The papermaking syndrome:
Using functional traits to explain patterns in ethnobotany

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System & Motivation

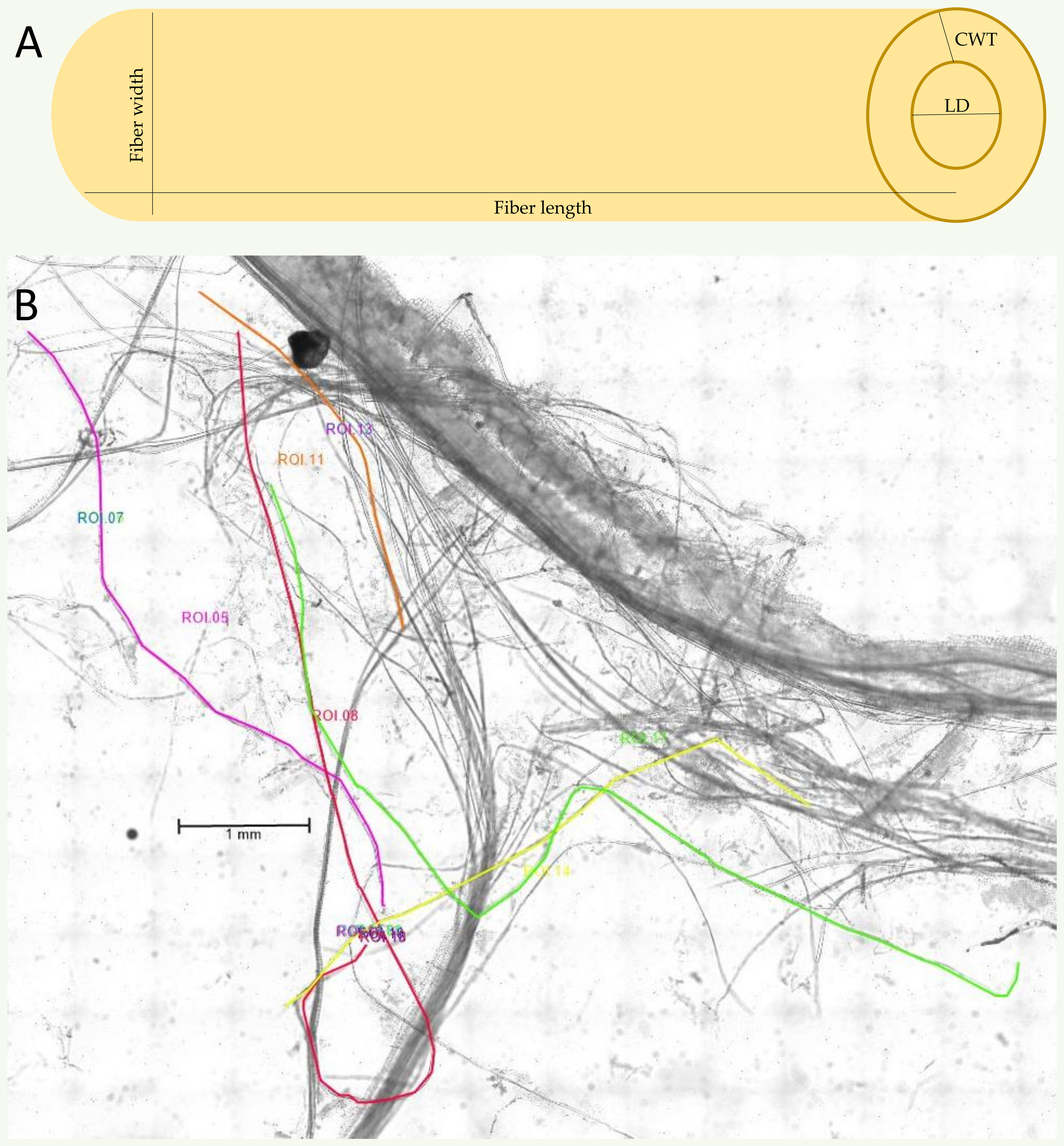
- Although the field of ethnobotany is filled with many examples of plant-people interactions—like papermaking (**Figure 1**)—there are few quantitative methods to test why some species, and not others, are represented in these relationships.
- Pairing hypothesis testing with quantitative methods can reveal patterns between the characteristics of a plant and how it is used (Gaoue *et al.* 2017).
- The **plant use value hypothesis** posits that *the usefulness of a plant is determined by evaluating many of its characteristics simultaneously*, including but not limited to *botanical family* (Phillips & Gentry 1983; **Figure 2**).
- Using functional trait measurements and multivariate statistical comparisons, we test whether fiber physiology is a useful filter to explain the extreme selectivity of traditional papermakers in choosing plants as a raw material for hand papermaking.

