

# Principal components analysis of morphological variation of the *Ptelea trifoliata* species complex

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# What is *Ptelea trifoliata*?

- Family Rutaceae, citrus
- Wafer Ash or Hop Tree
- Endemic to North America
- Alternate compound leaves
- Winged fruit
- Glands
- Substitute for hops
- Medicinal properties:  
Alkaloids, traditional tonic







subspecies



variety

***Ptelea trifoliata***  
**Pistils:** glabrous/rarely slightly hairy  
**Filaments:** hirsute/rarely glabrous  
**Seeds:** flattened, 2 mm thick, width less than width of wing  
 Mid/south latitudes, except Great Valley of CA and Baja CA

**Twigs:** green/brown  
**Seeds:** round/oval/long, centered  
 East and south North America

**Terminal leaflet:** 5–10 cm  
**Margins:** flat, not revolute  
**Mesophytic:** woods/edges  
 S. Ont., S. Col., Mid Az to S Mex

**subsp. trifoliata**  
**Glands:** small  
**Seeds:** small, thin, center to above middle  
 Eastern US west to OK and Tex

**var. trifoliata**  
**Twigs/foilage:** mostly glabrous/glabrate  
**Leaves:** fine, microscopic pubescence on underneath of petiole or veins above (slender/hyaline)  
 Ontario S to Gulf, W to Ozarks, Ar, Ok, W

**var. mollis**  
**Twigs/foilage:** pubescent  
**Leaves:** densely villous under and on petioles, macroscopic, Pubescent above, esp. veins  
 Tx coast, E to NC and Vir, along Miss. R. to S Lake Mich.

**var. angustifolia**  
**Leaves:** densely/thinly villous, esp. beneath  
**Terminal leaflet:** short petiolules  
**Samaras:** orbicular, retuse (notched)  
**Seed:** narrower than wing, thinner  
 W Mex and N

**Leaves:** pale beneath with white veins, attenuate/acuminate tips (pointed or narrow)  
**Terminal leaflet:** petiolule  
 S and W range of subsp. angustifolia

**subsp. angustifolia**  
**Lateral leaflets:** equilateral 50–60°  
**Leaves:** glossy  
**Margins:** serrate-dentate  
 SW Mex north to SE AZ, NM, S Co, Tx, OK

**var. cognata**  
**Leaves:** glabrous to thinly pubescent  
**Terminal leaflets:** distinct petiolules  
**Samaras:** orbicular/oval, rounded at ends or cuneate (wedge point)  
**Seed:** broad/broader than wing, thick  
 SE Ariz, adjacent Mex, NM

**var. persicifolia**  
**Leaves:** pale, shiny, inconspicuous veins, acute to obtuse tips, cuneate/sessile base  
 Edwards Plateau, NW across central TX to OK

**subsp. polyadenia**  
**Lateral leaflets:** inequilateral 90°  
**Leaves:** dark above, light below  
**Margins:** crenate to entire  
**Glands:** large, many  
 N Tex, OK, Col, Trans-Pecos Tx, Mid to west AZ

**subsp. coahuilensis**  
**Terminal leaflet:** 2–5 cm  
**Margin:** crenulate to subentire, revolute  
**Xerophytic:** arid mts. and plateaus  
 West Nuevo Leon and east Coahuila to south Puebla and Ocala

**var. coahuilensis**  
**Leaves:** dark green above, pale/glaucous beneath  
**Terminal leaflet:** cuneate-obovate 2–4.5 cm long, 1/2–2/3 broad as long  
 Range of species

**var. pumila**  
**Leaves:** thinner and paler than var. coahuilensis, both sides glaucous  
**Terminal leaflet:** 1.5–3 cm, less than 1/2 broad as long  
 Southeastern Coahuila mixed with var. coahuilensis

Brown or green twigs

**subsp. pallida**  
**Twigs:** orange/straw/white  
**Seeds:** oval/oblong/round, centered or below middle  
 Plateau canyons, deserts  
 NW Ariz, S Color, W Tex

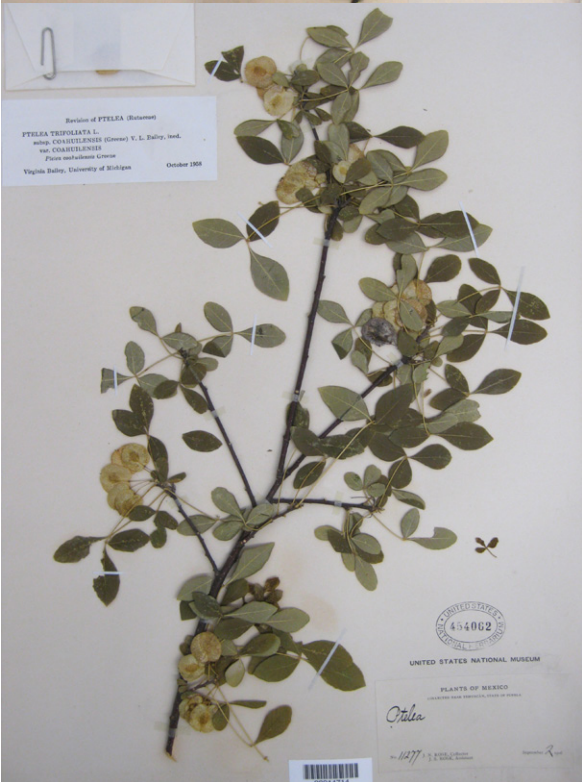
**Twigs:** finely pubescent  
**Foliage:** sparsely to densely pubescent or glabrate  
**Terminal leaflet:** obovate/ovate/ovate-lanceolate, 1/3–1/2 broad as long  
**Margins:** crenulate/crenulate-serrate/revolute

**var. pallida**  
**Leaves:** glabrous/sparsely pubescent (esp. underneath on mid-vein and petiolule)  
**Margin:** finely crenulate-serrate  
 Desert  
 AZ west of Grand Canyon and south to southern Col and W Tex

