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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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

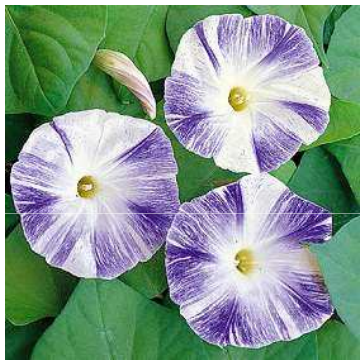
I. arborescens

Ipomoea spp. Flower Diversity

Medium Term

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

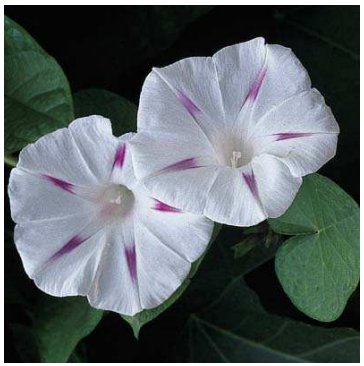
‘Cameo Elegance’



‘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

‘Yangi’

‘Sunrise Serenade’

‘Kikyou’

‘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

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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 Clavicipitaceous 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

Argyreia nervosa
fleshy fruit

Ipomoea 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

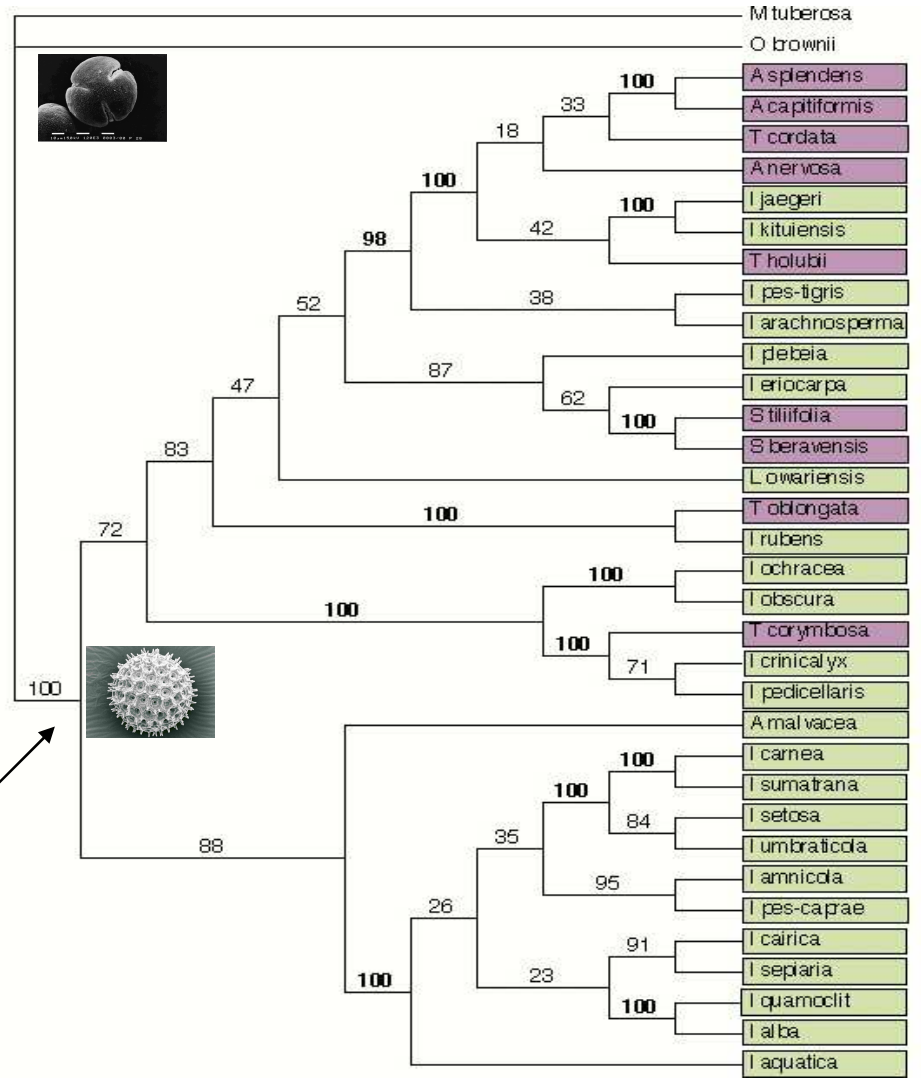
I. lacunosa, 2x GRIN, B+T

I. triloba, 2x, GRIN

I. cordatotriloba, 2x, GRIN

Morning glories with spiny pollen

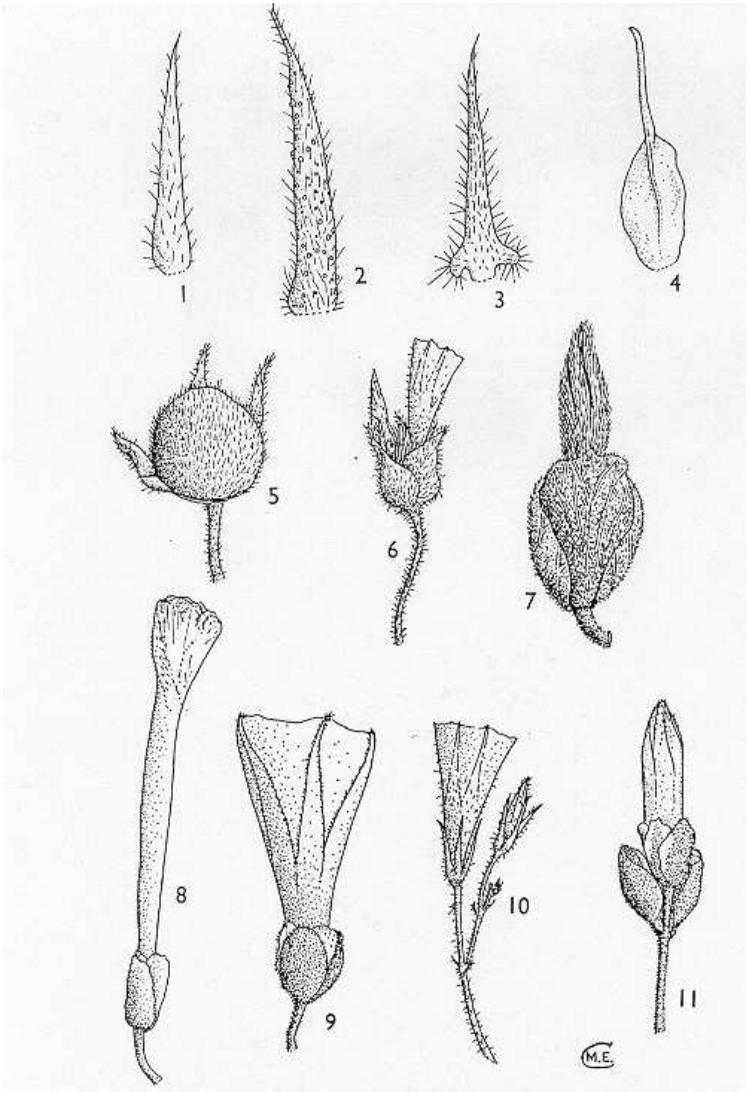
- *Ipomoea* is not monophyletic
- Tribe Ipomoeeae is a well-supported monophyletic group
- Spiny pollen is a synapomorphy for the group
- Includes *Argyreia*, *Stictocardia*, *Turbina*, etc.
- about 900 species
- Subtropics and tropics worldwide



Ipomoeeae

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 Ipomoeeae 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

Female	Male	Crossability
batatas	trifida	medium
batatas	x leucantha	low
cordato-triloba	lacunosa	medium
cordato-triloba	trifida	low-medium
cordato-triloba	triloba	medium
cynanchifolia	cordato-triloba	medium
cynanchifolia	grandifolia	high
cynanchifolia	ramosissima	medium
cynanchifolia	trifida	low
cynanchifolia	triloba	low
grandifolia	cordato-triloba	high
grandifolia	cynanchifolia	high
grandifolia	lacunosa	high
grandifolia	ramosissima	medium
grandifolia	trifida	low
grandifolia	triloba	medium
grandifolia	x leucantha	medium
lacunosa	grandifolia	medium
ramosissima	cordato-triloba	medium
ramosissima	tenuissima	high
ramosissima	tiliacea	high
ramosissima	trifida	medium
ramosissima	x leucantha	high