Figure 1. Papermakers in Nepal and Vietnam demonstrating typical hand papermaking process; example shown here from bast (phloem) fibers. (A) harvest of suitable paper plants; (B) removal of outer bark from bast; (C) boiling of bast in limewater to soften them and remove lignin; (D) washing bast to remove lime; (E) beating bast using a wooden mallet until fibers separate; (F) bleaching the fibers; (G) washing fibers to remove bleach; (H) removing debris from fiber-water suspension; (I) combination of fiber, mucilage, and water in a basin; (J) use of a mat and frame to make individual paper sheets; (K) removal of water from paper via sun-drying; and (L) removal of sheets from the frame once dry. Photos by James Ojascastro.

Methods

- Collect and measure four functional traits of non-wood fibers of a variety of plant species (**Figure 3**).
- Use nonmetric multidimensional scaling to visualize the spread of species and their associated functional traits in two dimensions.
- Run a multiple regression to test how botanical family, PP vs. NPP, and tissue of origin (e.g., whether the fiber was sourced from stem, leaf, root, fruit, or seed) influence clustering patterns in multivariate space.

Figure 3. (A) Four physiological fiber traits measured in this analysis: fiber length, fiber width, lumen diameter (LD), and cell wall thickness (CWT), (B) an example of fiber length measurement in NPP cultivated fig, *Ficus carica.*



