

## International Quinoa Conference 2016:

Quinoa for Future Food and Nutrition Security in Marginal Environments

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[www.quinoaconference.com](http://www.quinoaconference.com)

# Quinoa: Superplant? Superfood? Neither? Or Both?



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# Summary of Talking Points

- When you say “quinoa”, what are you thinking about?
  - *A pseudocereal crop **quinua** from the High Andes = NARROWEST DEFINITION*
    - Most Bolivian, Peruvian, Ecuadorian researchers
    - The rest of us are probably working on something slightly different
  - *A pseudocereal crop uniquely adapted to lowland Mediterranean climates, known to the Araucanians as **dzawe** or **quingua** = EXPANDED DEFINITION*
    - What those of us outside the High Andes mostly work with
  - ***Huauzontle** seed + vegetable crops from Mexico = EVEN BROADER DEFINITION*
    - Mexican researchers
  - *Avian goosefoot (C. hircinum) and pitseed goosefoot (C. berlandieri) wild ancestors = ALL-ENCOMPASSING DEFINITION*
    - Genomics people

# Quinoa's Genomic Structure: Summary

- *Chenopodium quinoa* is  $2n = 4x = 36$ , AABB subgenomes
- Most similar (DNA) AA diploid is from North America: *C. watsonii* best current candidate as the maternal ancestor of the original AABB allotetraploid
  - Kolano et al. (2016), *Mol Phylogenet Evol* 100:109-123
  - **Therefore, expectation is that wild 4x goosefoot from N. America is in the center of greatest wild/weedy diversity**
- Most similar BB diploids are Eurasian *C. suecicum* or *C. ficifolium*
  - **Therefore, BB diploids should be collected and conserved as genetic resources for quinoa improvement**

# Highland Andean Quinoa has Problems Outside the Andes

## *Chenopodium quinoa* Sensu Stricto

### Constraints:

- Limited adaptation; suitable for production in low-latitude, high-altitude environments
- *Minimal heat tolerance*
- Limited access to natural variation due to international germplasm exchange restrictions

OPPORTUNITIES FOR VALUE-ADDED LABELING: *Bolivian Quinoa Real*, *Peruvian Inka Quinoa*, etc.



# Highland Andean Quinoa's Limitations

*Chenopodium quinoa* Sensu Stricto: adaptively restricted outside its unique Altiplano (3000+ masl) environment

High temperatures average **16 C/61 F**  
during flowering and seed set



Climate data for Oruro									
Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Average high °C (°F)	16 (61)	15 (59)	16 (61)	16 (61)	16 (61)	15 (59)	15 (59)	16 (61)	17 (63)
Average low °C (°F)	3 (37)	2 (36)	2 (36)	0 (32)	-3 (27)	-6 (21)	-5 (23)	-4 (25)	-1 (30)
Average precipitation mm (inches)	94 (3.7)	84 (3.3)	51 (2.0)	15 (0.6)	5 (0.2)	3 (0.1)	3 (0.1)	10 (0.4)	15 (0.6)

