

Bridgestone's Perspective on a Domestic Source of Natural Rubber in the Desert



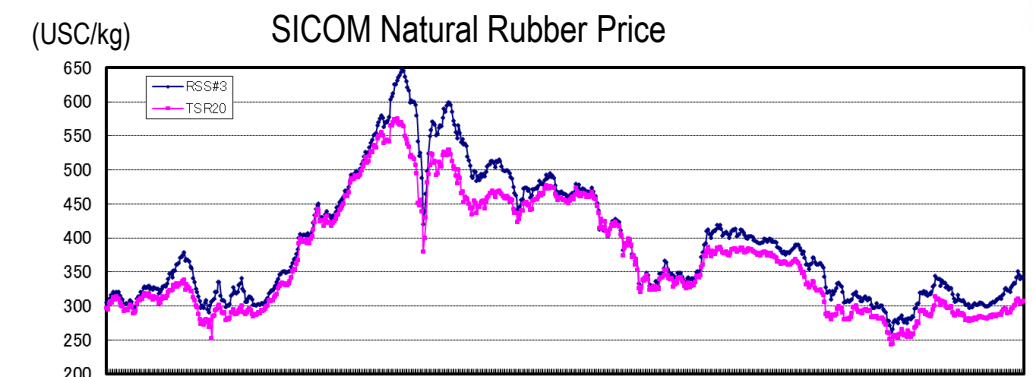
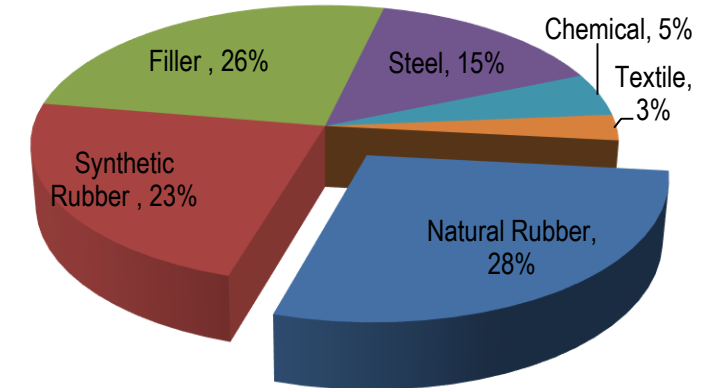
David Dierig, Mgr Agro Operations



Natural Rubber

- **Cis 1,4 Polyisoprene**
- **Biologically single-sourced: *Hevea Brasiliensis***
- **9.7 Million ha planted**
- **Geographically concentrated**
- **Global Production: 12,000,000 Metric Tons**
- **Approximately 2/3 consumed by the tire industry**
- **The major raw material for tire manufacturing**
- **Also a market traded commodity**
- **Cannot be fully replicated synthetically**

Asia	8,748.4	93%
Africa	482.2	5%
S. America	173.7	2%
Total	9,704.3	/1,000 ha

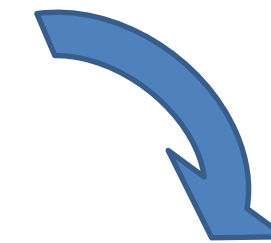


Past: Technology Catalyst

- Early investor
- Core rubber technology developer
- Demonstration through integrated demonstration scale

Now: Coalition Builder

- Complete agricultural research / variety development
- Solidify technology / business package(s) ... beyond rubber
- Co-Product technology support



Partnerships to
De-Risk technology
deployment

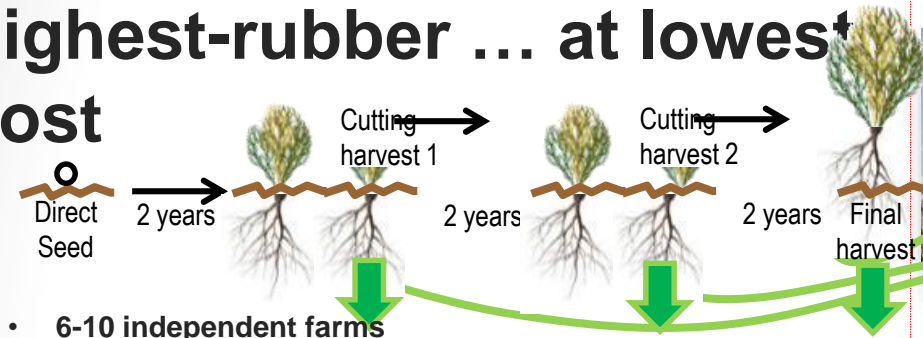
Future: Active Beneficiary

- Technology Licensor
- Customer through off take
- Investor
- JV Partner
- Owner/Operator

To the degree that supports
the core-business

Overall Fortitude Process: The Guayule Bio-Refinery

Agriculture: Produce Biomass with highest-rubber ... at lowest cost



- 6-10 independent farms
- 100,385 Acres harvested annually
- 30-40 mile avg. transit distance

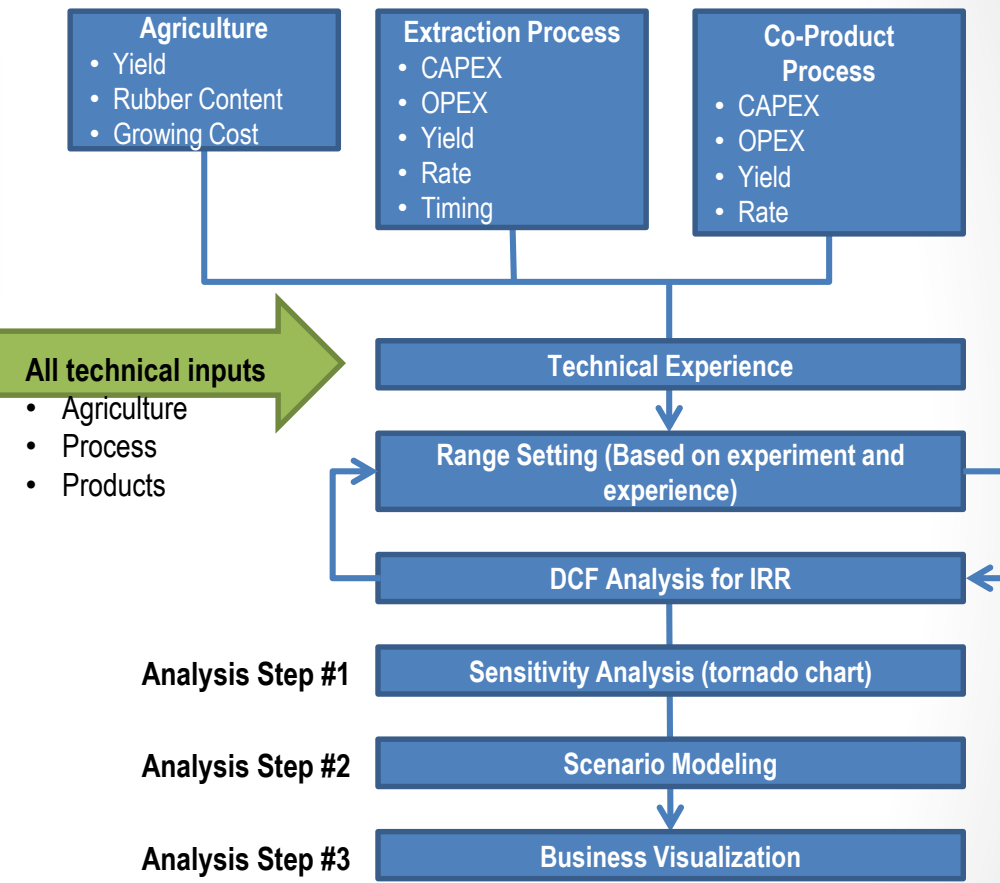
Process:

- Step 1:** Grinding & crushing to expose rubber
- Step 2:** Extraction, separation, purification, solvent-removal



- Quality level for tires
- 94% rubber extraction yield
- 90% resin extraction yield
- Reliable / continuous operations

Techno-Economic Model:



Products: Three product streams, each with



- Contribution from all 3 products
- Rubber revenue dominates
- Increasing rubber content through breeding presents a huge opportunity

Rubber
for tires
5-10% of volume

Resin
As asphalt additive
~10% of volume

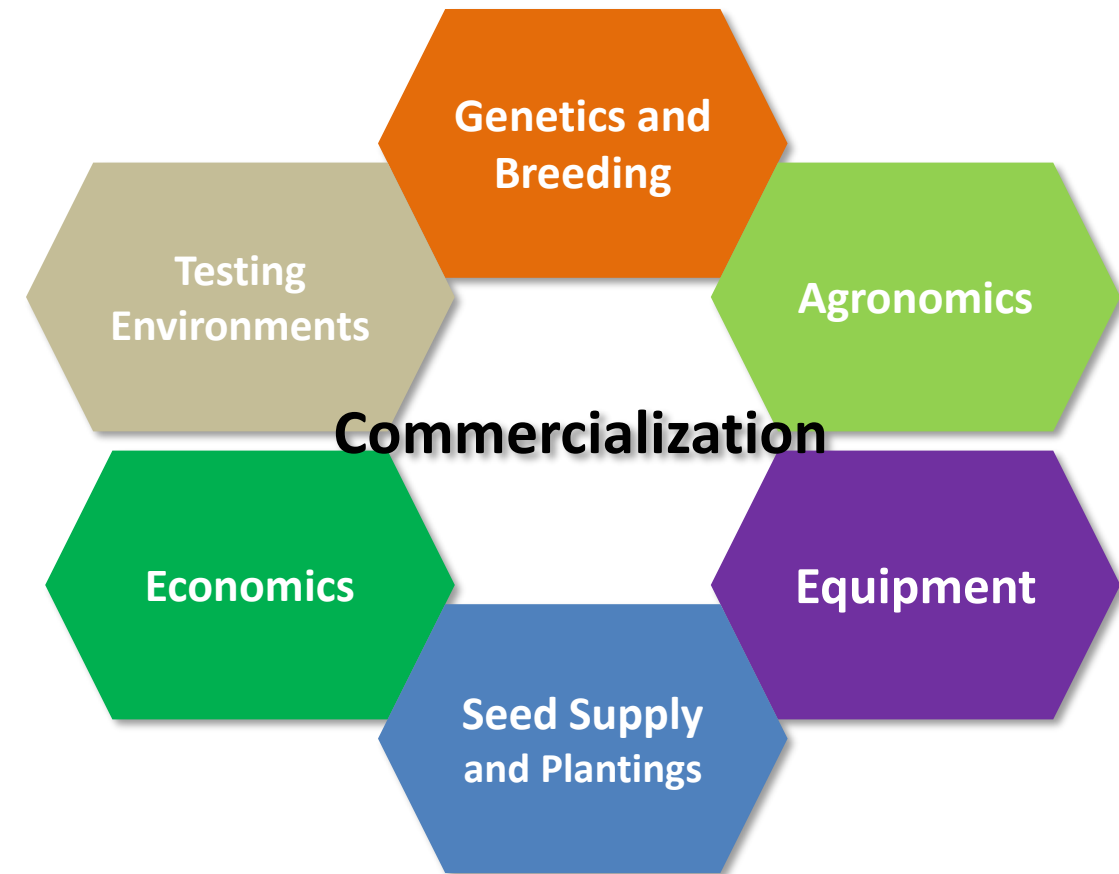
Bagasse
for fuel pellets, or higher value Product
80+% of volume

Commercialization Strategy:

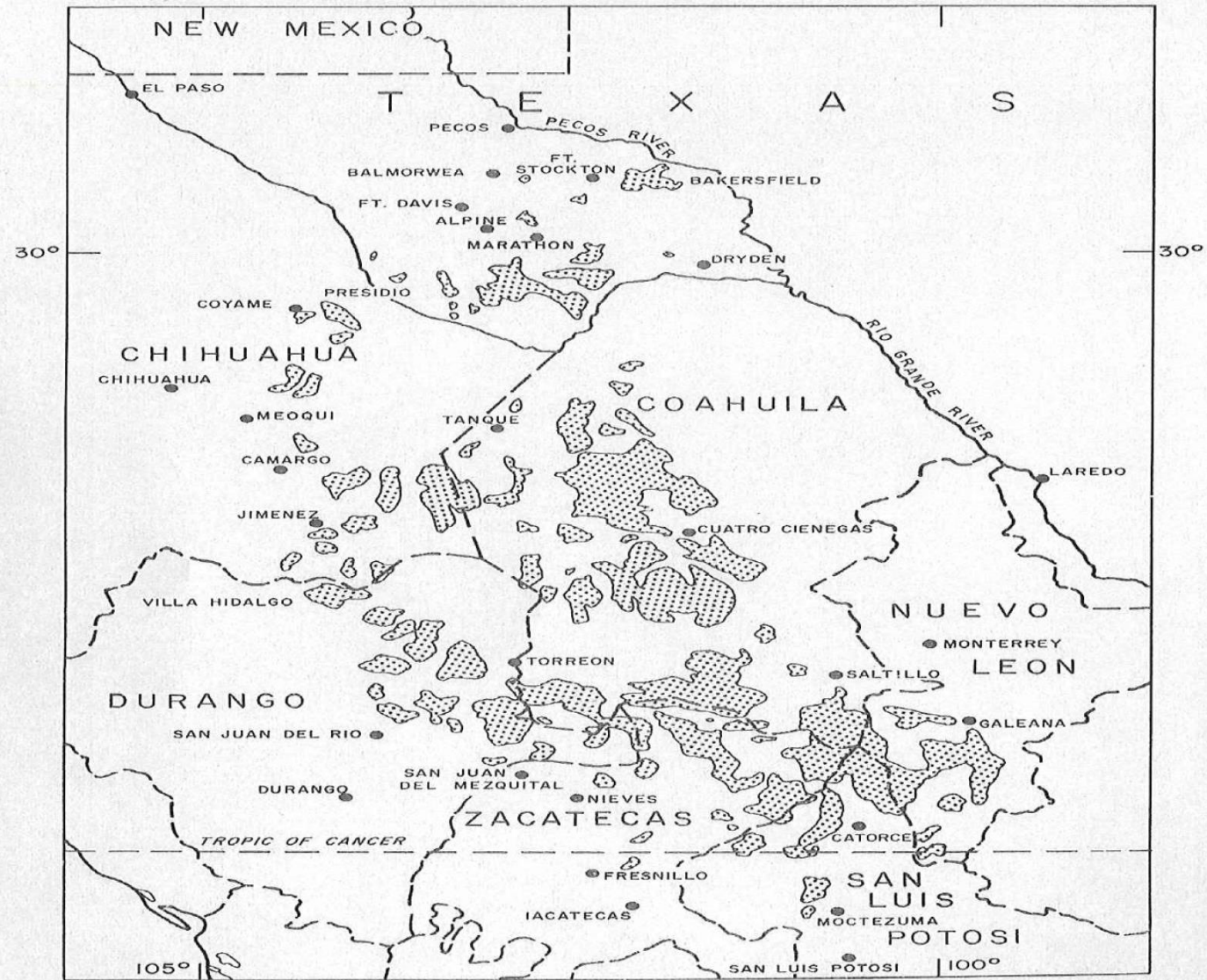
- Co-Product Utilization
- Sensitivity to key variables
- Risk/Reward
- Strategic fit

Agriculture Roadmap

- Guayule crop improvement is dependent on a wide base of diversity and the ability to form and select new recombinations that increase yield.
- Understanding agronomic management also reduces production costs. Major hurdles of replacing transplanting with direct seeding, controlling weeds and insects at planting, and obtaining registrations has been significant accomplishments.
- Establishing relationships with growers in different environments and addressing public perception of a new crops is essential.
- Design and engineering of necessary non-conventional equipment adaptable to different growing practices is critical.