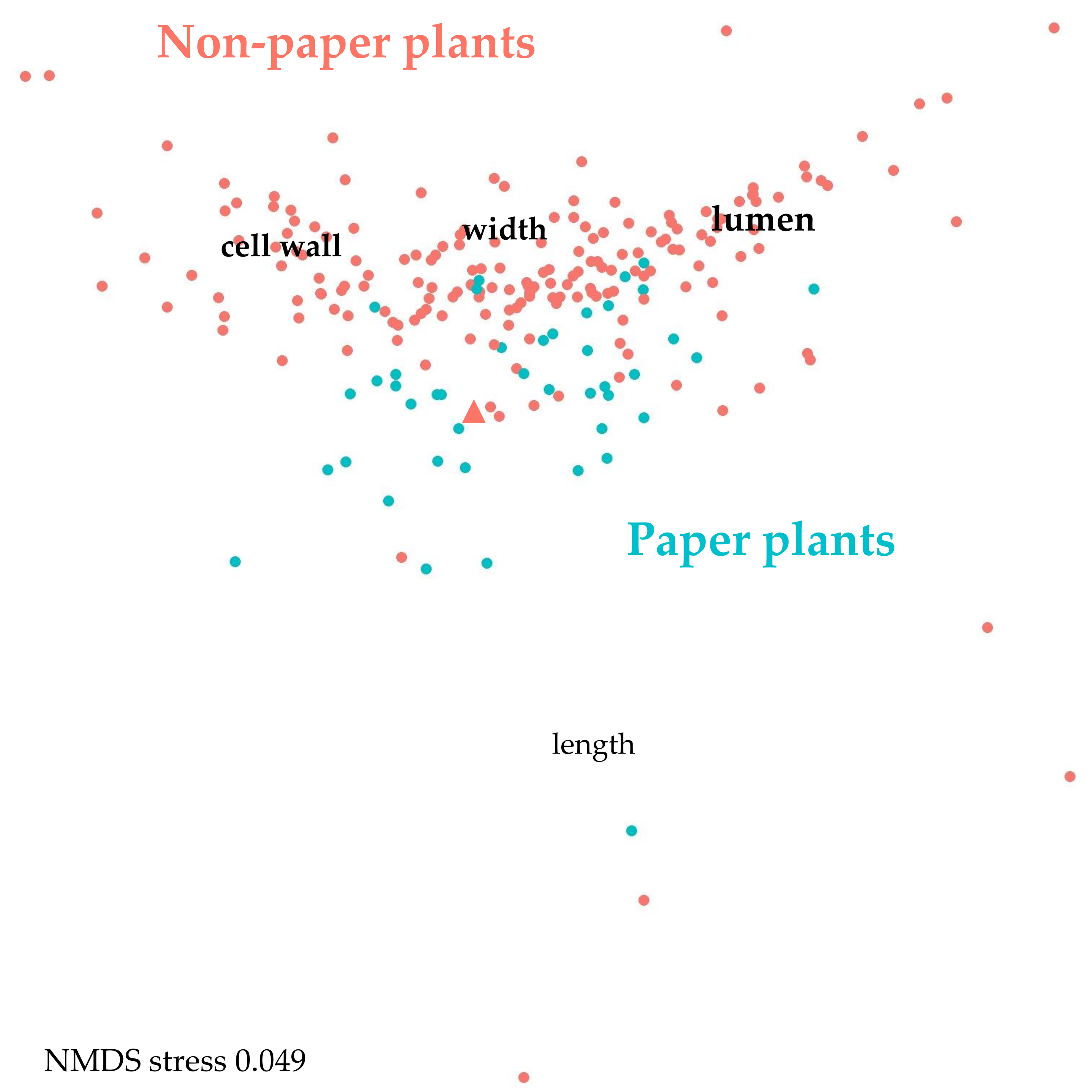


Figure 4. Nonmetric multidimensional scaling of traits of nonwoody fibers across 43 paper plant (PP) and 186 non-paper plant (NPP) species. Blue indicates PP; red indicates NPP. The red triangle indicates the position of NPP common fig (*Ficus carica*), which by fiber physiology should be a PP.

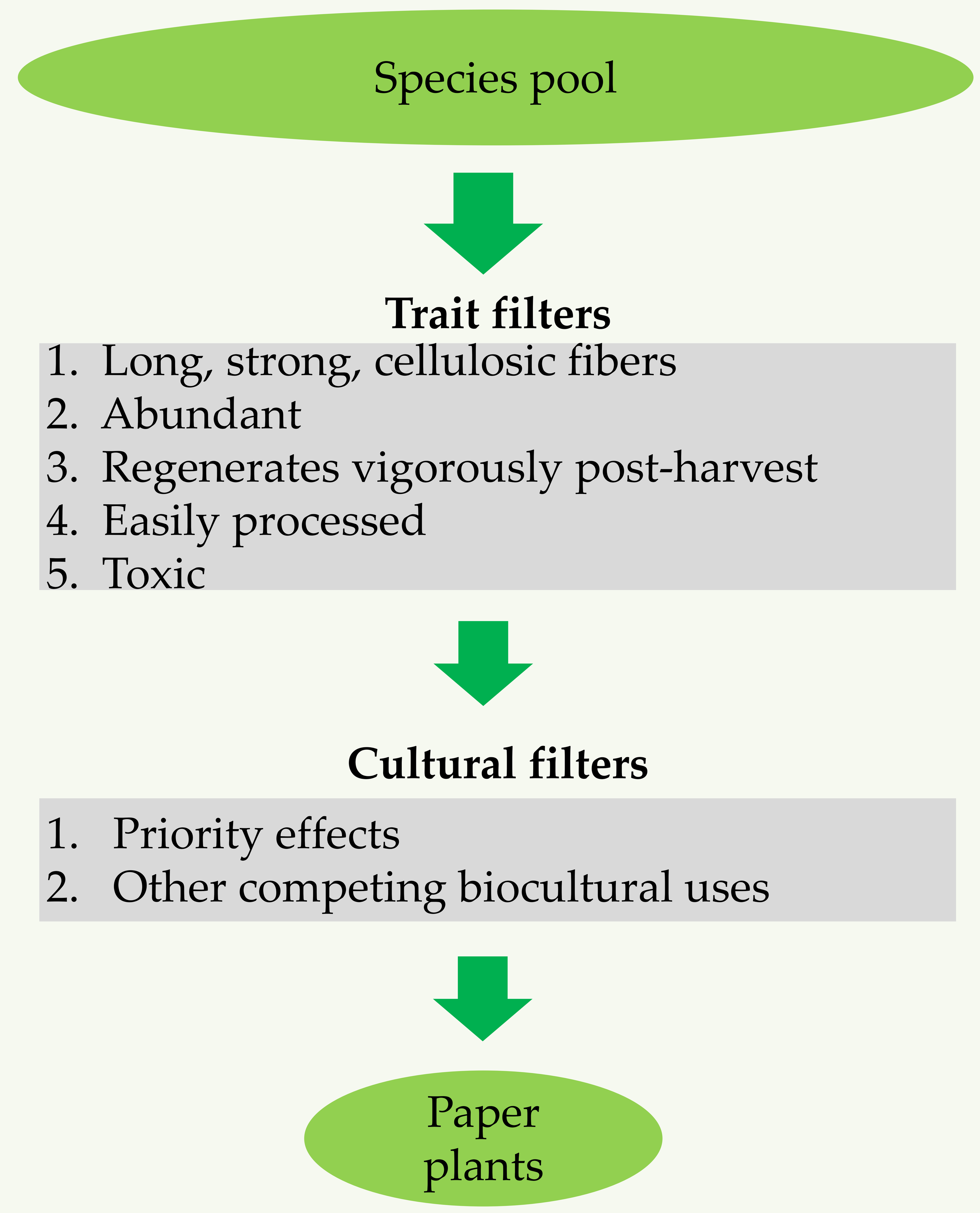
Conclusions

- Functional traits can be a very useful part of quantitative ethnobotany, allowing for hypothesis testing and generating explanations for why people use plants in particular ways.
- Trait measurements can help reveal possible cultural filters, by identifying species those that should be used in a certain way but inexplicably are not (**Figure 5**).