Source: Weatherbase <sup>[13]</sup>

Oruro, Bolivia, 3709 meters above sea level



# Highland Andean Quinoa's Limitations

*WHAT HAPPENED THE LAST TIME LOWLAND SUBSISTENCE FARMERS ADOPTED A HIGHLAND ANDEAN CROP...*



AN GHORTA MOR, the Irish  
Potato Famine of the  
1840's

Ireland's poor died, or  
emigrated, by the millions



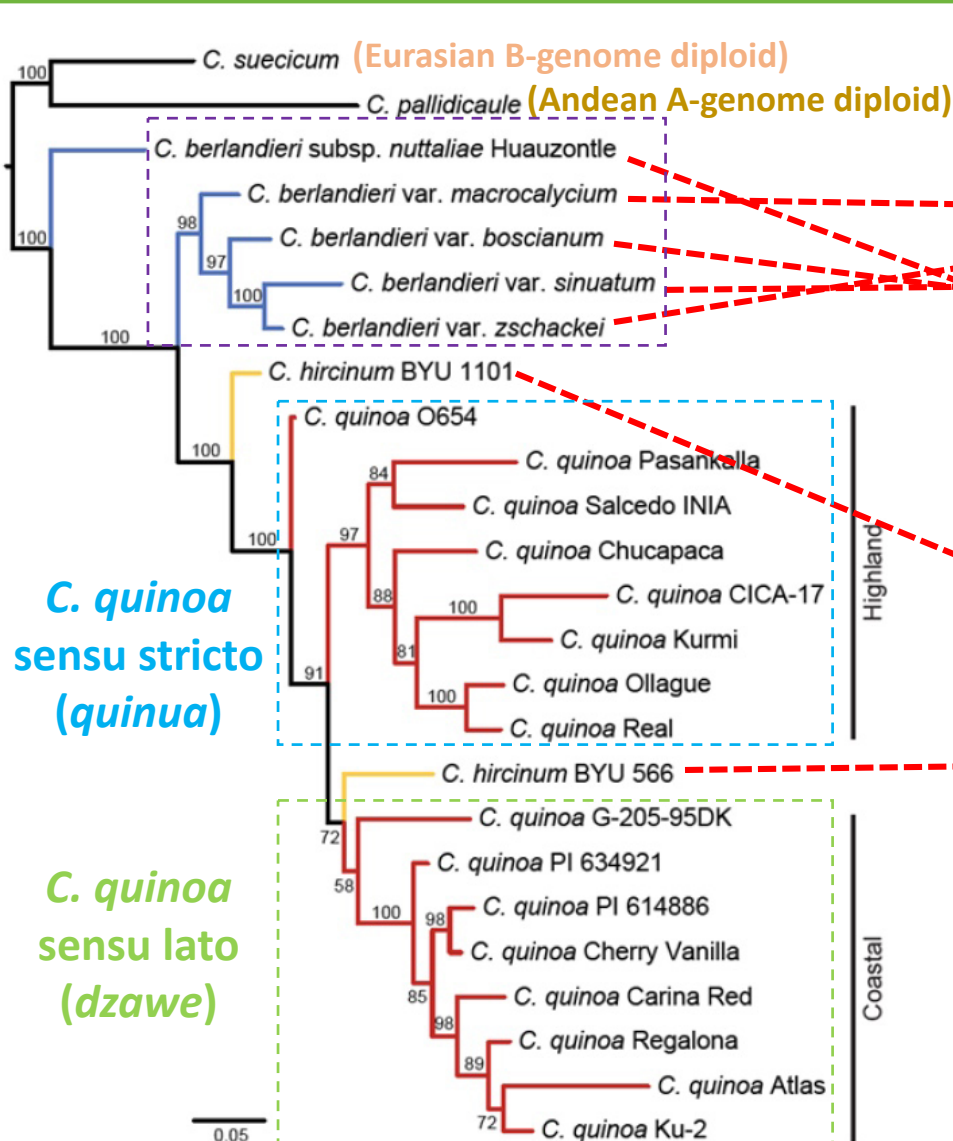
# *C. Quinoa* Sensu Lato = American Tetraploid Goosefoot Complex (ATGC)

## Very wide environmental adaptation of ATGC:

- Dzawe → Araucanian coastal region
- *C. hircinum* → wild/weedy forms from S. American Atlantic slope (and Pacific valleys?)
- Huauzontle → highland vegetable and seed domesticates from Mesoamerica
- *C. berlandieri* → N. American wild/weedy ecotypes: monsoon semi-desert, semi-arid steppes, coastal-torrid, coastal-temperate, temperate forest, domesticated (including an extinct cultigen from Eastern North America)



# ATGC Phylogenetic Tree (D. Jarvis et al., in preparation)





# ATGC Members are Interfertile – Without Embryo Rescue

We do PASSIVE (approach) crossing in the greenhouse by bagging parent panicles together under heat stress