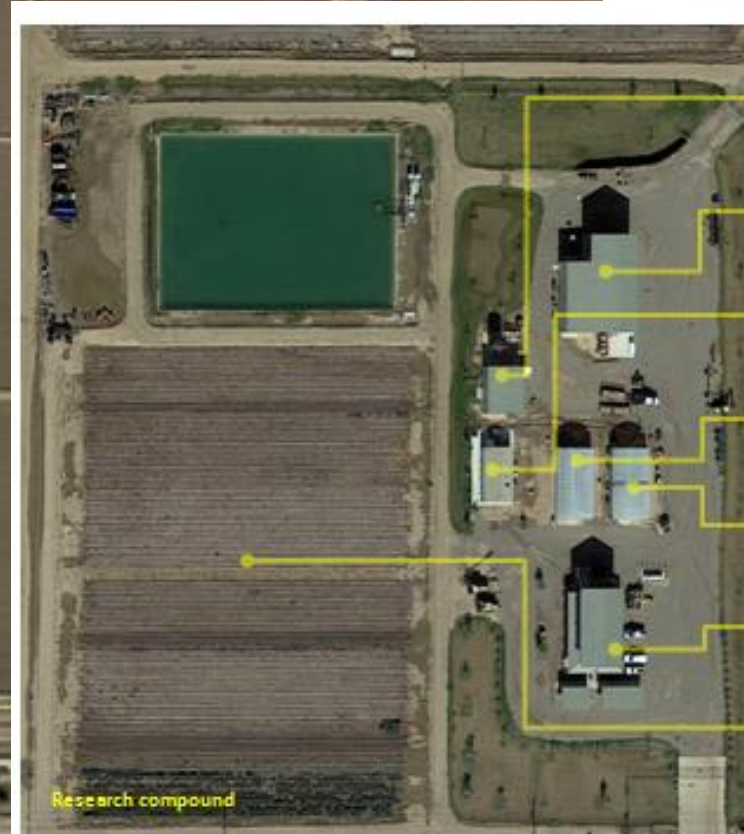
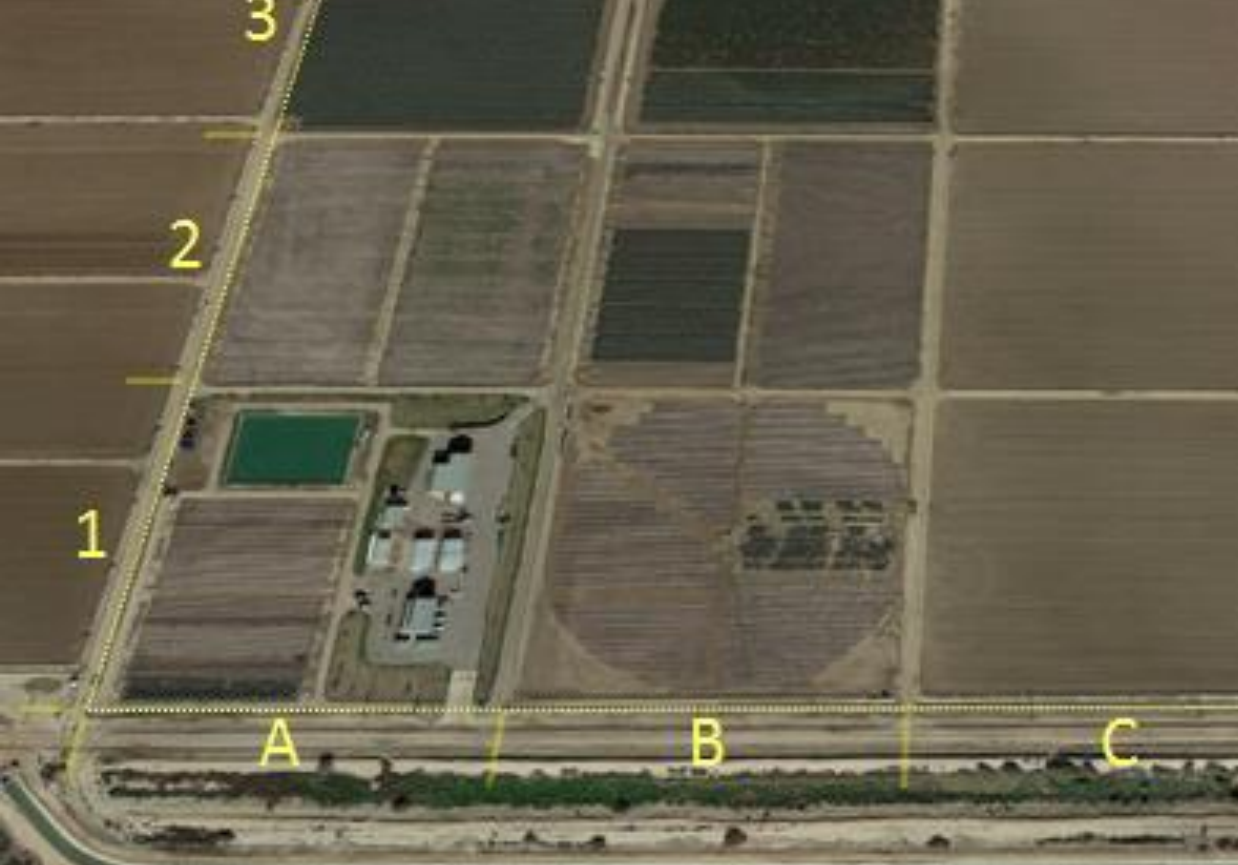
Guayule – Native Desert Plant of Mexico and U.S.



DISTRIBUTION OF NATIVE GUAYULE IN MEXICO AND TEXAS. AFTER JENKINS (1946)

What Guayule Requires:

- Grown in the Southwestern AZ, Mexico, Australia, Spain, Italy.
- Lowest Temperature ~20°F (-7°C). Survives lower temps but rubber yield is reduced
- Temperature lower than 40°F in winter
- Irrigation amount around 3 to 4 acre feet/year depending on soil type
- Well drained calcareous soils
- Little fertilization
- Conventional farm equipment except for shrub harvest and seed harvest.



