Investigating Phylogenetic Patterns of Palm Phytolith Morphology and Applications for Reconstructing the Paleoecology of the Arecaceae

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Project Goals: To quantify morphological variation of phytoliths within the palm family Arecaceae, and to investigate relationships between phytolith morphology, phylogeny, and ecology for applications to fossil palm phytoliths.

Background

- Palms (Arecaceae) are traditionally used as key indicators of tropical paleoenvironments, but inhabit a wide range of habitats and climates
- Phytoliths abundantly produced by palms are well represented in the fossil record, but lack resolution below family
- Previous studies analyzed palm phytolith shape, but used few traits and had a limited taxonomic scope (e.g., Albert et al. 2009, Morcote-Ríos et al. 2016)
- Globular (spheroid) echinate and Hat Morphotypes (see Figure 3)

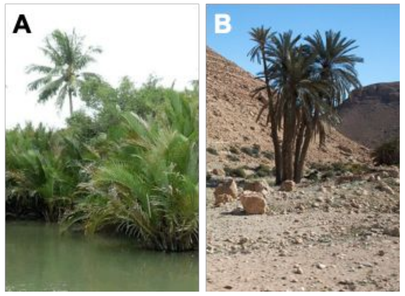


Figure 1. A. Palm of wet tropical habitats: *Nypa fruticans* (foreground) and *Cocos nucifera* (background). **B.** *Phoenix dactylifera* (date palm), a cultivated species of dry habitats. Photos: Mark Merlin (A), and Katina Rogers (B).

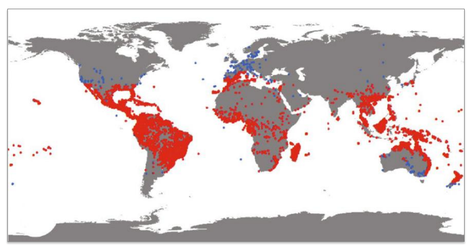


Figure 2. Palm species occurrence, after Reichgelt et al. (2018). Red and blue dots represent data, respectively, used and discarded by Reichgelt et al. (2018).

Methods

- Preliminary dataset :
  2,923 phytoliths from 84 palm species
  448 phytoliths from 13 outgroups
- Imaging - high resolution z-stacks obtained via confocal microscopy
- Measurement - size and shape data by semi-automated ImageJ script (Fig.4)
- Analyze correlations between phytolith morphology and phylogeny or ecology using multivariate analysis models
- Grouping by phylogeny and ecology
  - Ecologies designated as Tropical Rainforest (TRF) or Non-TRF (cooler and/or drier) by clustering methods based on climate data (temperature, precipitation) (see Figure 7).

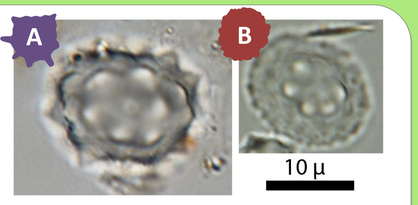


Figure 3. Major palm phytolith morphotypes. **A.** Globular (spheroid) echinate; **B.** Hat.

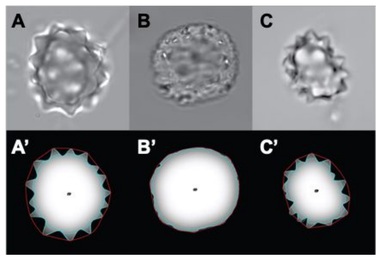


Figure 4. Phytoliths and measured outlines of three palm species. **A,A'.** *Corypha taliera* (subfamily Coryphoideae), **B,B'.** *Nypa fruticans* (Nypoideae), **C,C'.** *Dypsis lutescens* (Arecoideae).

Results

- Mixture Discriminant Analysis (MDA) model shows some success at differentiating palms at the subfamily level.
- Moderate-weak correlation between ecology and phytolith morphology
  - Accuracy does not improve by incorporating phylogenetic data
- Higher accuracy differentiating between palms and non-palm outgroups

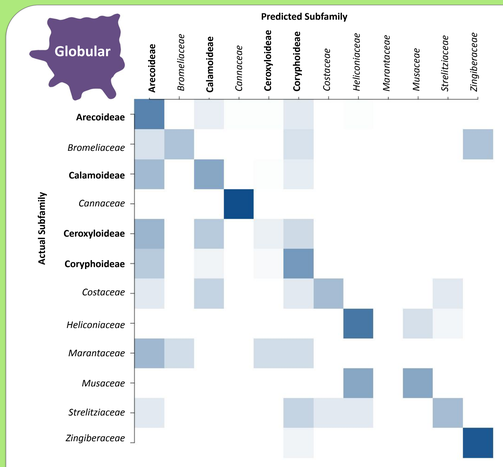


Figure 5. Mixture Discriminant Analysis (MDA) Plot for Globular Morphotype Phytoliths from Palms and Outgroups. Accuracy 59%, NIR 43%, K = 0.45, p < 0.001. Darker diagonal sections indicate higher accuracy. Subfamilies of the Arecaceae shown in **bold**, outgroups *italicized*.