## Evaluations of intertaxa populations:

- Quinoa x dzawe = ~ 90-100% fertile  $F_2$ 's
- Quinoa x *C. hircinum* = ~100% fertile  $F_2$ 's
- Quinoa x huauzontle = variable fertility in  $F_2$ 's
- Quinoa x *C. berlandieri* = >80% fertile  $F_2$ 's
  - 'Real-1' mother = 84% fertile (51/319)
- Dzawe (Co407D) x *C. berlandieri* = 87% fertile

NOTE: fertility is likely UNDERESTIMATED due to native heat-induced sterility in quinoa



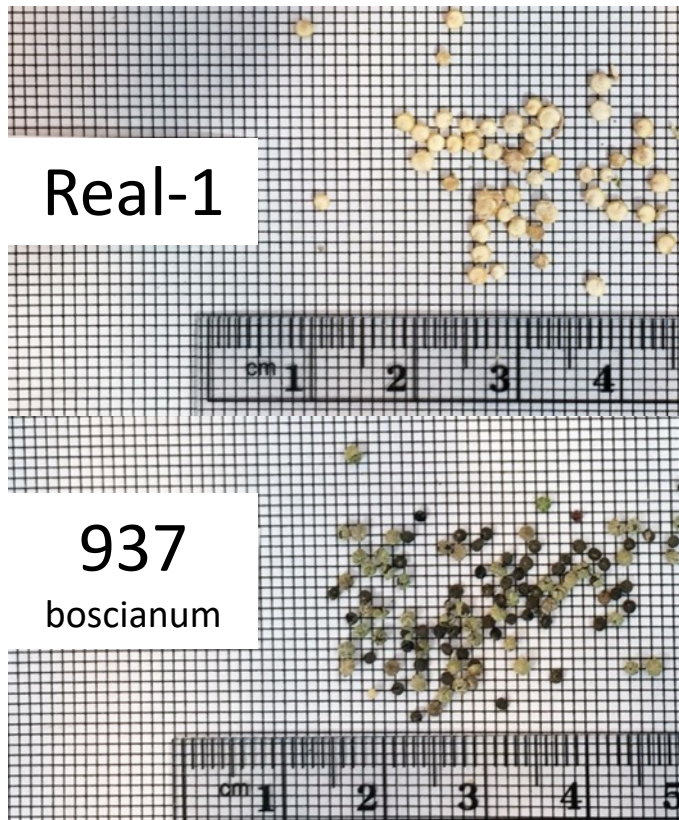
# Passive Gene Exchange in New World Quinoa Fields

## Quinoa Production Fields in:

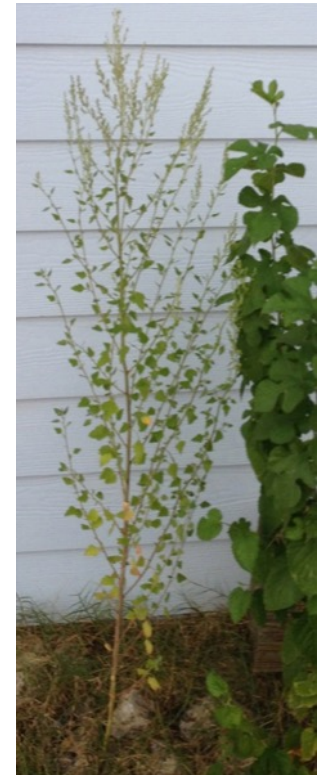
- U.S. Pacific Northwest
  - Wilson & Manhart (1993) Crop/weed gene flow: *Chenopodium quinoa* Willd. and *C. berlandieri* Moq., *Theor Appl Genet* 86:642-648
  - >30% hybrid progeny on wild goosefoot plants in/near quinoa fields
- Argentina/Uruguay/Paraguay
  - Expect similar pattern in quinoa fields with sympatric *C. hircinum*
- Eastern Hemisphere
  - *C. album* is BBCCDD so hybrids with quinoa would be ABBCD (5x) and, most likely, sterile