White or orange twigs

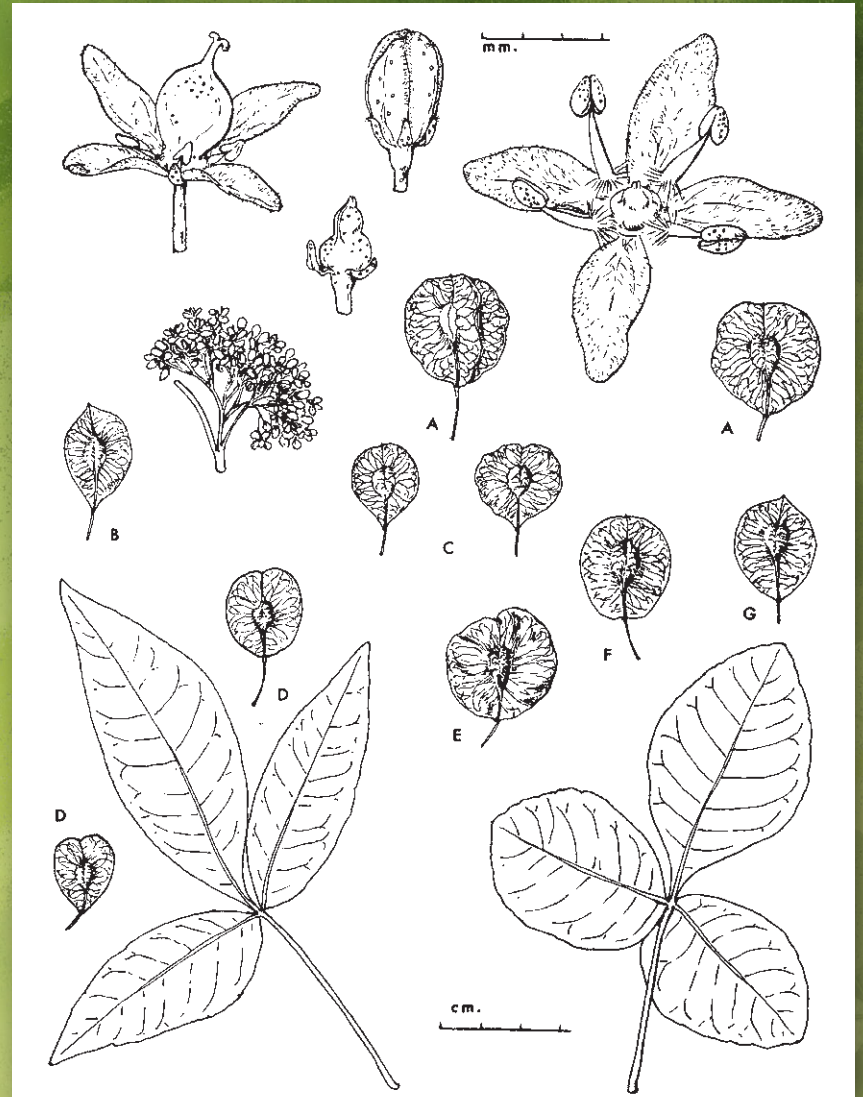
**var. confinis**  
**Leaves:** pubescent, tomentose on underside of petioles  
**Margin:** revolute/entire  
 Rio Grande, El Paso, TX, NM

**var. lutescens**  
**Twigs/foilage:** glabrous  
**Terminal leaflet:** lanceolate (broadly or narrowly), less than 1/3 broad as long  
**Margin:** serrate/dentate/entire/rarely revolute  
 N AZ and S Utah, canyons of Colorado R. and tributaries



# Highly variable morphology, or why so many classifications?

- Revision is based on highly variable morphological characters
  - Pubescence
  - Leaf margin
  - Fruit wing
  - Gland width



Bailey 1962

# Are these classifications polymorphic variation?

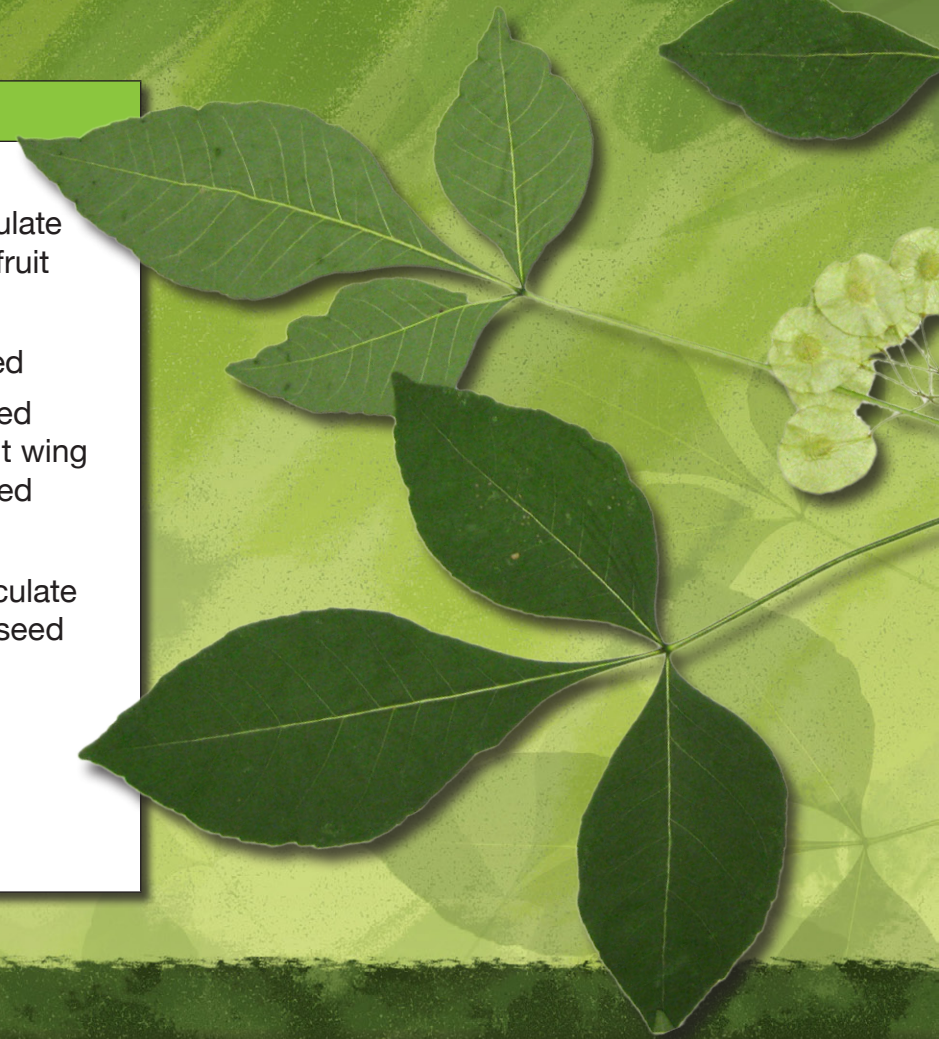
- Is there morphological evidence that supports Bailey's description of *Ptelea trifoliata*?
- Tested qualitative and quantitative findings against the current revision
  - Principal components analysis of the quantitative characters used by Bailey to create the descriptions
  - Comparison of characters to the current description



