Evolutionary relationships among morning glories and the wild relatives of sweet potatoes: Identifying the potential gene pool relevant to *Ipomoea batatas*

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Rick Miller

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*Ipomoea chenopodiifolia* in Oaxaca, Mexico
Seeds
GRIN
CIP
Colleagues: M. Clegg M. Rausher many others
Road Map

• Two-part presentation:
  – Brief introduction to morning glories
  – Consider the potential gene pool relevant to sweet potato pre-breeding among the crop wild relatives
Ipomoea

- 500-700 species, largest in Convolvulaceae
- 3 Subgenera, 12 sections
- Diploids, tetraploids, hexaploid – I. batatas

‘Sunrise Serenade’
I. quamoclit
I. arborescens
Ipomoea spp. Flower Diversity

**Medium Term**

2. *I. nil*, *I. purpurea*, *I. tricolor*

- ‘Cameo Elegance’
- ‘Flying Saucers’
- ‘Kniolas Black’
- ‘Ismay’
- ‘Milky Way’
- ‘Carnevale di Venezia’
- ‘Rosita’
- ‘Scarlett Ohara’
Ipomoea spp. Flower Diversity

Medium Term

2. *I. nil*, *I. purpurea*, *I. tricolor*

- ‘Kikyou’
- ‘Yangi’
- ‘Sunrise Serenade’
- ‘Picotee Blue’, ‘Picotee Red’
Ipomoea spp. Phenotypic Diversity

- *Ipomoea purpurea*
  - common morning glory
  - showy purple flowers
  - annual twining vine
  - disturbed habitats
  - New World distribution now spread worldwide
  - model organism in evolutionary studies
    - anthocyanin biosynthetic pathway characterized
    - genes to ecology

*Ipomoea purpurea* in a soybean field in North Carolina
Phenotypic Diversity

- *Ipomoea arborescens*
  - tree morning glory
  - found in Mexico
  - large white flowers
  - pollinated by variety of animals
    - bees, hummingbirds, perhaps bats

photo by Richard Evans Schultes of *I. arborescens* & Lynn Bohs
Phenotypic Diversity

- *Ipomoea arborescens*
  - tree morning glory
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  - large white flowers
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photo by Richard Evans Schultes
Ipomoea spp. Phenotypic Diversity

- *Ipomoea pes-caprae*
  - beach morning glory
  - semi-succulent leaves
  - pantropical distribution
  - produces ergot alkaloids through symbiotic relationship with Clavicipitaceae fungus
Ipomoea spp. Phenotypic Diversity

- *Ipomoea quamoclit*
  - American bird-pollinated morning glory
    - hummingbird
  - Mina group
  - monophyletic group
  - morphological synapomorphy
    - unique sepal morphology
*Ipomoea spp.* Phenotypic Diversity

- *Stictocardia beraviensis*
  - African bird-pollinated morning glory
    - sunbird?
  - robust red flowers
  - unique fruits
  - liana
  - another ergot positive species
Ipomoea spp. Phenotypic Diversity

- *Argyreia nervosa*
  - Asian liana
  - fleshy fruits
  - ergot positive

Argeyria nervosa
fleshy fruit

Ipomea carnea
dry dehiscent fruit
hairy seeds
What is a morning glory?

- Generally, species of the genus *Ipomoea*
  - family Convolvulaceae
  - convolvulate flowers
  - perennial twining vines
  - capitate stigmas
  - dry indehiscent capsules
  - common in disturbed habitats

*Ipomoea alba* – fragrant, night blooming moth-pollinated species common in Mexico
Closely related Ipomoea

Sweetpotato, I. batatas, 6x

I. tabascana, 4x  I. littoralis, 4x  I. tiliaceae, 4x  I. trifida, 2x
Closely related Ipomoea

I. ramosissima, 2x, GRIN
I. xleucantha, 2x, GRIN
I. umbraticola, 2x, GRIN
I. lacunosa, 2x, GRIN, B+T
I. triloba, 2x, GRIN
I. cordatotriloba, 2x, GRIN
Morning glories with spiny pollen

- *Ipomoea* is not monophyletic
- Tribe Ipomoeae is a well-supported monophyletic group
- Spiny pollen is a synapomorphy for the group
- Includes *Argyreia*, *Stictocardia*, *Turbina*, etc.
- about 900 species
- Subtropics and tropics worldwide
Morning glory diversity

- Diverse life forms
  - twining vines, shrubs, small trees, prostrate herbs
- Floral diversity
  - flowers typical of bee, bird, moth, and bat pollination, as well as selfing species
- **Sepal morphology**
  - Important trait for identifying morning glories
    - trifling trait, *sensu* Darwin
- Brief tour of diversity…
Systematics of morning glories and placement of sweetpotato and relatives

- Current phylogenetic hypothesis
  - 26-gene phylogeny
  - Use ITS tree as dominant tree for comparison
  - Gene tree – species tree approach
    - paradigm shift in systematics
  - Let each gene tell its own story
  - Emphasizing potential to detect discordance between gene histories