- Head house and seed storage**
- Machine shop & seed processing**
- Offices**
- Greenhouse 1**
- Greenhouse 2**
- Offices & Laboratories**
- Breeding nursery**

BioRubber Processing Research Center (BPRC) – Mesa, Arizona

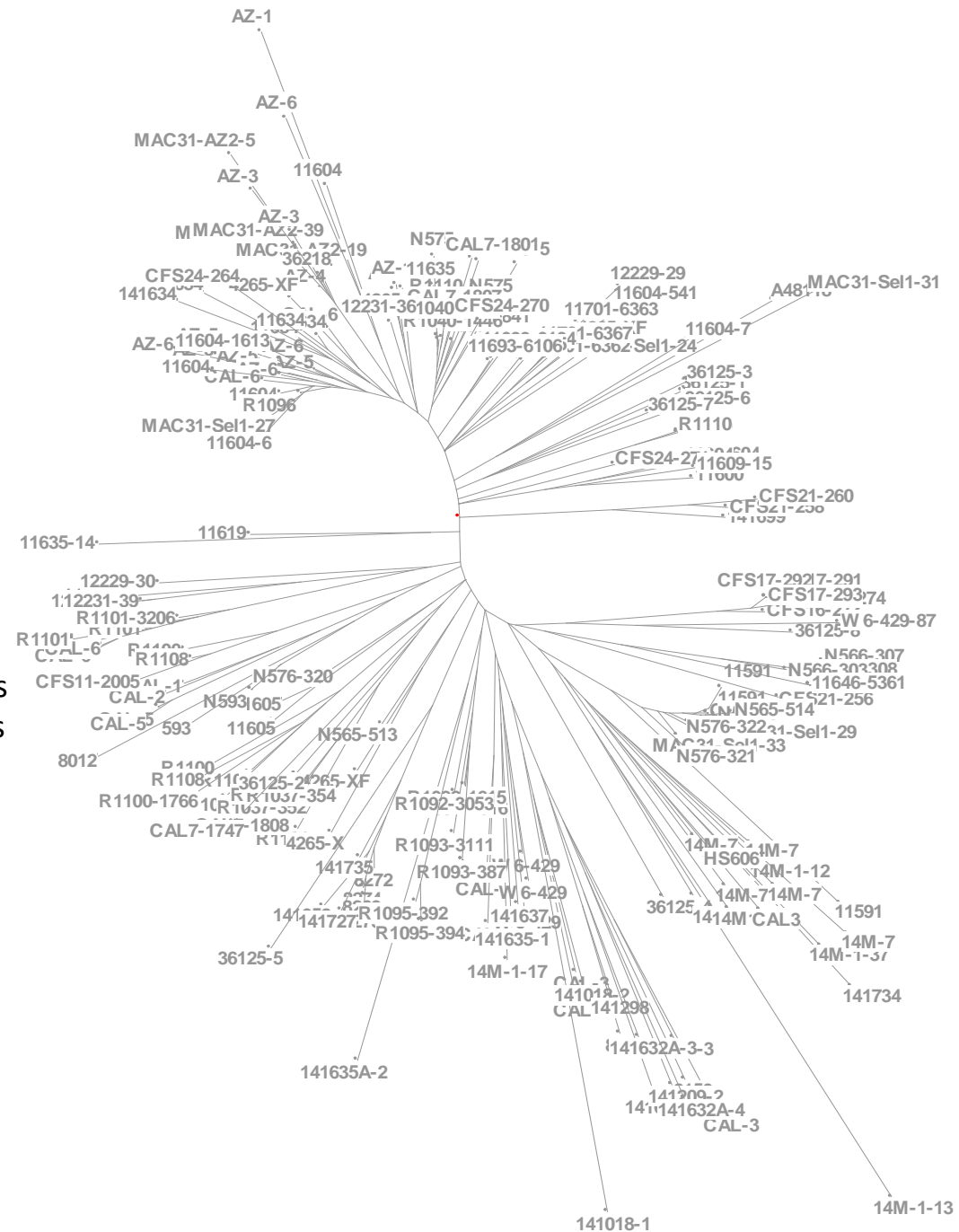


Genetics and Plant Breeding

Genetic similarity between a subset of Bridgestone accessions and available public germplasm



estone s
germplas



— Bridgestone proprietary germplasm
— Public germplasm

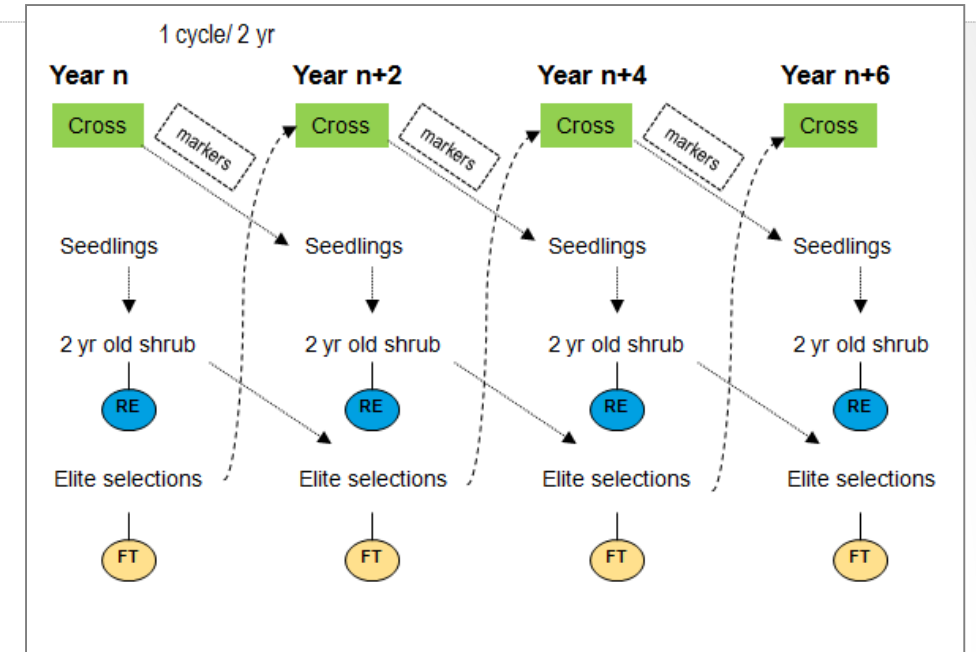
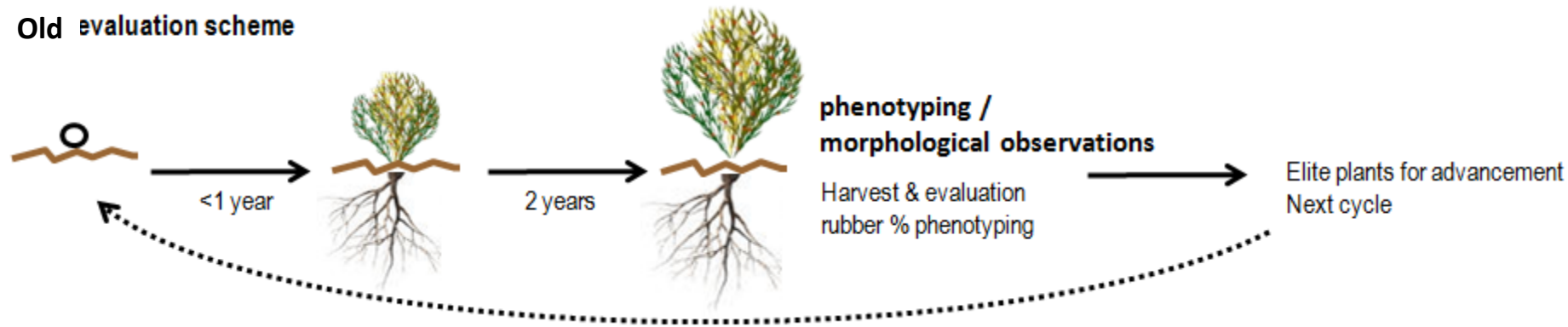
-U.S. National Plant Germplasm System. (Publically available)