# Quantitative analysis of morphological data

- Principal components analysis to assess morphological variation
- Data taken from 361 mature, fruiting specimens representing all subspecies and varieties

Largest leaf	Largest fruit
<ul style="list-style-type: none"><li>• Length of petiole</li><li>• Length of terminal leaflet</li><li>• Breadth of terminal leaflet used to calculate ratio of length to breadth of terminal leaflet</li><li>• Base to widest point of terminal leaflet</li><li>• Length of petiolule of terminal leaflet</li><li>• Length of lateral leaflet</li><li>• Breadth of lateral leaflet used to calculate ratio of length to breadth of lateral leaflet</li><li>• Base to widest point of lateral leaflet</li><li>• Angle of lower margin to midrib on lateral leaflet</li><li>• Diameter of leaf gland</li></ul>	<ul style="list-style-type: none"><li>• Length of fruit</li><li>• Breadth of fruit used to calculate ratio of length to breadth of fruit</li><li>• Depth of fruit wing</li><li>• Depth of fruit wing above seed</li><li>• Depth of fruit wing below seed used to calculate ratio of fruit wing above to fruit wing below seed</li><li>• Length of seed</li><li>• Breadth of seed used to calculate ratio of length to breadth of seed</li><li>• Length of peduncle</li></ul>





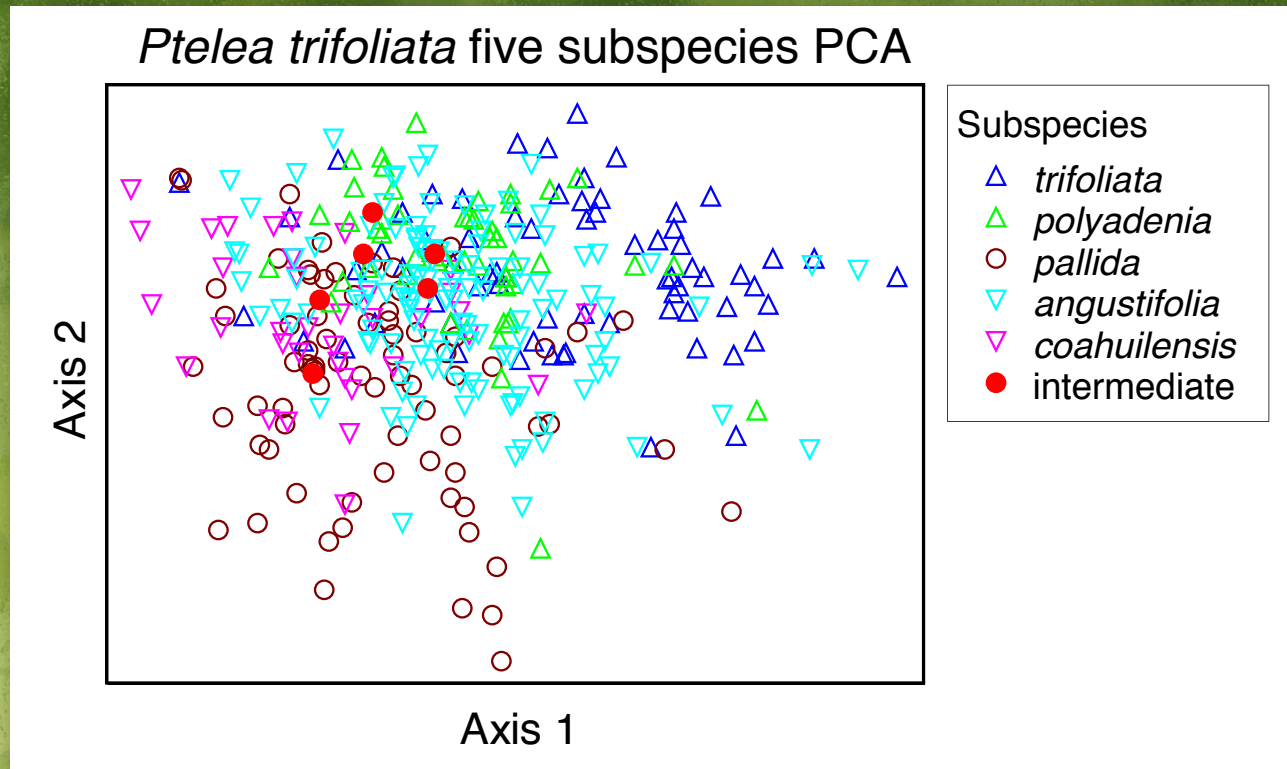
# Qualitative comparison of characters

- Characters based on Bailey's description
- Teratological fruit were also observed