Hypothesis

- H_A: Plants used in hand papermaking traditions (paper plants; PPs) have a statistically significant difference in fiber physiology and systematic placement than plants not used in hand papermaking traditions (non-paper plants; NPPs)
- H_0: There is no difference in non-wood fiber physiology and systematic placement between PPs and NPPs.

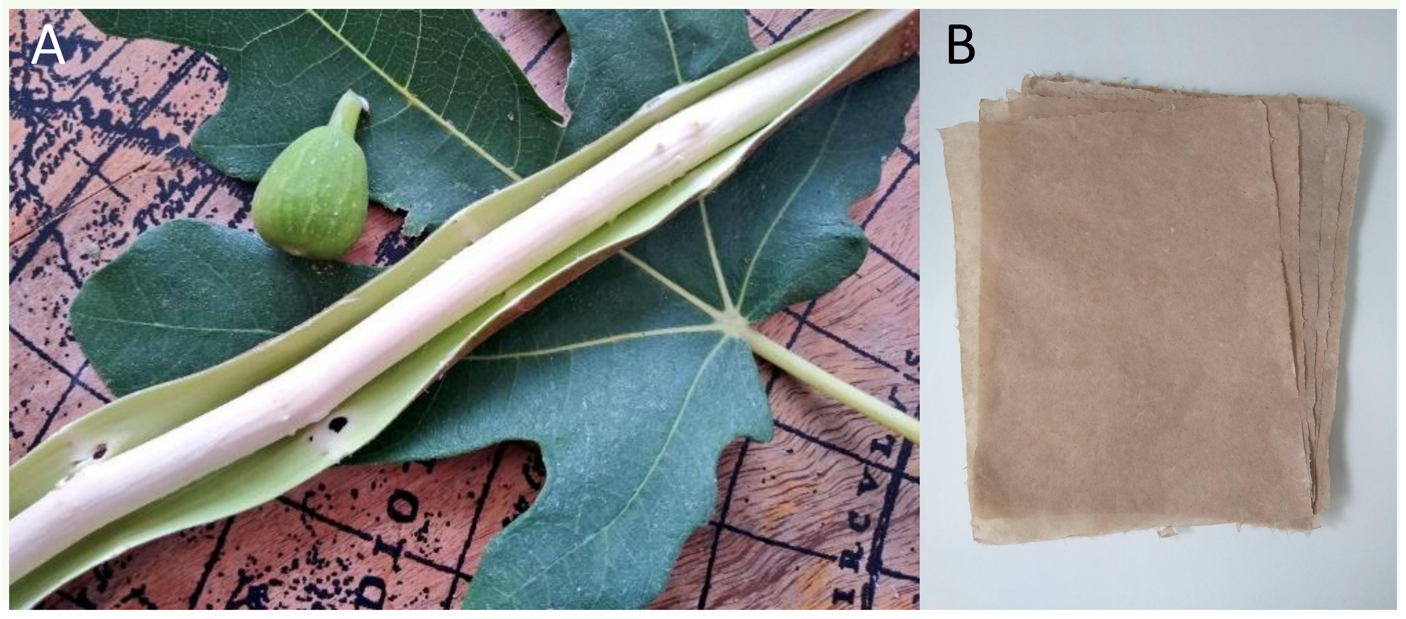
Figure 2. Conditions necessary for a plant to be chosen for hand papermaking traditions. Traits measured here focus on the first condition. Note: since evolutionarily related plants tend to have similar traits, botanical family can be a useful covariate or proxy for these conditions.



Results

Fiber physiology, plus botanical family and tissue of origin, all significantly explain patterns of use and disuse of different nonwoody fibers across species for traditional papermaking ($p < 0.05$ for all; **Figure 4**).

Figure 5. Common fig (A) may be culturally filtered from being a PP in Europe due to cultural preference in cultivating figs for food and flax for fiber, despite *F. carica* having long (5-10 mm), flexible phloem fibers (Figure 3) that experimentally yield strong handmade paper (B).



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