Phylogeny and taxonomy of the genus *Arundinaria* (Poaceae: Bambusoideae)

Jimmy Triplett
Iowa State University
Outline

I. What is bamboo?

II. *Arundinaria* and kin: the Temperate Bamboos

III. Molecular studies (cpDNA, AFLPs)

IV. *Arundinaria sensu stricto*

*Arundinaria faberi*
Yunnan Province, China
Bamboo: importance
BAMBUSOIDEAE (true bamboos)

- Worldwide, both tropical and temperate zones
- Only major group of grasses to diversify in forests
- Defined by the presence of strongly asymmetrically invaginated arm cells in the leaf mesophyll
- Ca. 100 genera and at least 1,450 species, currently classified into two tribes, the Olyreae (herbaceous bamboos) and the Bambuseae (woody bamboos)
Olyreae

- unisexual, one-flowered spikelets, females with indurate lemmas; plants monoecious; restricted branching; no culm leaves; seasonal flowering.

- $x = (7, 9) \ 10, 11 \ (12)$, diploids and tetraploids

- understory of tropical moist forests, up to 1,000 m elevation; a few in more open habitats

- 21 genera and ca. 115 described species; primarily American, 1 Olyra in Africa; 1 monotypic genus in New Guinea

*Sucra monophylla*

Photo by L.G. Clark
Bambuseae

- perennating lignified culms; differentiation of culm and foliage leaves; complex branching; gregarious, monocarpic flowering; bisexual florets

- \( x = 10, (11), 12 \); tetraploids and hexaploids, 1 diploid?

- tropical to temperate forests, some in dry forests or high-altitude grasslands; in gaps or along edges; diversity primarily montane

- 78-101 genera, ca. 1,320 described species; worldwide

*Indosasa sinica*
Yunnan Province, China
Subtribes of Bambuseae (woody bamboos)

Neotropical bamboos
- Arthrostylidiinae (12/162)
- Guaduinae (5/35)
- Chusqueinae (2/155)

Paleotropical bamboos
- Bambusinae (17-23/331)
- Melocanninae (8-9/87)
- Hickeliinae (9/37)
- Incertae Sedis (6/7)

Temperate bamboos
- Arundinariinae (14-24/338)
- Shibataeinae (5-7/164)
Recent molecular studies support the monophyly of major groups (including neo- and paleotropical subtribes) while revealing several surprising relationships.

**Bamboo Phylogeny Group**

Preliminary combined analysis of 5 cpDNA regions

*ndhF, rpl16, rps16, trnDT, trnTL*

4231 bp (gaps excluded)

Strict consensus of 60 MP trees

$L = 1452; CI=0.57, RI=0.71$
Temperate Woody Bamboos

• 19-31 genera, ca. 502 described species.
• Vast majority of diversity in Asia, a few species in India, Sri Lanka & Africa; 3 species native to SE U.S.
High morphological diversity in the temperate clade
The *Arundinaria* complex

Hypothetical phylogeny of the Temperate Bamboos
Arundinaria

Oldest name for temperate bamboos (1803).

Originally described by Michaux for species in North America: *A. macrospdera* (now *A. gigantea*) and *A. tecta*

Type species = *A. gigantea* (Walt.) Muhl.

Longstanding taxonomic controversies: Species limits? Generic boundary?
**Arundinaria Complex**

rhizomes monopodial, leptomorph; branches 1-7; inflorescences semelauctant; stamens 3(-5), stigmas 2-3

*Arundinaria s.s.* (US)

*Bashania* (4 spp., China)

*Ferrocalamus* (2 spp., China)

*Indocalamus* (35 spp., East Asia)

*Pleioblastus* (42 spp., Japan, China)

*Pseudosasa* (36 spp., Japan, China)

*Oligostachyum* (18 spp., China)

*Sarocalamus* (2 spp., China)

*Pseudosasa amabilis*
Taxonomic controversies surrounding *Arundinaria*

Is the *Arundinaria* complex monophyletic?

Who are the closest relatives of *Arundinaria s.s.*?

Should morphologically similar species from Asia (e.g., *Pleioblastus, Pseudosasa, Bashania, Sarocalamus*) be included in *Arundinaria*?

How many species are there in North America?
Molecular phylogenetic analyses of the temperate bamboos
(with an emphasis on the Arundinaria complex)

NJ analysis; combined plastid data: *rps16-trnQ, trnC-rpoB, trnDT, trnTL*
Maximum parsimony, strict consensus tree (total evidence: 13 cpDNA regions)
Hypothesized phylogeny
Hypothesized phylogeny

Polyphyly!
The *Arundinaria* Clade

### Lineages

**A. Sasa & allies (Japan)**
- Sasa s.s., Sasaella, Hibanobambusa

**B. Chinese clade**
- Acidosasa, Indosasa, Pseudosasa subg. Sinicae

**C. Japanese clade**
- Pleioblastus s.s., Pseudosasa subg. Pseudosasa, Sasaella, Sasamorpha, Semiarundinaria

**? Arundinaria s.s.**
- A. appalachiana, A. tecta, A. gigantea
The *Arundinaria* Clade

**cpDNA analysis:**
Unresolved issues

Is *Arundinaria s.s.* monophyletic?