# Wild ATGC Members: Undesirable and Desirable Traits



- Shattering
  - NOT *C. berlandieri* var. *boscianum*
- Small seeds
- Seed dormancy
- Branching habit
- Foul odor (trimethylamine), dominant trait
  - *C. hircinum*
  - *C. berlandieri* var. *boscianum*
- Lax panicle
- Indeterminate maturity
- Daylength sensitivity



*C. Berlandieri* var. *boscianum*, Eagle Point Marina, San Leon, Texas; accession BYU 1301

- Superior "wild" panicle type
- Variable branching phenotypes
- Non-shattering (tropical cyclone-dispersed seeds)
  - Very mild seed dormancy
  - SD. LD and DN flowering phenotypes



# Goosefoot's Range of Environmental Adaptation



Mojave Desert;  
igneous cool interior  
desert (Idaho);  
Intracoastal Saline  
Bayou; Gulf of  
Mexico Coast;  
California chaparral





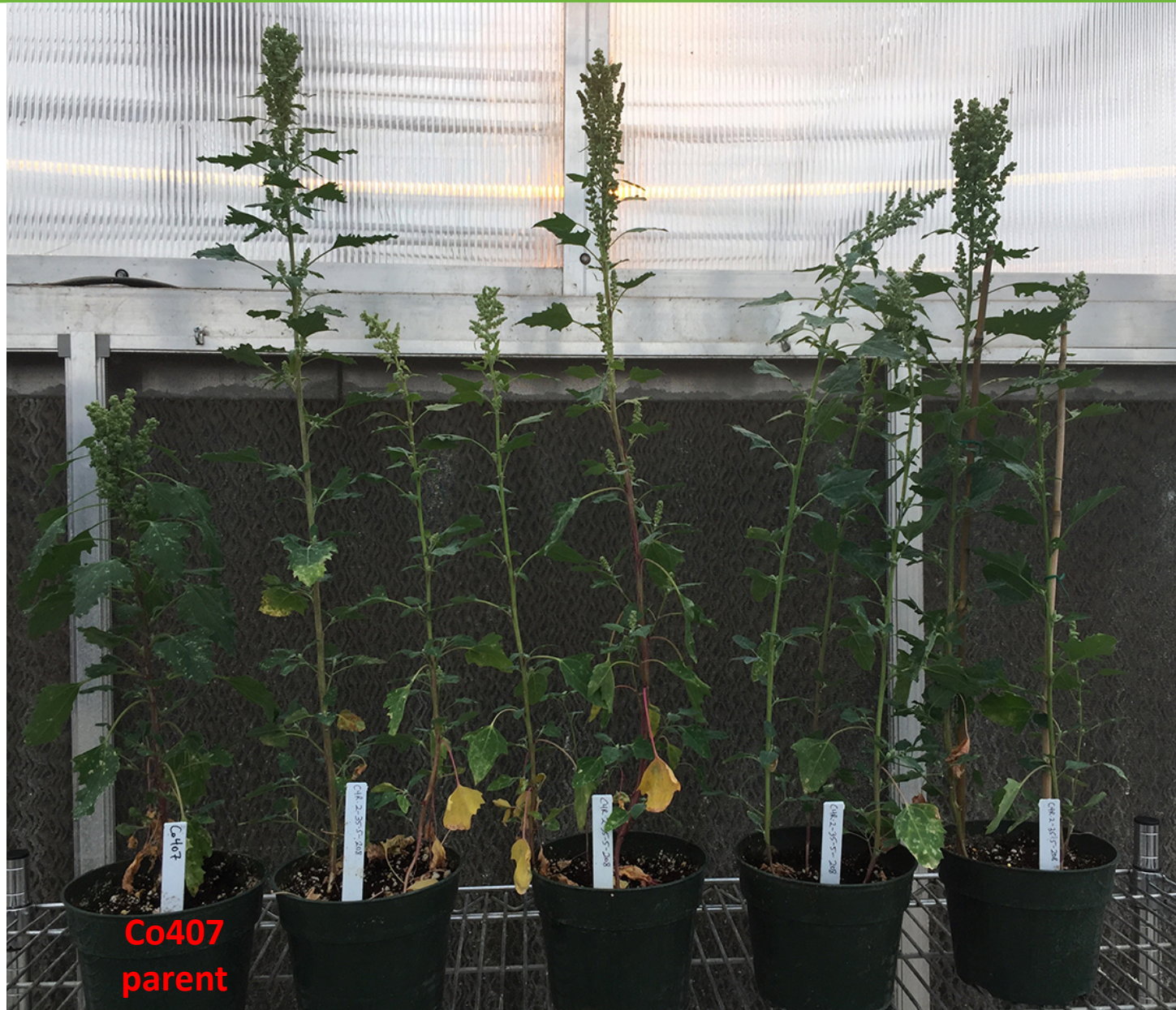
# Goosefoot's Resistance to Diseases and Pests

