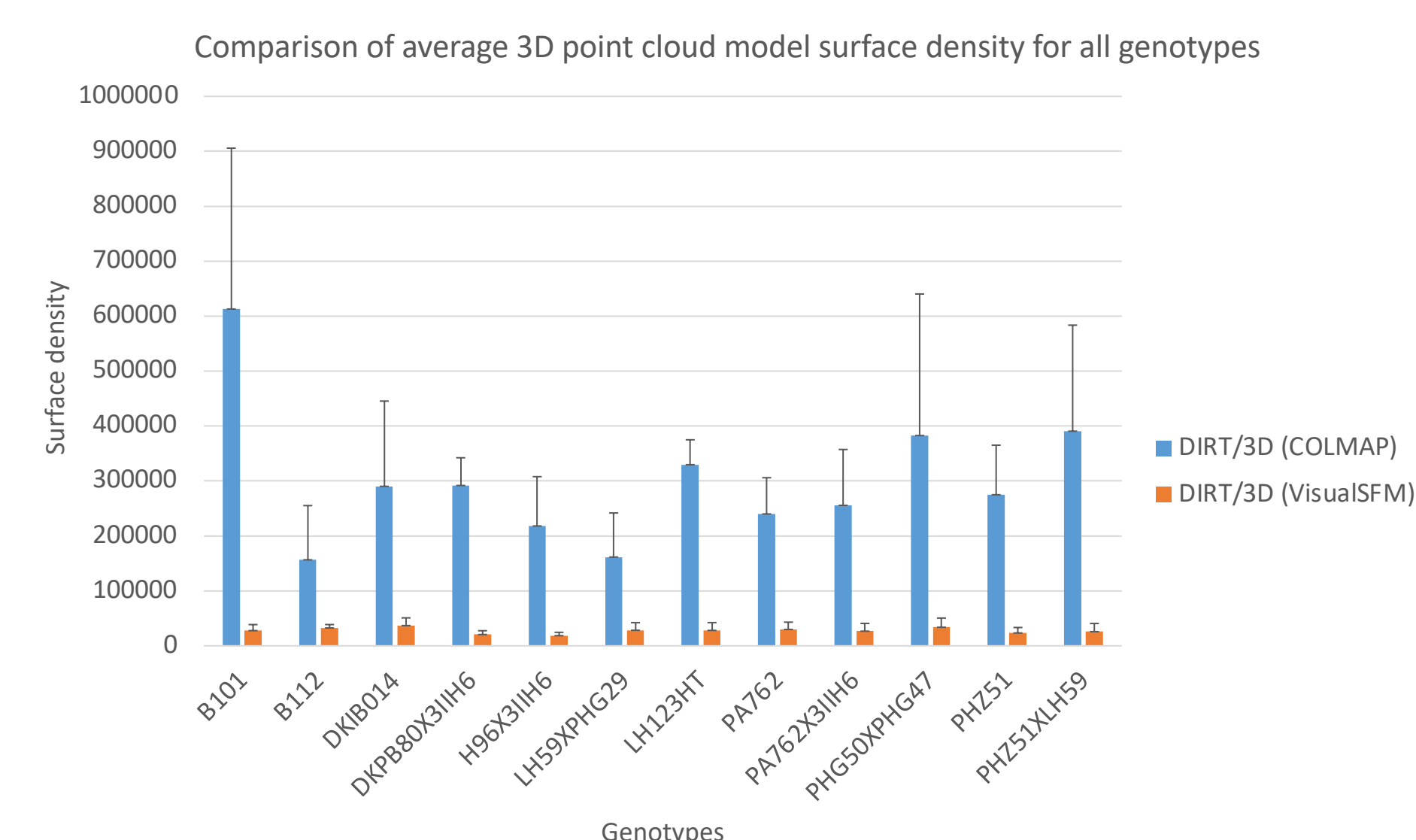


Figure 5. Comparison of surface density between models generated with DIRT/3D (COLMAP) and DIRT/3D (VisualSFM) using 5-10 replicates per genotype.