Female	Male	Crossability
tenuissima	cordato-triloba	high
tenuissima	trifida	high
trifida	batatas	low
trifida	cordato-triloba	low
trifida	ramosissima	low
trifida	tenuissima	low
trifida	x leucantha	low
triloba	cordato-triloba	high
triloba	cynanchifolia	high
triloba	lacunosa	high
triloba	ramosissima	low
triloba	trifida	low
triloba	trifida	ovule culture
triloba	x leucantha	high
triloba x lacunosa	batatas	ovule culture
x leucantha	cordato-triloba	medium
x leucantha	cynanchifolia	high
x leucantha	grandifolia	high
x leucantha	lacunosa	high
x leucantha	tenuissima	high
x leucantha	trifida	low
x leucantha	triloba	high

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

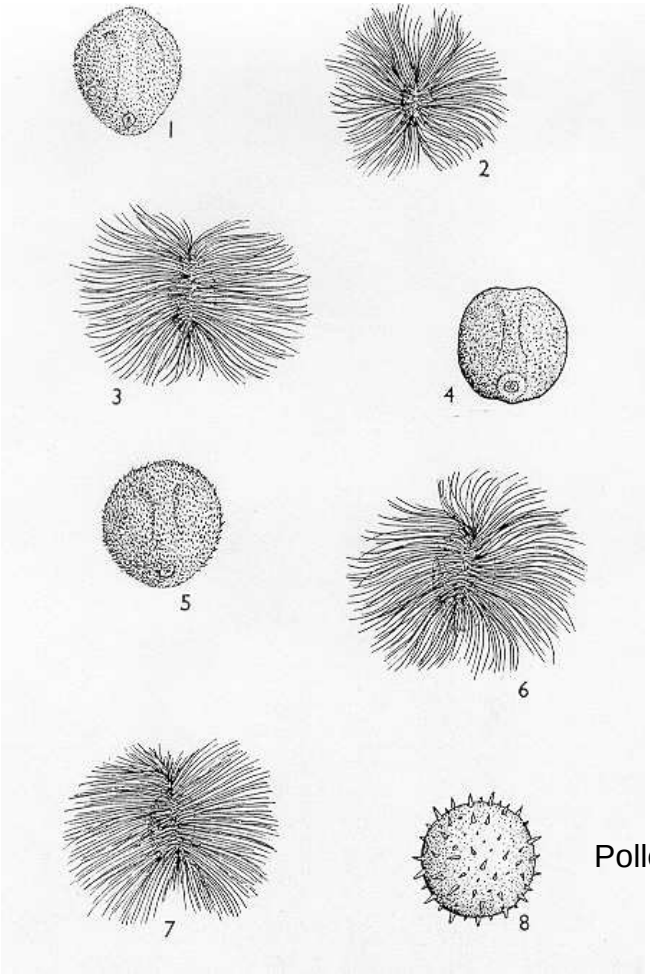
Batatas species form a distinct group

- 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



Pollen

Seed vestiture in morning glories

Ipomoea section *Batatas*

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

Ipomoea batatas 60,90
Ipomoea cordatotriloba 30
Ipomoea cynanchifolia 30
Ipomoea grandifolia 30
Ipomoea lacunosa 30
Ipomoea littoralis 30
Ipomoea leucantha 30
Ipomoea ramosissima 30
Ipomoea tabascana 60
Ipomoea tenuissima 30
Ipomoea tiliacea 60
Ipomoea trifida 30
Ipomoea triloba 30
Ipomoea umbraticola 30

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

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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 and Aristotle by Raphael

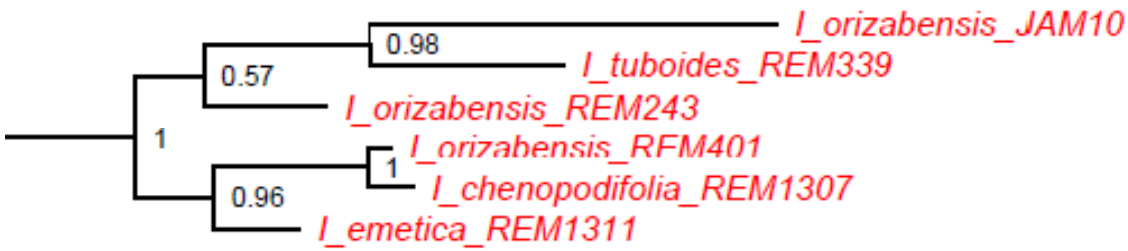
Plato – ideal type

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

I. tuboides
Hawaii

I. 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