Leaf	Fruit
<ul style="list-style-type: none"><li>• Pubescence of petiole</li><li>• Leaf margin</li></ul>	<ul style="list-style-type: none"><li>• Base of fruit wing</li><li>• Teratological fruit</li></ul>

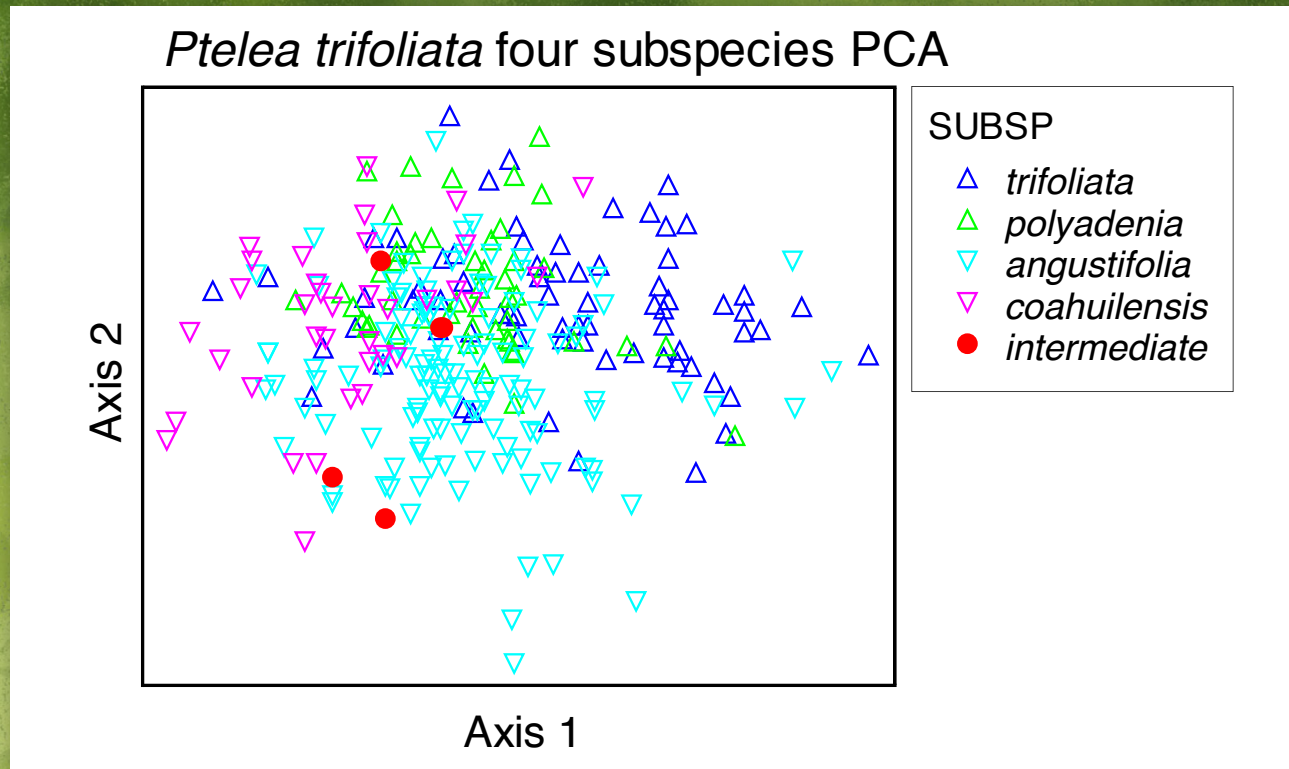


# PCA of 5 subspecies



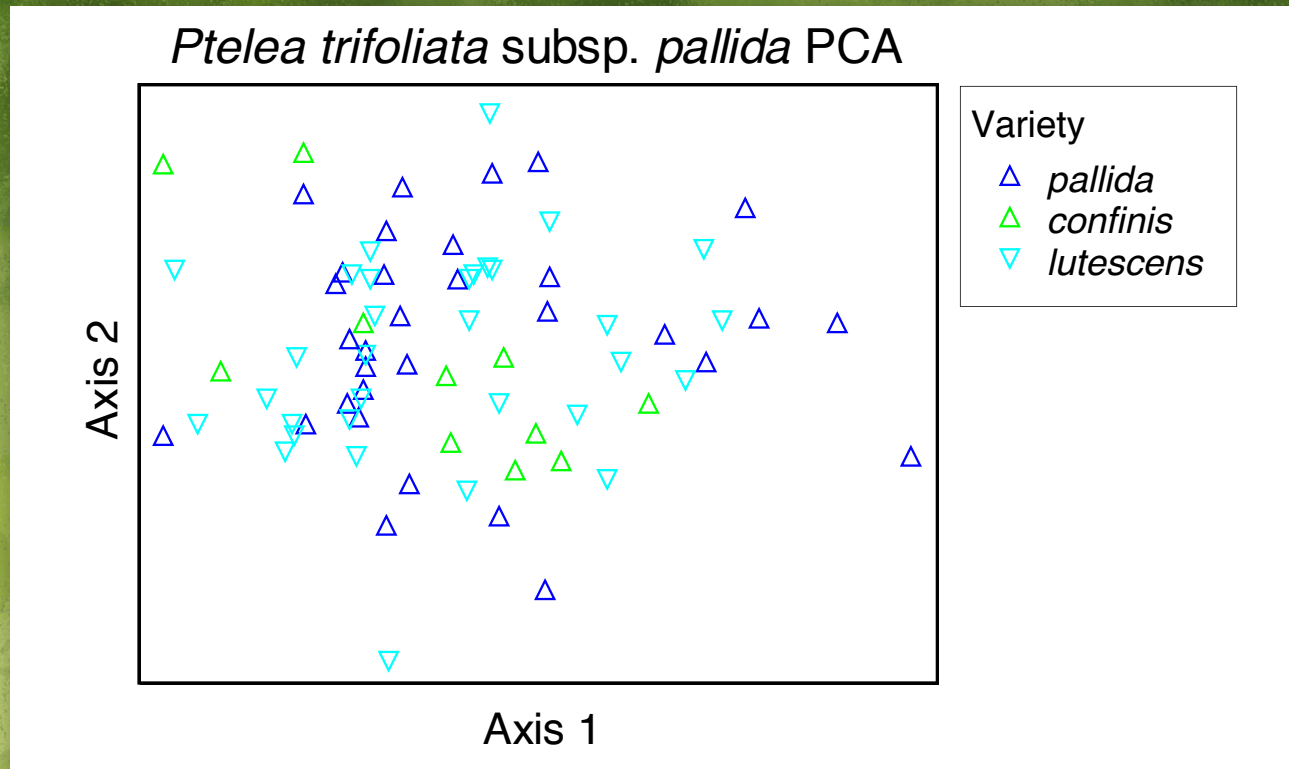
- Subspecies *pallida* is somewhat distinct
  - Only subspecies with white and orange bark