-Source of 23 of 26 USDA cultivars and germplasm lines from a single collection

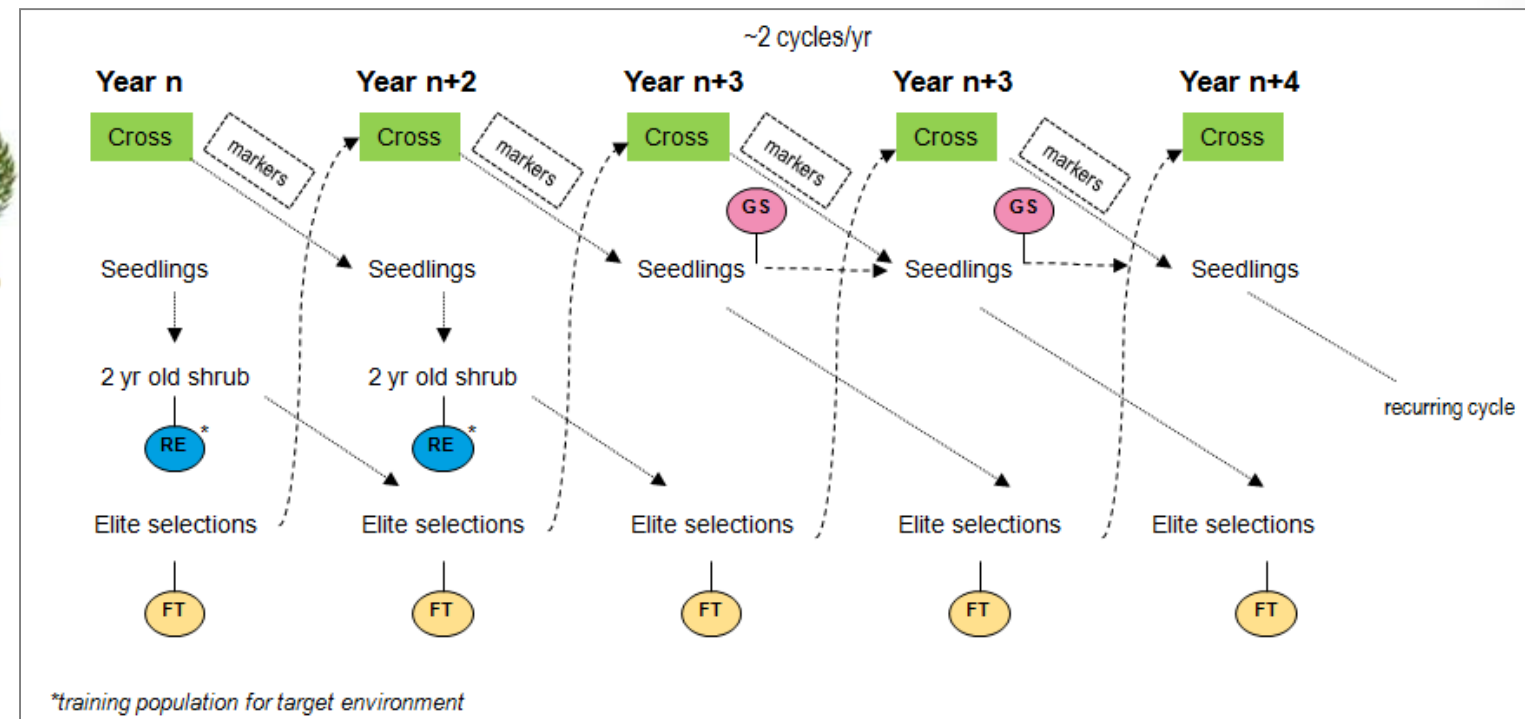
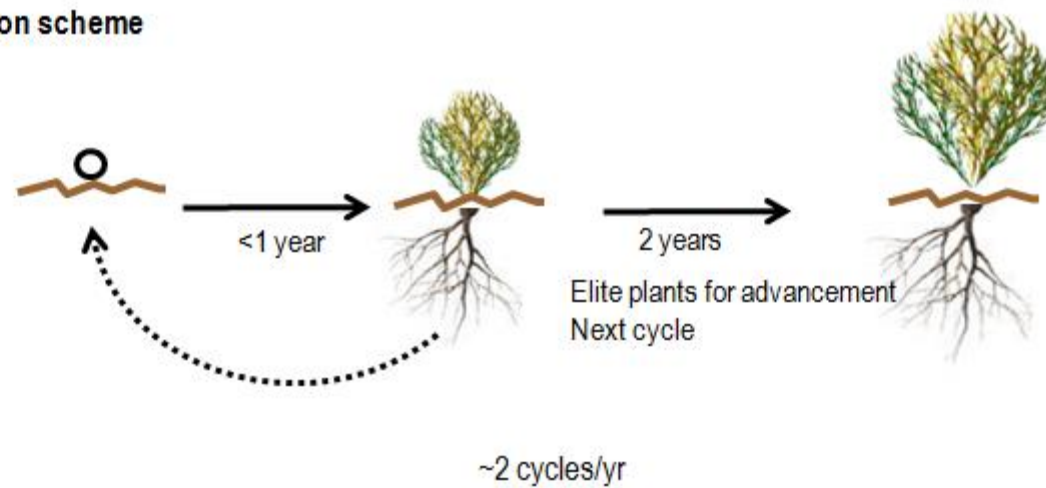
-Firestone Collection from the Fort Stockton, Texas Station- includes Mexican Bulk and diploid lines. (private collection)

Guayule genomic selection - implementation

Old evaluation scheme



selection evaluation scheme



*training population for target environment

Agronomy and Production:- Field production according to elevation

Marana, 40 acres
Elev: 600 m
Jan. min temp: 1.5°C (35F)
July max temp: 38.3°C (101F)

Eloy, 85 acres
Elev: 461 m
Jan. min temp: 1.7°C (35F)
July max temp: 39°C (103F)

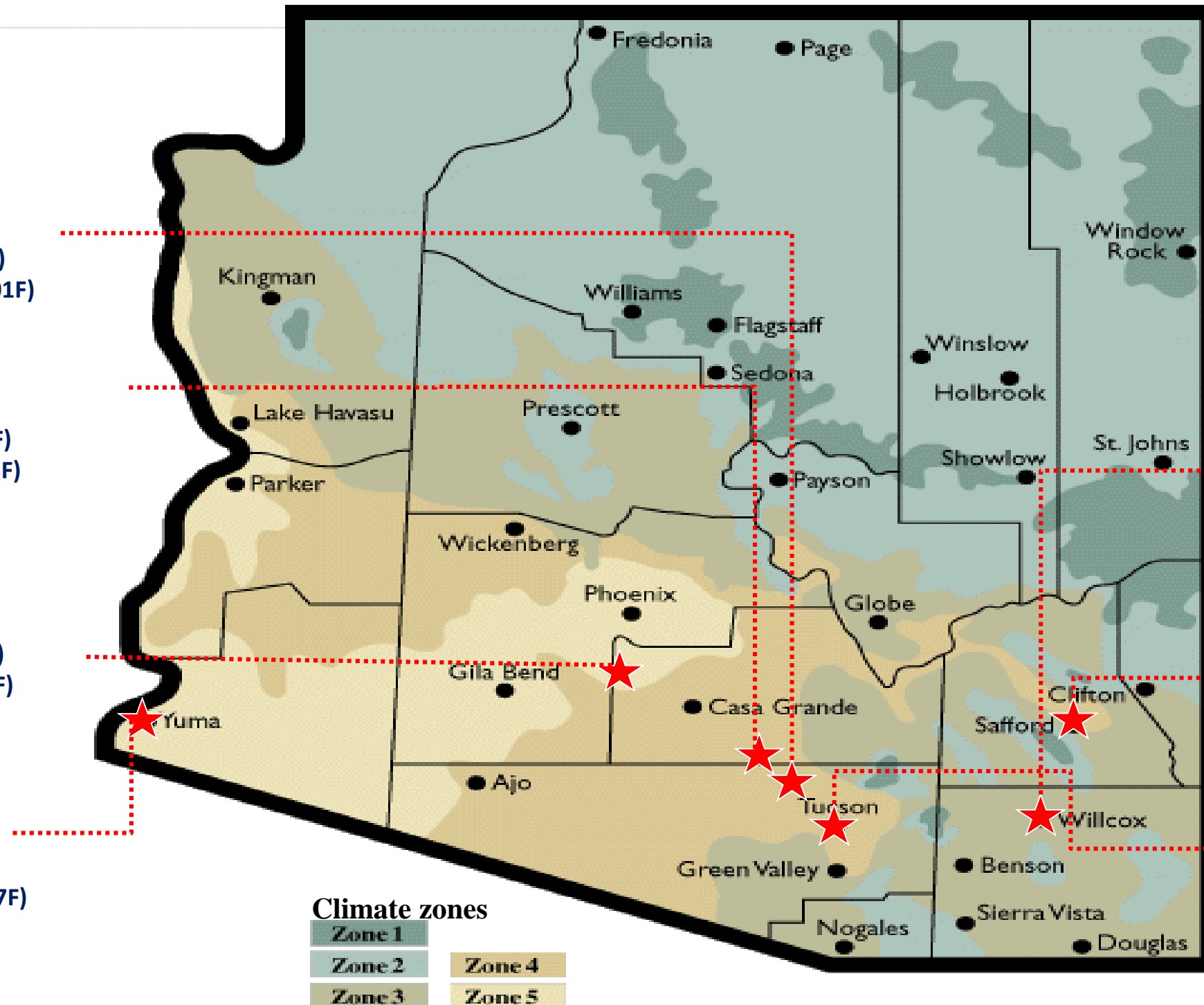
Maricopa, 45 acres
Elev: 361 m
Jan. min temp: 2.2°C (36F)
July max temp: 40°C (104F)