Test 3: Comparison of root traits to manual ground truth

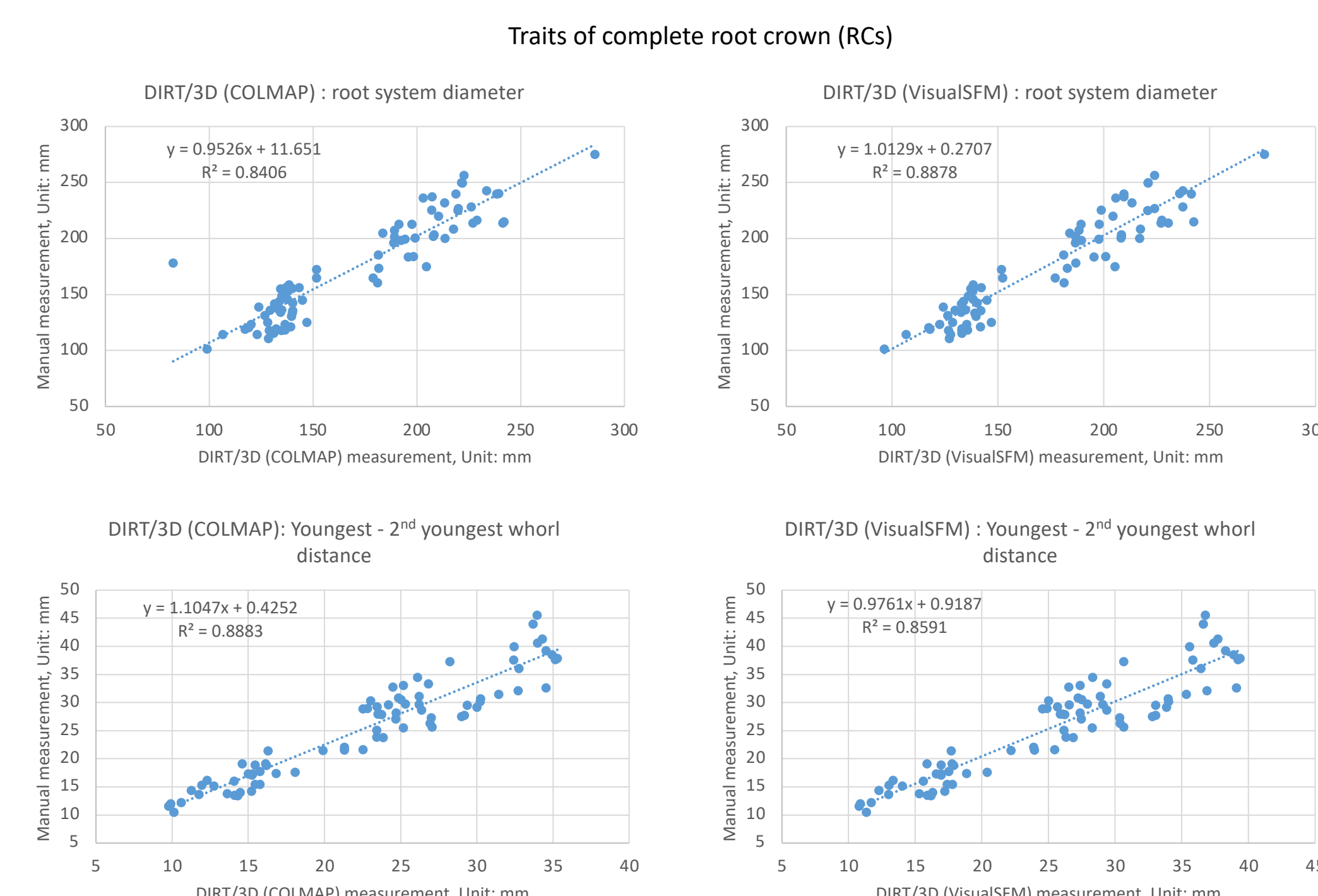


Figure 6. Comparison of correlation analysis of complete root traits.