# PCA of 4 subspecies



- No separation
- Qualitatively similar

# PCA of subspecies *pallida*

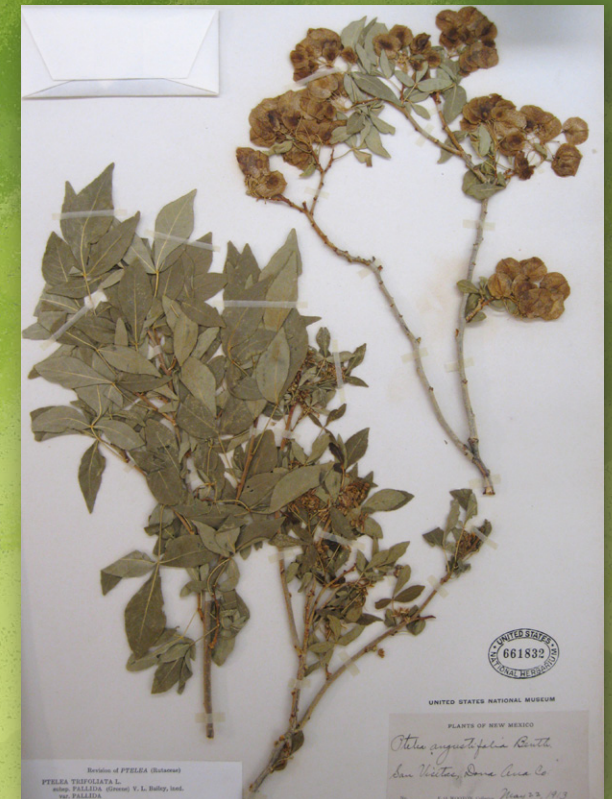


- No distinction between varieties

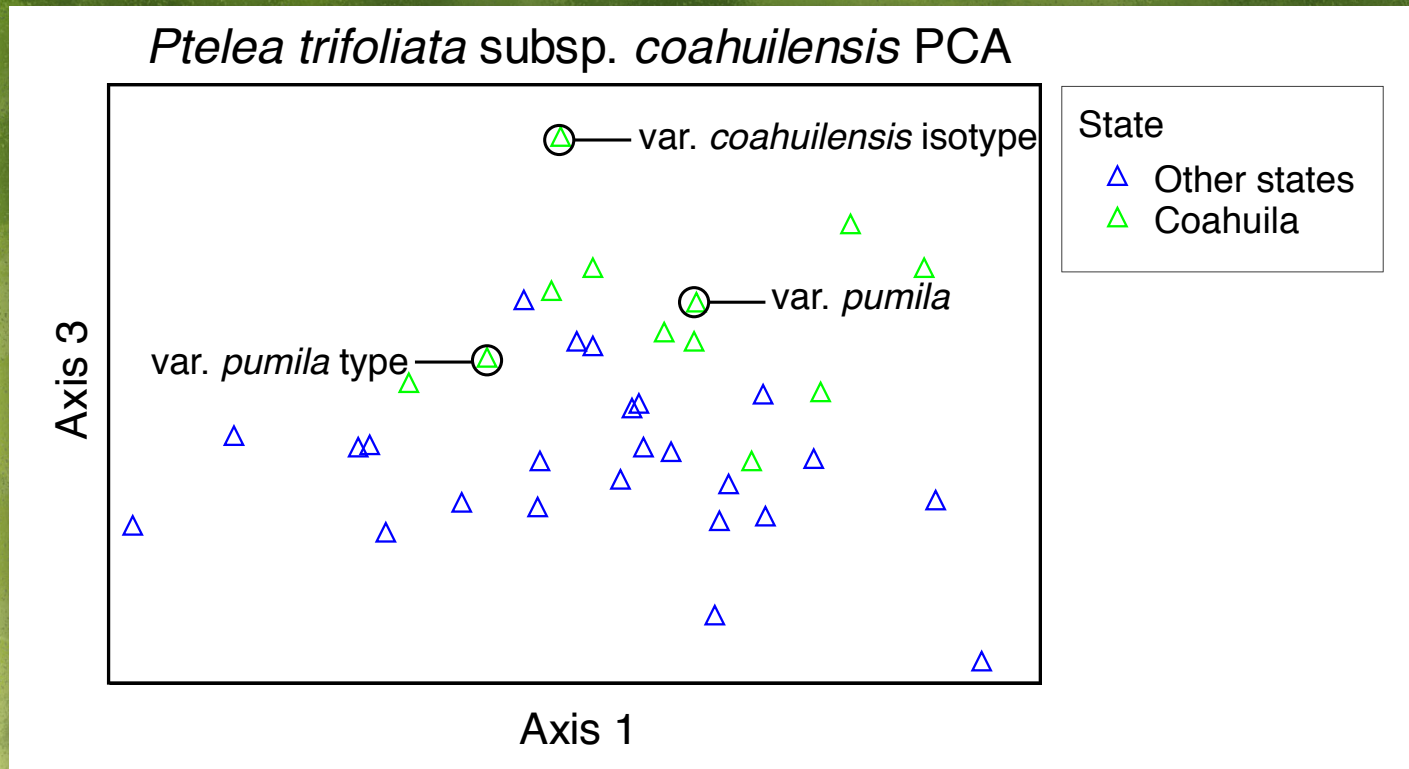
# Qualitative characters of subspecies *pallida*