Yuma, 1 acre
Elev.: 32 m
Jan. min temp: 6°C (43F)
July max temp: 42°C (107F)

Willcox, 10 acres
Elev: 1284 m
Jan. min temp: -7.2°C (19F)
July max temp: 32.8°C (91F)

Safford, 3 acres
Elev: 901 m
Jan. min temp: -2.2°C (28F)
July max temp: 36.7°C (98F)

Tucson, 1 acre
Elev: 713 m
Jan. min temp: 1.1°C (34F)
July max temp: 37.2°C (99F)



Expand growing regions – guayule cold tolerance screening

- Cold temp germination
- Freezing tolerance

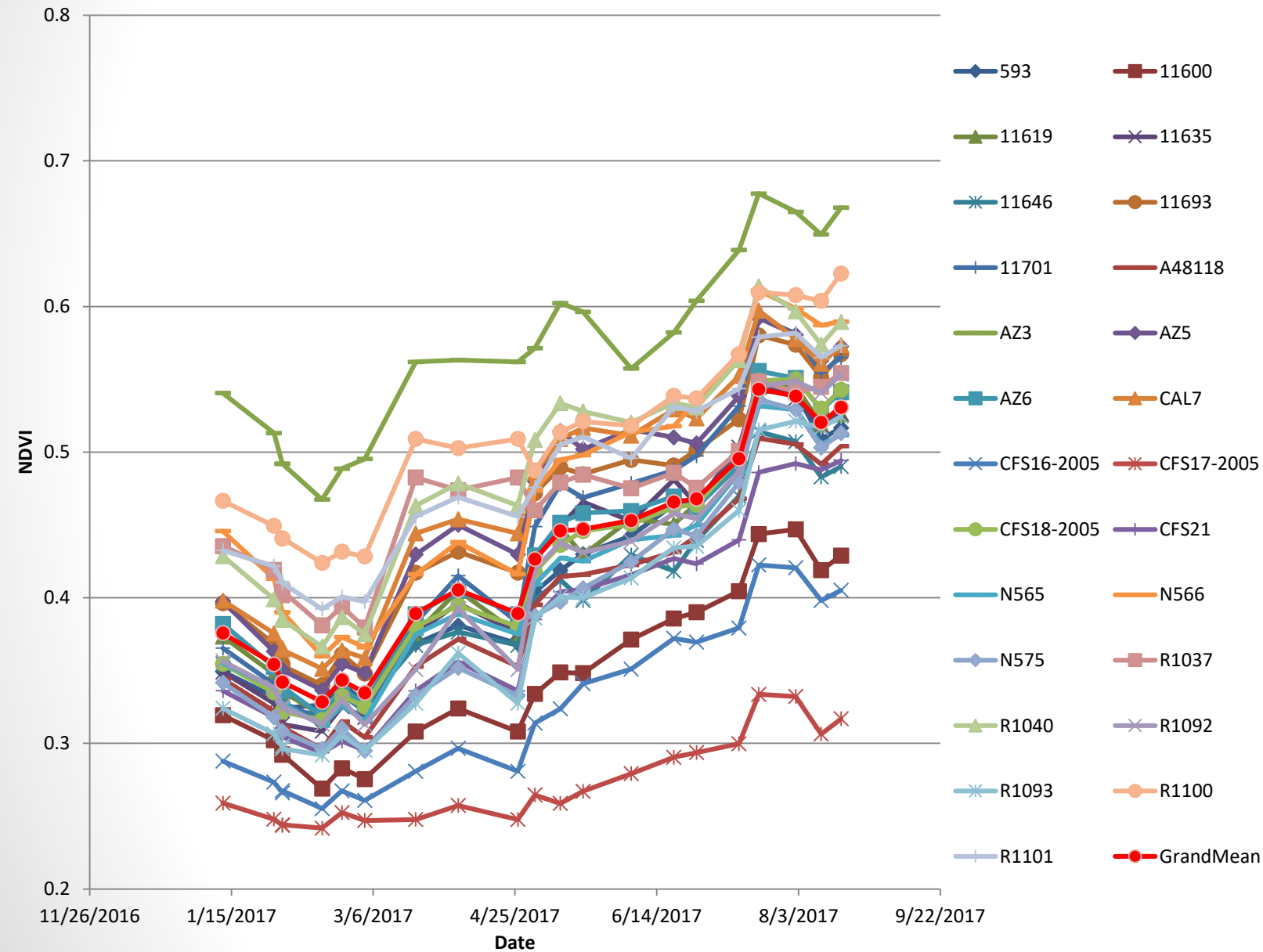


For successful production in higher elevations or colder regions, cold tolerant germplasm is needed.



Phenotypic Measurements - USDA lines

Estimate of biomass accumulation in Year 1 (2017)