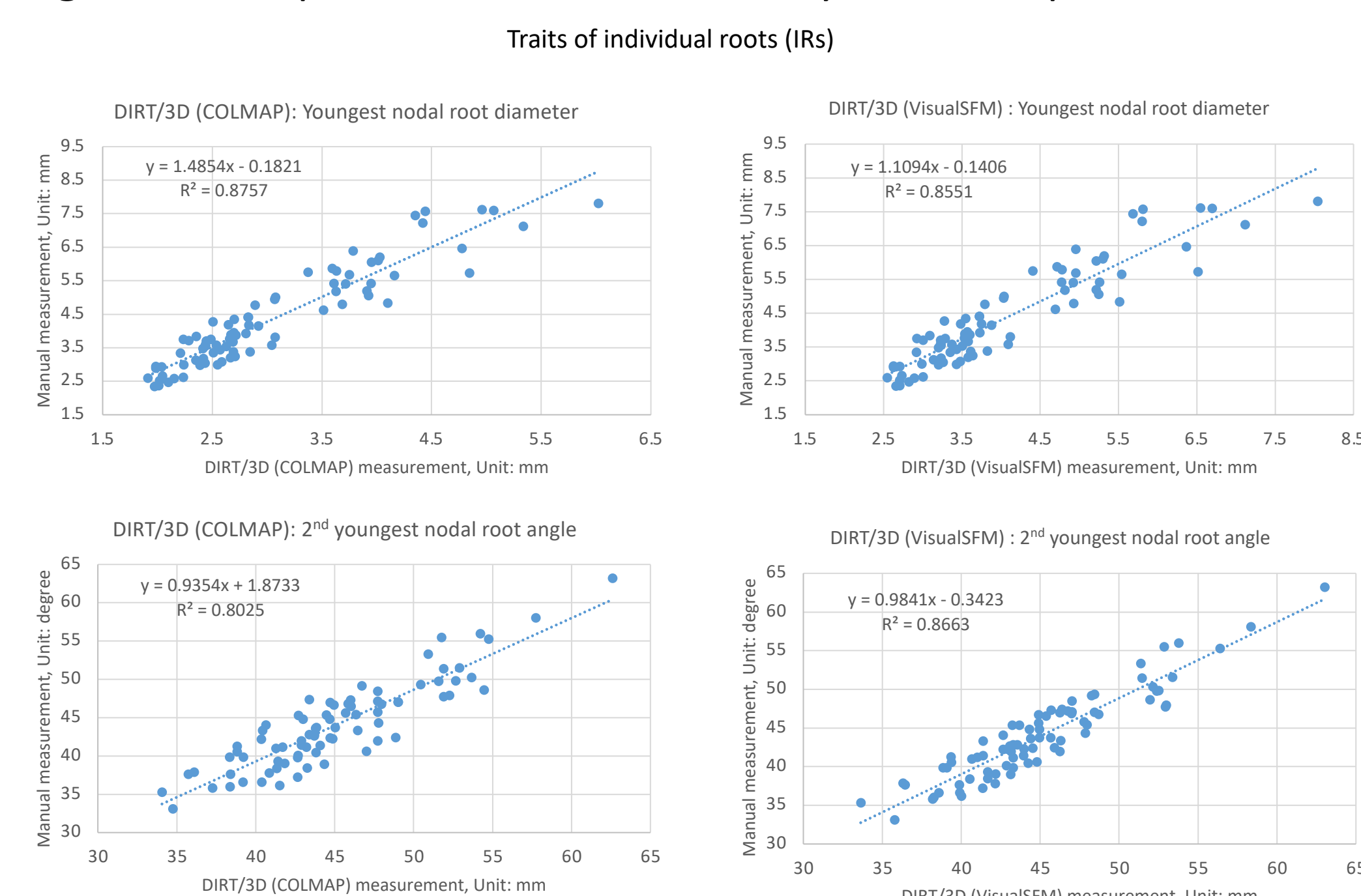


Figure 7. Comparison of correlation analysis of individual root traits.

Conclusion

1. Using COLMAP for 3D reconstruction reduced the number of images for a dense 3D model from 3000~3600 to 300~600.
2. Denser 3D models improved the accuracy of the 3D root-trait measurement [2]
3. Reducing the number of images reduces data storage needs
4. The updated DIRT/3D pipeline enables faster image collection without compromising the accuracy of 3D root-trait measurements.

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