- Variety *confinis*
  - Never glabrous, absent from Arizona
- Variety *lutescens*
  - Primarily in Arizona
  - Glabrous, consistent with description
- No specimen had revolute margins, contrary to description
- Pubescence of foliage consistent with description

<i>Ptelea trifoliata</i>	Pubescence of terminal leaflet			
	Glabrous	Sparsely pubescent	Sparsely pubescent throughout	Strongly villous
subsp. <i>pallida</i>	69.33%	8.00%	5.33%	17.33%
var. <i>confinis</i>	0.00%	27.27%	18.18%	54.55%
var. <i>lutescens</i>	100.00%	0.00%	0.00%	0.00%
var. <i>pallida</i>	62.50%	9.38%	6.25%	21.88%



# PCA of subspecies *coahuilensis*

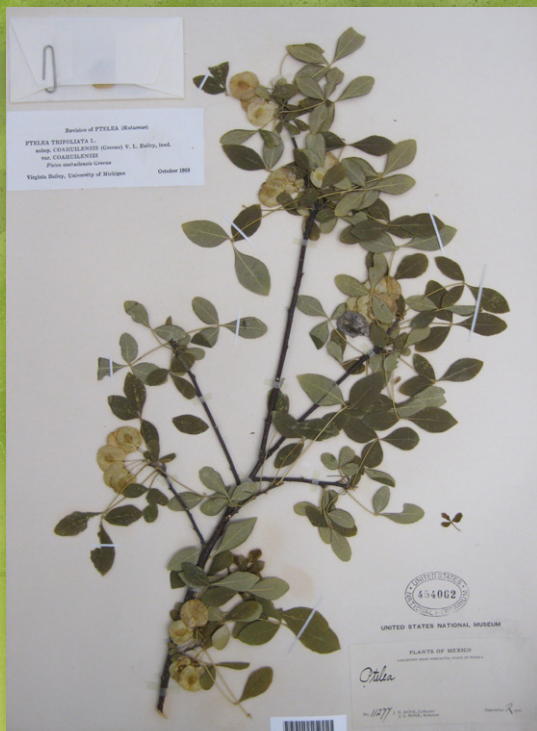


- Specimens from Coahuila vary somewhat
- Type specimens for *pumila* and *coahuilensis* do not coincide with any group or geographic location

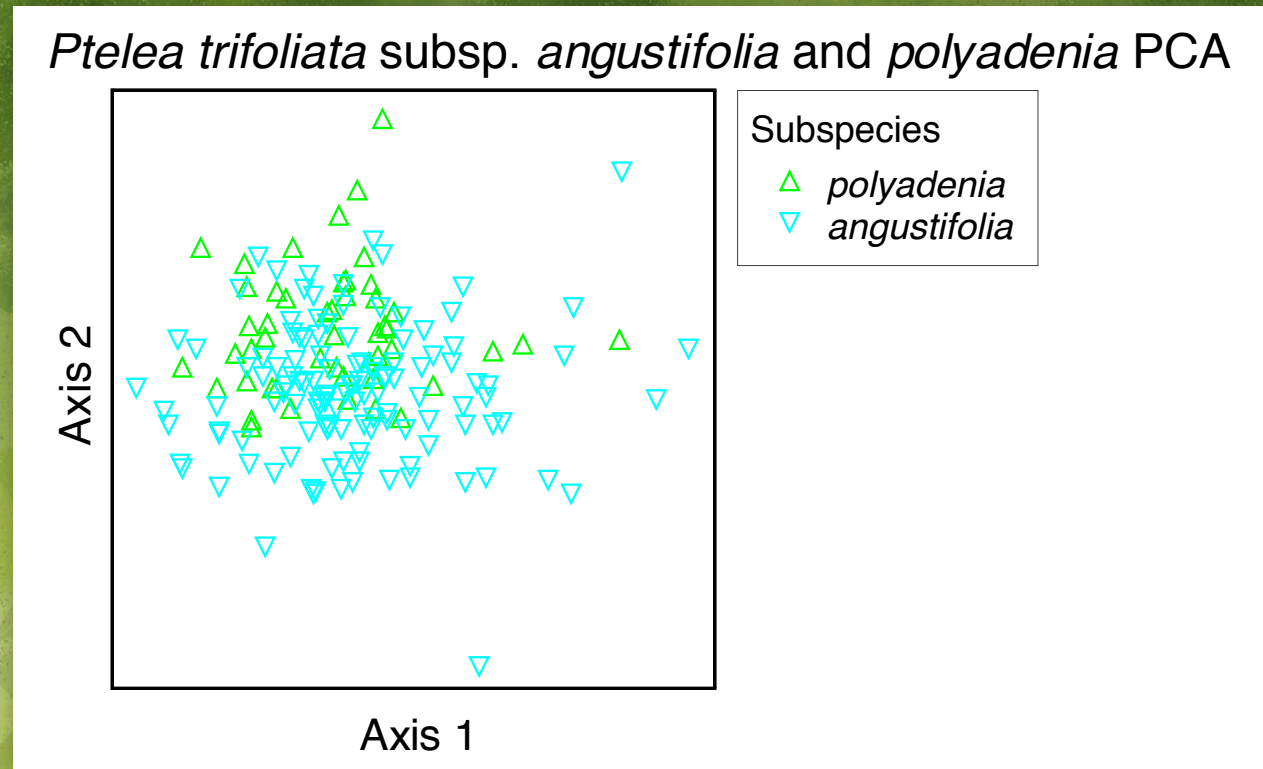
# Qualitative characters of subspecies *coahuilensis*