Who is sister to *Arundinaria* in North America? *(Sasa?!)*
Summary tree: major lineages of temperate bamboos

1. *Pleioblastus Nezasa* clade (Japan)
2. *Pleioblastus Ryukyu* clade (Japan)
3. *Sinicae* clade (SE Asia)
4. *Sasa s.s.* & allies (Japan)
5. *Arundinaria s.s.* (North America)
6. *Phyllostachys* & allies (SE Asia)
7. *Chimonocalamus* (SE Asia)
8. *Thamnocalamus tessellatus* (S. Africa)
9. *Shibataea* & allies (SE Asia)
10. *Yushania alpina* & allies (C. Africa, Madagascar)

Branching order remains a mystery (Likely due to “rapid” radiation)
Summary: Arundinaria and relatives

- The *Arundinaria* complex is not a natural group; *e.g.*, Bashania, Sarocalamus, Indocalamus, and Oligostachyum are in fact closer to Phyllostachys

- *Pleioblastus s.s.* (Japan) and the Sinicae clade (China) represent distinct lineages

- *Pleioblastus s.l.* and *Pseudosasa s.l.* are problematic taxa, but none of the species are close to *Arundinaria s.s.*

- *Sasa spp.* may be the closest relatives of *Arundinaria s.s.*
Sequence Divergence in the Temperate Bamboos*

<table>
<thead>
<tr>
<th>Among Genera</th>
<th>% Divergence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arundinaria : Shibataea</td>
<td>0.8440</td>
</tr>
<tr>
<td>Arundinaria : Pleioblastus</td>
<td>0.6606</td>
</tr>
<tr>
<td>Arundinaria : Phyllostachys</td>
<td>0.5872</td>
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<tr>
<td>Arundinaria : Sasa</td>
<td>0.2936</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Among Species</th>
<th>% Divergence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pleioblastus s.s.</td>
<td>0.3670</td>
</tr>
<tr>
<td>River Cane : Switch Cane</td>
<td>0.2936</td>
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<tr>
<td>Shibataea</td>
<td>0.0734</td>
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<tr>
<td>Sasa s.s.</td>
<td>0.0734</td>
</tr>
<tr>
<td>Switch Cane : Hill Cane</td>
<td>0.0367</td>
</tr>
<tr>
<td>Phyllostachys</td>
<td>0.0367</td>
</tr>
</tbody>
</table>

*Based on 4 cpDNA regions, ca. 4547 characters
Arundinaria sensu stricto

How many species in North America?

River Cane  Switch Cane  Hill Cane
switch cane vs. river cane

+ 

reports of a deciduous cane in the Appalachians

= 

field work

River cane
Switzerland Co., IN
rhizome anatomy

river cane, hill cane

hill cane

switch cane
branching

river cane

switch cane, hill cane
internode groove
in river cane

(absent in switch cane
and hill cane)
leaf blade underside hairiness and tessellation

hill cane

river cane

switch cane
AFLP studies of *Arundinaria s.s.*
Arunardinaria field sites
AFLP analysis:
6 primer combinations
338 characters

NJ analysis;
Nei-Li distance matrix

A. gigantea (river cane)
A. tecta (switch cane)
A. appalachianna (hill cane)
Outgroup (Sasa)
A. gigantea
A. appalachiana
A. tecta
(x) Hybrids
Proposed taxonomic treatment of native canes in North America

Three species:

**River cane** (*A. gigantea*)
- brownwater floodplains, moist forest understory
- mostly lowland, but up to 1,500 ft
- widespread in the SE US

**Switch cane** (*A. tecta*)
- blackwater floodplains, swamps, moist forest understory
- Coastal Plain, rarely further inland (?)

**Hill cane** (*A. appalachiana*)
- moist to dry forests, seeps
- Southern Appalachians and upper Piedmont, 1,500-3,400 ft
river cane (*A. gigantea*)

Leaf L = 11 cm (± 2)

Leaf W = 1 cm (± 0.2)

TK = 6-8
*Arundinaria gigantea* (River or Giant Cane)
TK = 10-12

switch cane (*A. tecta*)

Leaf L = 20 cm (± 3)

Leaf W = 1.7 cm (± 0.3)
hill cane (*A. appalachiana*)

Leaf L = 10 cm (+ 1)

Leaf W = 0.9 cm (+ 0.1)

TK = 8-11
Caution: hybridization happens!
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Questions?
E Asia

E North America

3 species of native cane

ca. 1:150

~450 species
midrib metaxylem vessels

hill cane

river cane

switch cane
Hypothetical phylogeny of the Temperate Bamboos