- 30 whole-chloroplast genomes
  - 81 genes
  - exemplar sample of Ipomoeaeae diversity
Systematics of morning glories and placement of sweet potato and relatives

- *Ipomoea batatas*
  - currently a member of *Ipomoea* section *Batatas*
  - very closely-related morning glory species
  - well-supported monophyletic group
    - all gene regions examined show strong support
  - members of *Eriospermaceous* species
    - hairy-seeded morning glories
  - almost all *Batatas* species do not have hairy seeds
The gene pool relevant to sweet potato

• Important to determine gene pool relevant to improvement of sweet potato, *Ipomoea batatas*

• Informed by our understanding of evolutionary relationships among wild relatives of sweet potato

*Ipomoea batatas*

photo by J. A. McDonald
## Closely related Ipomoea - Interspecific hybrids

<table>
<thead>
<tr>
<th>Female</th>
<th>Male</th>
<th>Crossability</th>
</tr>
</thead>
<tbody>
<tr>
<td>batatas</td>
<td>trifida</td>
<td>medium</td>
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<tr>
<td>batatas</td>
<td>x leucanthes</td>
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<td>cynanchifolia</td>
<td>grandifolia</td>
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<td>ramosissima</td>
<td>tenuissima</td>
<td>high</td>
</tr>
<tr>
<td>ramosissima</td>
<td>tiliacea</td>
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<tr>
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*Note: ovule culture indicates a specific growth condition.*
Batatas species form a distinct group

- Morphologically distinct among morning glories
- Sepal morphology unique
  - easily to recognize a morning glory as member of Batatas group

Ipomoea cordatotriloba
Photo Patrick Alexander
Batatas species form a distinct group

- Common morphological features
  - herbaceous twining vines
  - lavender corollas with darker throats
  - common highly disturbed habitats and considered weeds
  - one species, *Ipomoea umbraticola* has hairy seeds, large flowers, self-incompatible

*Ipomoea cordatotriloba*
Current taxonomic status

- *Ipomoea* section *Batatas*
- Members of subgenus *Eriospermum*
  - hairy-seeded morning glories
  - *Batatas* species do not have hairy seeds
- These species have been considered a separate genus
  - dynamic nature of taxonomy of these species

Seed vestiture in morning glories
Ipomoea section Batatas

- Fourteen named species
  - includes polyploids
    - parentage remains elusive
- New World distribution
  - except Australian
    *Ipomoea littoralis*

<table>
<thead>
<tr>
<th>Species</th>
<th>Percentage</th>
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<tbody>
<tr>
<td><em>Ipomoea batatas</em></td>
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<tr>
<td><em>Ipomoea cordatotriloba</em></td>
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Taxonomy of *Ipomoea* section *Batatas*

- Dan Austin has provided most comprehensive treatment
  - emphasizes it is a preliminary treatment
  - additional work needed to develop definitive taxonomy for these species

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The *Ipomoea batatas* complex—I. Taxonomy

Daniel F. Austin

Department of Biological Sciences, Florida Atlantic University,
Boca Raton, Florida 33431

Austin, Daniel F. (Dept. Biol. Sci., Florida Atlantic Univ., Boca Raton, Florida 33431). The *Ipomoea batatas* complex—I. Taxonomy. Bull. Torrey Bot. Club 105: 114–129. 1978.—Eleven species, two named hybrids and an un-named hybrid are known to be allied with *Ipomoea batatas*. All but two of these taxa are New World plants, the remaining two are apparently native to the Old World. Species and hybrid populations are characterized.
Taxonomy of *Ipomoea* section *Batatas*

- Dan Austin has provided most comprehensive treatment
  - important to recognize treatment developed using typological species concept
  - morphologically-based recognition of species
  - based, in part, on quantitative assessments of characters
    - sometimes overlapping
  - does not necessarily reflect evolutionary relationships

Plato – ideal type

Plato and Aristotle by Raphael
Future directions

• Focused studies on small monophyletic groups to develop well-resolved species-level phylogenies
  – taxonomic work may be needed
• Increased taxon sample
  – 900 species!
• Multi-gene approach
  – gene capture to develop 500-gene phylogenies using transcriptome data
• *Monografía rápida de campanillas!*
  – Robert Scotland and colleagues

*Ipomoea tuboides*  
Hawaii

*Ipomoea orizabensis*  
Mexico
Conclusions

• Strong support for *Ipomoea* section *Batatas* representing a species complex
  – Phylogenetic analyses resolved some clades corresponding to named species, but not common
• Populations of different named species closely-related
  – Indicates incongruence between pattern of morphological variation and evolutionary relationships
Future directions

- Determine degree of interfertility among populations
  - Studies to evaluate crossing success among pairs of populations within the species complex
  - Careful attention to details for each accession
- Population genetic structure within species complex
  - Additional multi-gene studies
  - Widespread sample
  - Better understand geographic and historical factors that may contribute to genetic structure
Future directions

• Ecological characteristics of populations
  – Field trials to evaluate important traits
    • resistance to insect pests
    • resistance to pathogens
    • drought resistance
    • life history traits

3,240 *Ipomoea purpurea*
Reaction norm experiment
Miller and Rausher