- Terminal leaflet shape and size influenced by abiotic factors
- Range of PCA does not coincide with a variety
- Leaf margin is sometimes revolute

<i>Ptelea trifoliata</i>	Leaf margin				
	Revolute	Sharply toothed	Crenate	Revolute/crenate	Subentire
subsp. <i>angustifolia</i>	0.81%	2.42%	59.68%	0.81%	36.29%
subsp. <i>coahuilensis</i>	36.11%	2.78%	36.11%	5.56%	19.44%
subsp. <i>pallida</i>	0.00%	1.33%	58.67%	0.00%	40.00%
subsp. <i>polyadenia</i>	0.00%	0.00%	71.43%	0.00%	28.57%
subsp. <i>trifoliata</i>	0.00%	11.27%	59.15%	0.00%	29.58%



# PCA of subspecies *polyadenia* and *angustifolia*



- Overlap extensively



# Qualitative characters of subspecies *polyadenia* and *angustifolia*

- Similar in pubescence, leaf margin, base of fruit wing and the presence of teratological fruit
- Overlapping range
- Bailey differentiates by angle of lateral leaflet to midrib, leaf color and glossiness



subsp. *angustifolia*  
var. *cognata*

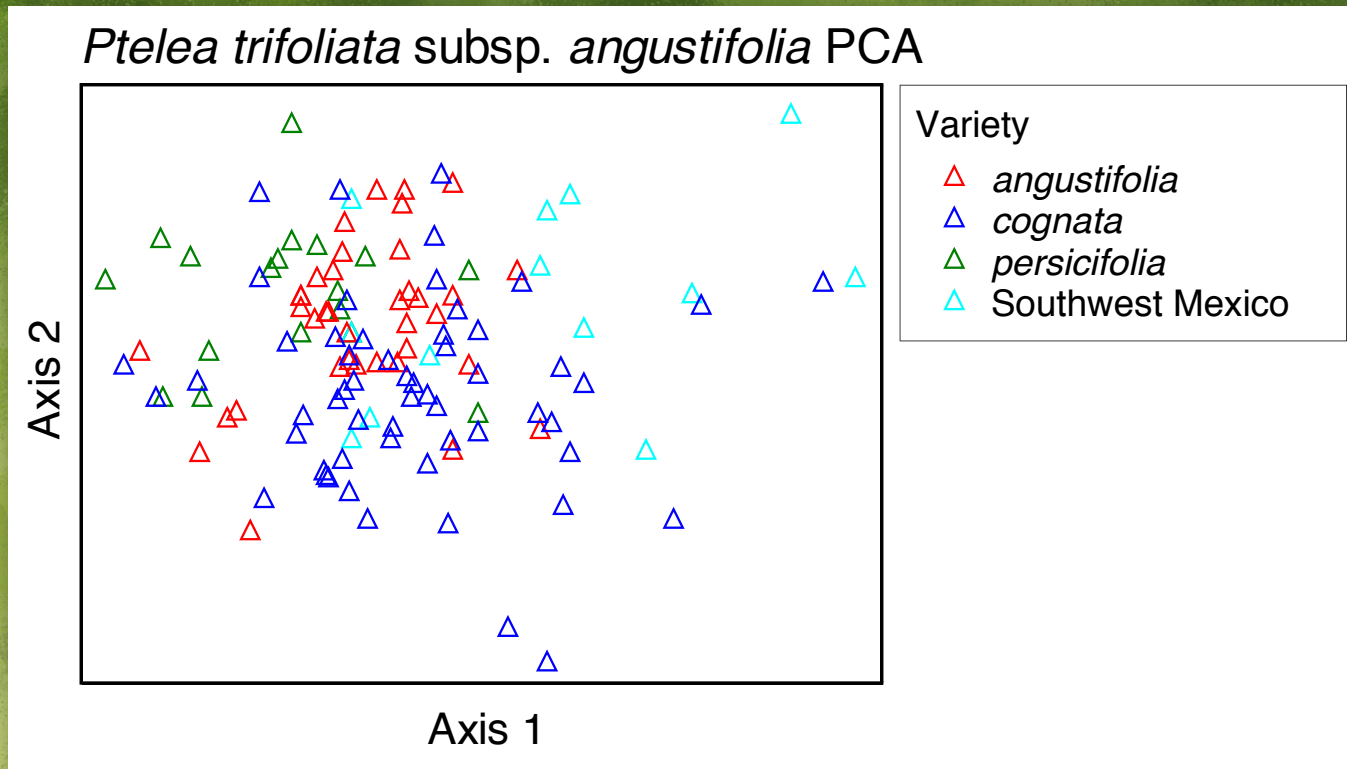


subsp. *polyadenia*

<i>Ptelea trifoliata</i>	Teratological fruit	Pubescence of terminal leaflet				Leaf margin					Base of fruit wing			
		Glabrous	Sparsely pubescent	Sparsely pubescent throughout	Strongly villous	Revolute	Sharply toothed	Crenate	Revolute/crenate	Subentire	Cuneate	Rounded	Cordate	Cordate/rounded
subsp. <i>angustifolia</i>	35.48%	40.32%	10.48%	13.71%	35.48%	0.81%	2.42%	59.68%	0.81%	36.29%	24.19%	32.26%	41.94%	1.61%
subsp. <i>polyadenia</i>	34.69%	10.20%	4.08%	18.37%	67.35%	0.00%	0.00%	71.43%	0.00%	28.57%	24.49%	42.86%	32.65%	0.00%



# PCA of subspecies *angustifolia*



- No distinction between varieties
- Specimens collected from southwest Mexico with subentire leaf margins and smaller glands are indistinct.