Agronomy and Production – Direct Seeding

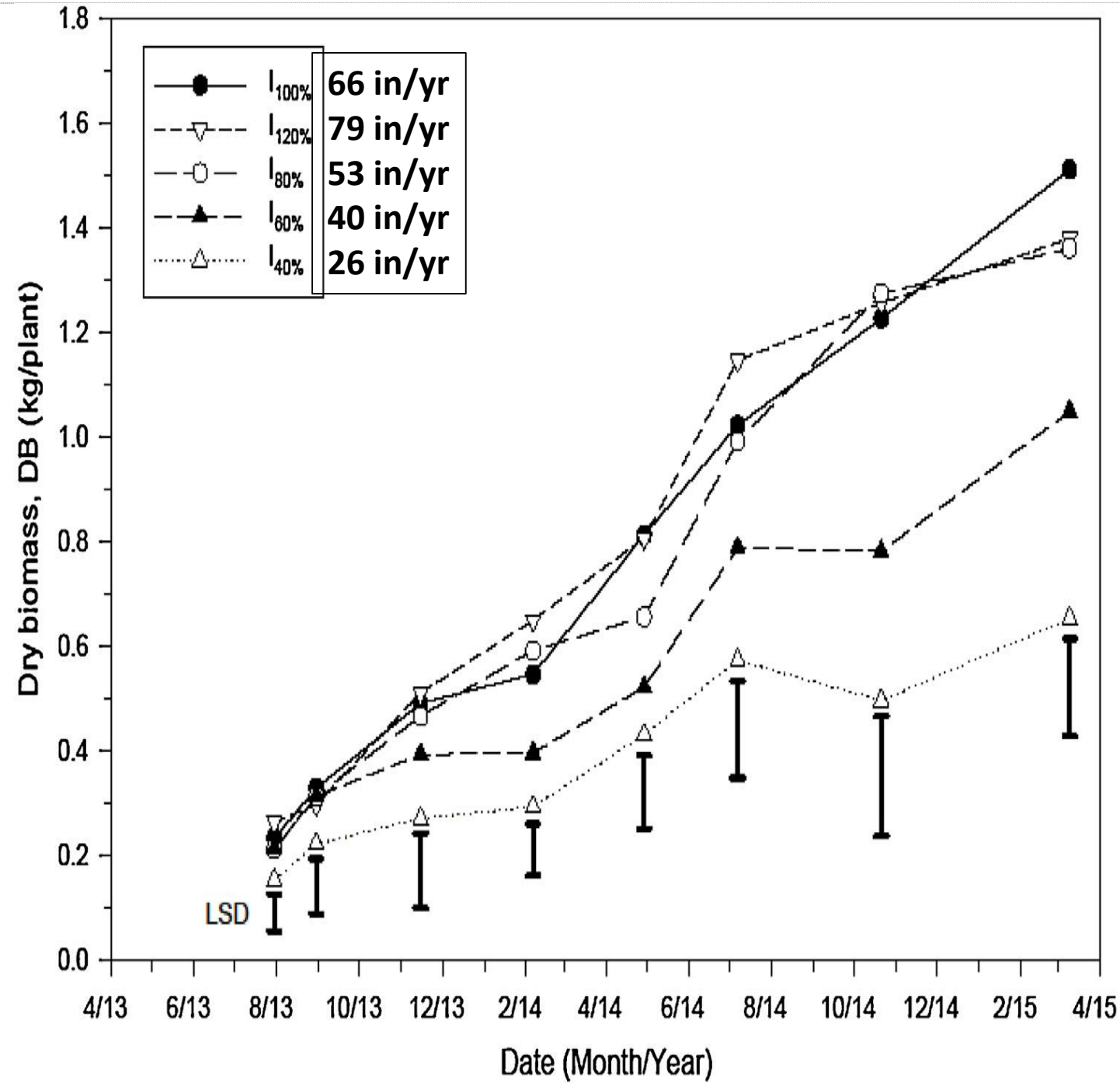
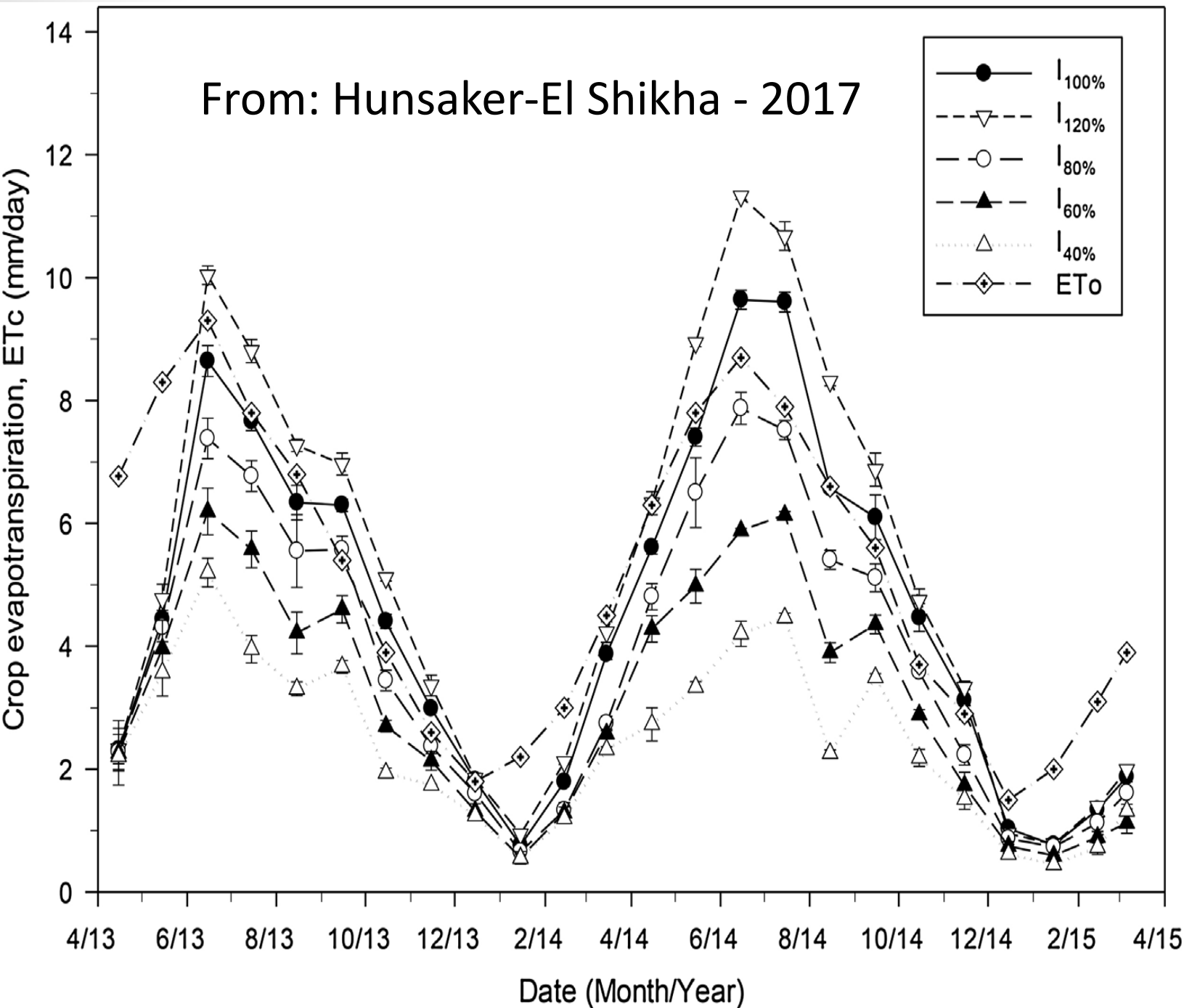


Direct seeding demonstrating commercial scalability. New field research is needed accounting for the difference in root depth and higher populations.