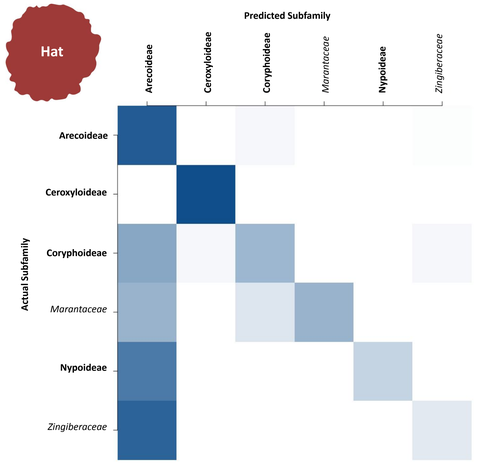
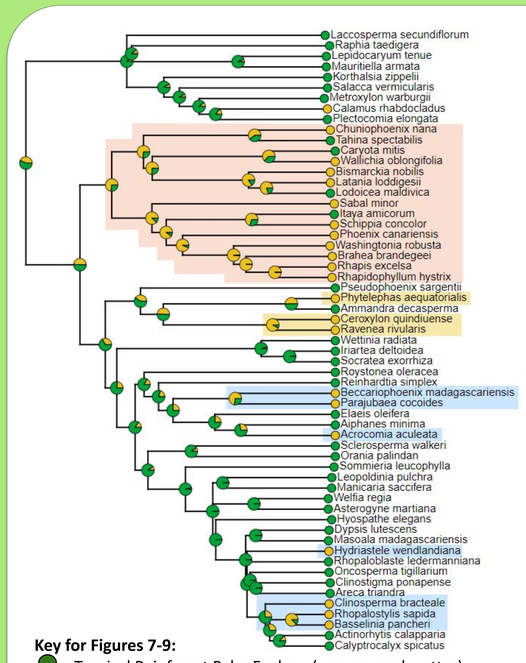


Figure 6. Mixture Discriminant Analysis (MDA) Plot for Hat Morphotype Phytoliths from Palms and Outgroups. Accuracy 73%, NIR 64%, K = 0.43, p = 0.017. Darker diagonal sections indicate higher accuracy. Subfamilies of the Arecaceae shown in **bold**, outgroups *italicized*.



Key for Figures 7-9:
= Tropical Rainforest Palm Ecology (warmer and wetter)
= Non-TRF Palm Ecology (cooler and/or drier)
Clades showing independent transitions to a Non-TRF Ecology highlighted within the palm subfamilies Coryphoideae, Ceroxyloideae, and Arecoideae.

Figure 7 (above). Palm Ecology Ancestral State Reconstruction based on phylogeny by Faurby et al. 2016. Highlighted clades demonstrate transitions from the ancestral TRF palm ecology to derived, Non-TRF ecologies (see Fig. 8). Highlighted colors designate clades demonstrating transitions to Non-TRF ecologies within palm subfamilies: red = Coryphoideae, yellow = Ceroxyloideae, and blue = Arecoideae (see Fig. 9).

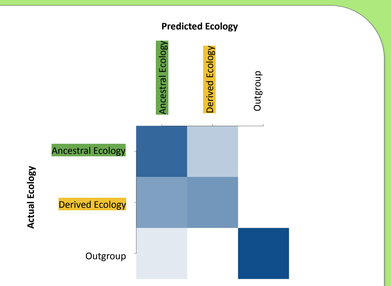


Figure 8 (above). Mixture Discriminant Analysis (MDA) Plot of Palms by Ecology. Accuracy 67%, NIR 58%, K = 0.41, p < 0.001. Groupings of palm taxa by their ecology (see Figure 7), with either the ancestral palm ecology, a derived ecology, or being a non-palm outgroup (not shown on Figure 7).

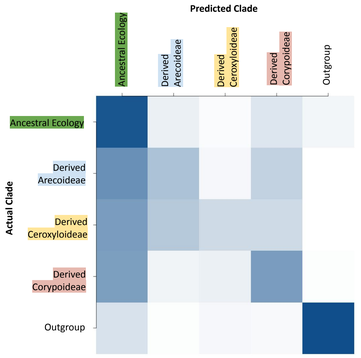


Figure 9 (above). Mixture Discriminant Analysis (MDA) Plot of Eco-taxonomic Palm Groups. Accuracy 62%, NIR 54%, K = 0.40, p < 0.001. Groupings correspond to highlighted clades in Fig. 7 with derived, Non-TRF ecology, ancestral TRF ecology, and non-palm outgroups (not shown on Fig. 7).

Conclusions

- Morphology correlated with both phylogenetic and ecological components
- Predictive models for phylogenetic and ecological affiliations based on palm phytolith morphology show promise, but require refinement

Ongoing Work

- Refining and expanding our modern image dataset with high-quality consistent images, and iterating on our model to improve model accuracy
- Generating consistent and accurate model for predicting phylogeny and paleoecology of fossil palm phytoliths based on their morphology
- Applying our methods to putative fossil palm phytoliths from Eocene-Miocene localities in the Americas and Turkey

Literature

Albert RM, Bamford MK, Cabanes D. 2009. Palaeoecological significance of palms at Olduvai Gorge, Tanzania, based on phytolith remains. Quaternary International, 193: 41-48.
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Acknowledgments

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