- Aphid preference for quinoa cv. 'Real-1' (right) over wild goosefoot (*boscianum*, left)





# Co407 x BYU 937: F<sub>5</sub> Family C4R-2-35-5-208



**Co407  
parent**



# Co407 x BYU 937: F<sub>5</sub> Family C4R-2-35-5-212





# NL-6 (Carmen) x WM 11-54: F<sub>3</sub> Family NLB-1-1Ab





# NL-6 (Carmen) x WM 11-54: F<sub>3</sub> Family NLB-1-4Ab



# North American *C. berlandieri* Available in BYU Collection

(Most have been shared with USDA-NPGS and are curated by D. Brenner at Ames, Iowa)

- Variety *boscianum* = 29 accessions
  - Texas, Louisiana, Mississippi, Alabama, Florida
- Variety *sinuatum* = 16 accessions
  - Arizona, New Mexico, California
- Variety *zschackei* = 72 accessions
  - Arizona, California, Colorado, Delaware, Idaho, Illinois, Missouri, Montana, Nevada, New Jersey, New Mexico, Oregon, Wyoming
- Unclassified = 25 accessions



# Quinoa as a Superfood?



## Attributes:

108 amino acid  
score (excellent)  
45 nutritional  
completeness  
(good)  
Glycemic load = 18  
(excellent)

## Liabilities:

8g (15%) protein  
(vs soy 15g, 25%)  
Saponins  
Oxalates

## Quinoa, cooked

Serving size: 1 cup (185g)

[Add to Tracking](#)  
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### FOOD SUMMARY

## Nutrition Facts

Serving Size 185 g

Amount Per Serving

Calories 222      Calories from Fat 32

% Daily Value\*

Total Fat 4g      5%

Saturated Fat      0%

Trans Fat

Cholesterol 0mg      0%

Sodium 13mg      1%

Total Carbohydrate 39g      13%

Dietary Fiber 5g      21%

Sugars

Protein 8g

Vitamin A 0% • Vitamin C 0%

Calcium 3% • Iron 15%

\*Percent Daily Values are based on a 2,000 calorie diet. Your daily values may be higher or lower depending on your calorie needs.

NutritionData.com

[Download Printable Label Image](#)

### Nutritional Target Map [What is this?](#)



### NutritionData's Opinion [What is this?](#)

Weight loss: ★★★★★

Optimum health: ★★★★★

Weight gain: ★★★★★

**The good:** This food is very low in Cholesterol and Sodium. It is also a good source of Magnesium and Phosphorus, and a very good source of Manganese.

### Caloric Ratio Pyramid [What is this?](#)



### Estimated Glycemic Load

18

0 250

Typical target total is 100/day or less

[What is this?](#)

# Looking Toward the Future

- What genes of value can we exploit in the closest wild diploid relatives of quinoa/dzawe/huauzontle?
  - *C. ficifolium* and *C. suecicum*: diploid bridges to the massive diversity of the Eurasian Album Polyploid Complex
- Researchers in China, Nepal, Bhutan, and India will look back toward discovering the virtues of their own native pseudocereal chenopods
  - Unique marketing brand: “Himalayan Bithua”, etc.
- “Quinoa-like” Caryophyllous plants to domesticate that are true superplants
  - *Amaranthus*, *Atriplex*, *Salicornia*, *Suaeda*, etc.