Monthly ETc rates measured for 5 irrigation treatments

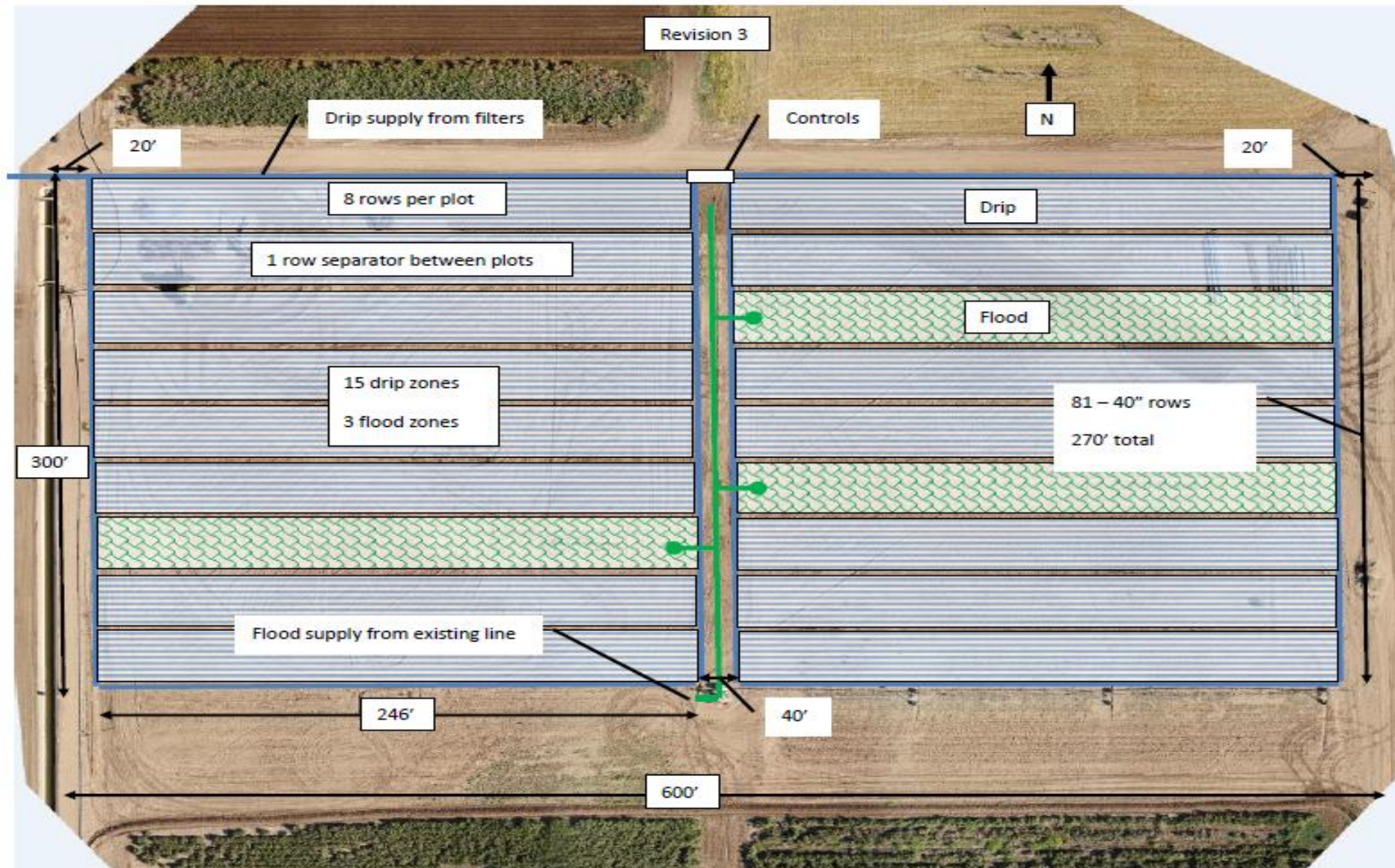


Dry weights for 5 irrigation treatments



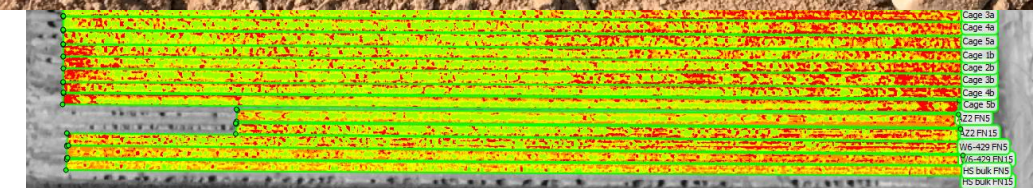
Spring 2018 – Irrigation Study and Density Study, each in 2 locations

Replicated Irrigation study comparing drip and flood at different rates – 2 locations



Partnership with Environmental Defense Fund in Spring 2018 -

- Provides biomass for research processing facility
- Provides production cost information within the MSID
- Enhances our network of producers
- Encourages focus on reduced irrigation with high yields.

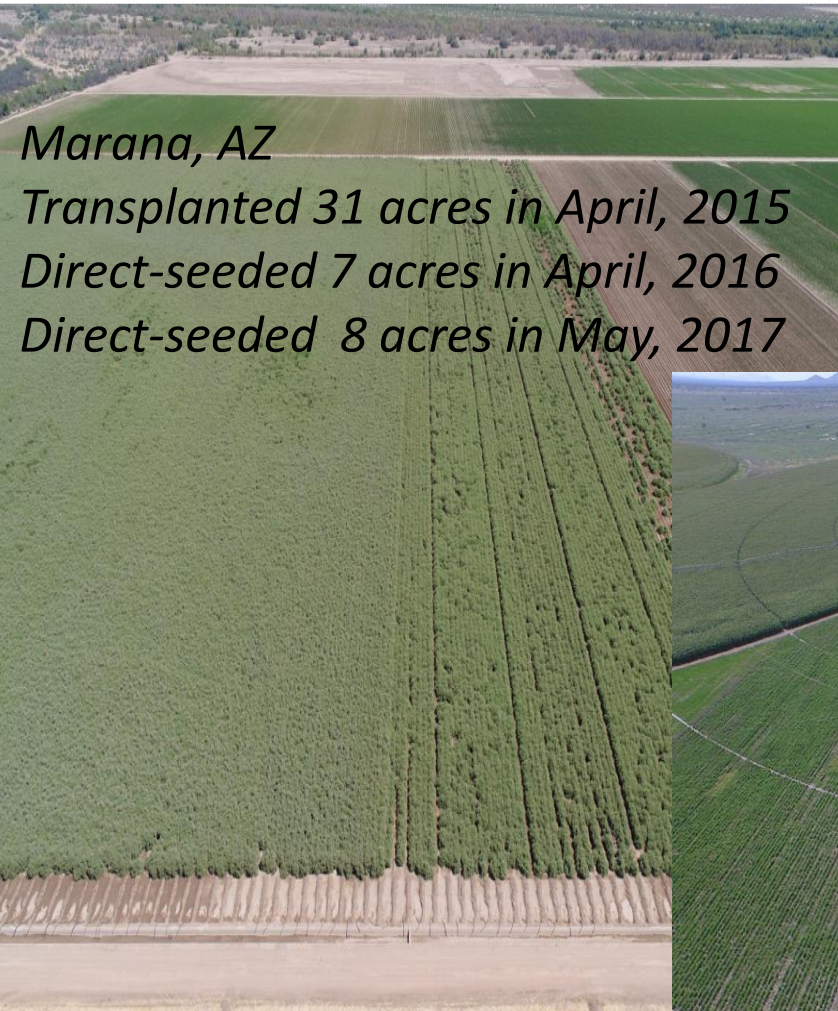


Agronomy and Production – Pesticides registrations

- Insect and weed problems in direct-seeded guayule
- Herbicides with registrations on transplanted guayule need to be tested direct seeded plants and new herbicides need to be screened.
- Registrations are needed for commercial scale production



Identify suitable areas and growers



Marana, AZ
Transplanted 31 acres in April, 2015
Direct-seeded 7 acres in April, 2016
Direct-seeded 8 acres in May, 2017



transplanted (10 acres)
and direct-seeded (2 acres)
in April, 2015



USDA, NIFA, AFRI CAP Grant Kick-off Meeting -Tucson Aug 31 and Sept 1



Pre-meeting tour of Bridgestone research facilities



Sustainable Bioeconomy for Arid Regions (SBAR)