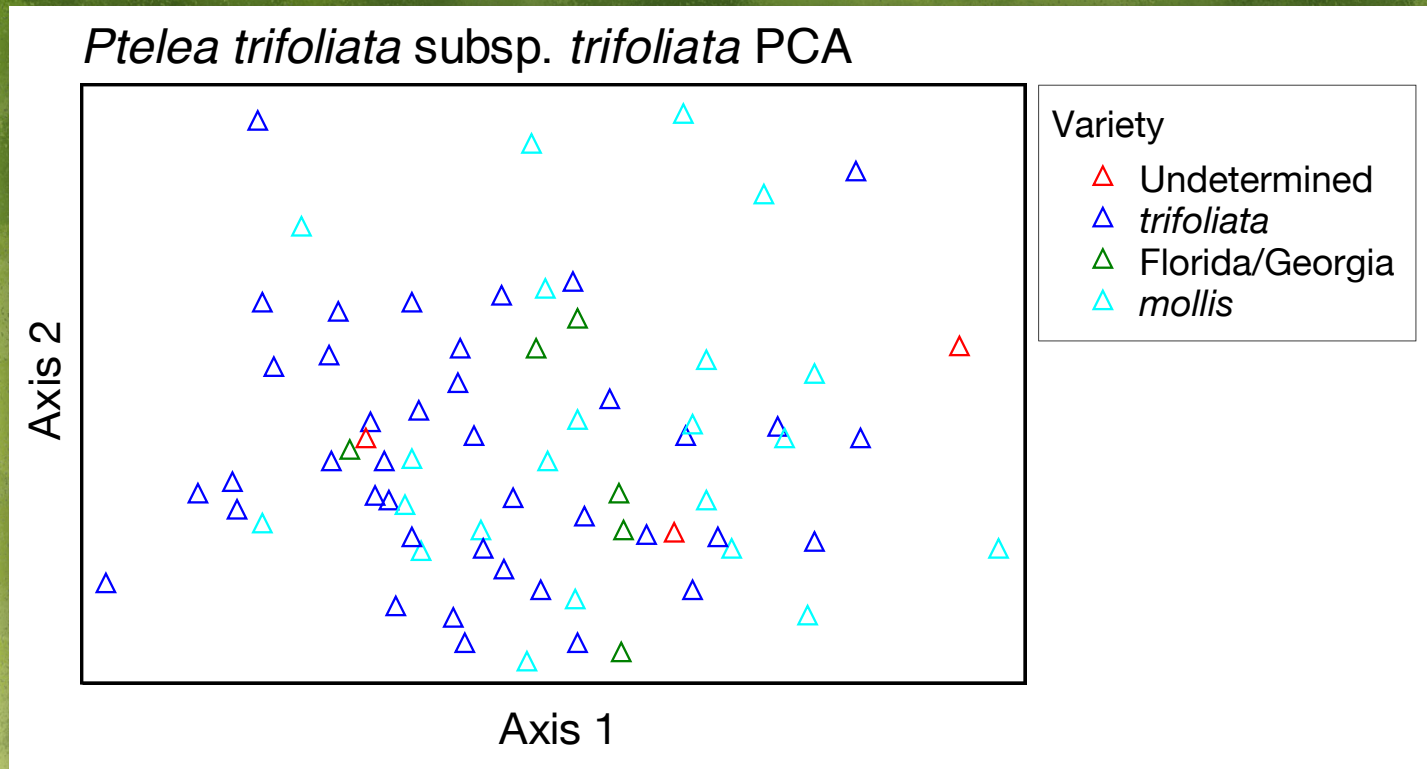
# Qualitative characters of subspecies *angustifolia*

- Petiolule length varies
- Margins occasionally revolute, contrary to key
- Gland size ranges on the larger, similar to subsp. *polyadenia*

<i>Ptelea trifoliata</i>	Leaf margin				
	Revolute	Sharply toothed	Crenate	Revolute/crenate	Subentire
subsp. <i>angustifolia</i>	0.81%	2.42%	59.68%	0.81%	36.29%
var. <i>angustifolia</i>	2.70%	0.00%	67.57%	2.70%	27.03%
Southwest Mexico	0.00%	0.00%	0.00%	0.00%	100.00%
var. <i>cognata</i>	0.00%	3.57%	76.79%	0.00%	19.64%
var. <i>persicifolia</i>	0.00%	5.56%	33.33%	0.00%	61.11%
Intermediate	0.00%	0.00%	83.33%	0.00%	16.67%



# PCA of subspecies *trifoliata*



- No distinction between varieties
- Specimens from the Florida and Georgia with less pubescence and mostly cuneate fruit wing bases were not distinct

# Qualitative characters of subspecies *trifoliata*

- Located in the gulf region, east coast and around the Mississippi River and Lake Michigan
- Pubescence: Somewhat consistent, varies



# Conclusions

Findings support the recognition of subsp. *pallida*.

- PCA: Subsp. *pallida* appears somewhat distinct from the other subspecies.
- White or orange bark instead of brown or green.
- Subsp. *pallida* differs from other subspecies by containing the alkaloid marmesinin (Bailey 1971).

No findings support the separation of other subspecies or varieties of *Ptelea trifoliata*.

- Specimens of subsp. *coahuilensis* from Coahuila differ from other specimens do not fit Bailey's description of either var. *coahuilensis* or var. *pumila*.
- No distinctions between varieties of subsp. *pallida* were found. Var. *lutescens* and var. *confinis* have some geographic differences.
- Subsp. *polyadenia* and *angustifolia* are indistinct from the findings.
- The varieties of subsp. *trifoliata* are distinguished only by pubescence and habitat.



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