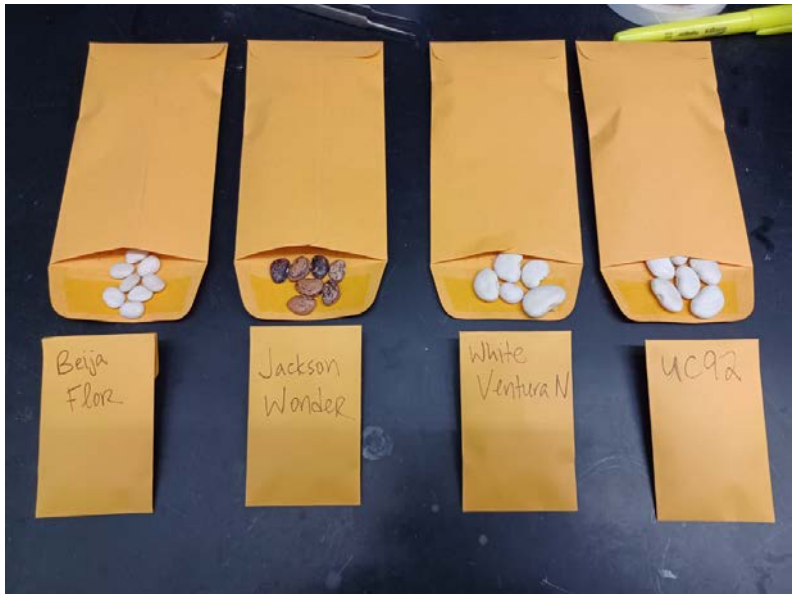
Lima and Garbanzo Breeding and Dry Bean Heat Stress Testing

Christine Diepenbrock

UC Davis Department of Plant Sciences

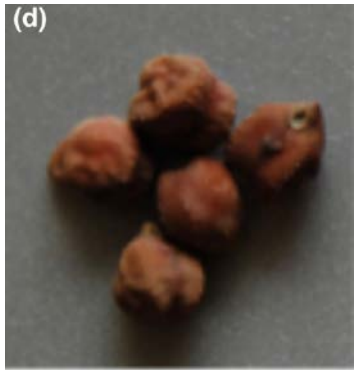
What are we breeding in this program?

Large-seeded and baby-seeded lima beans with lygus tolerance



Large-seeded kabuli-type garbanzos

Kabuli



Desi (only shown for comparison)

Photos from Varma Penmetsa and team, 2016

with a focus on regional adaptation, maximizing yield and seed quality

Breeding program objectives

- Testing and selection of advanced-generation lines, including in regional trials
- New crosses to generate early-generation lines for evaluation
- Additional pre-breeding research that feeds into the breeding program

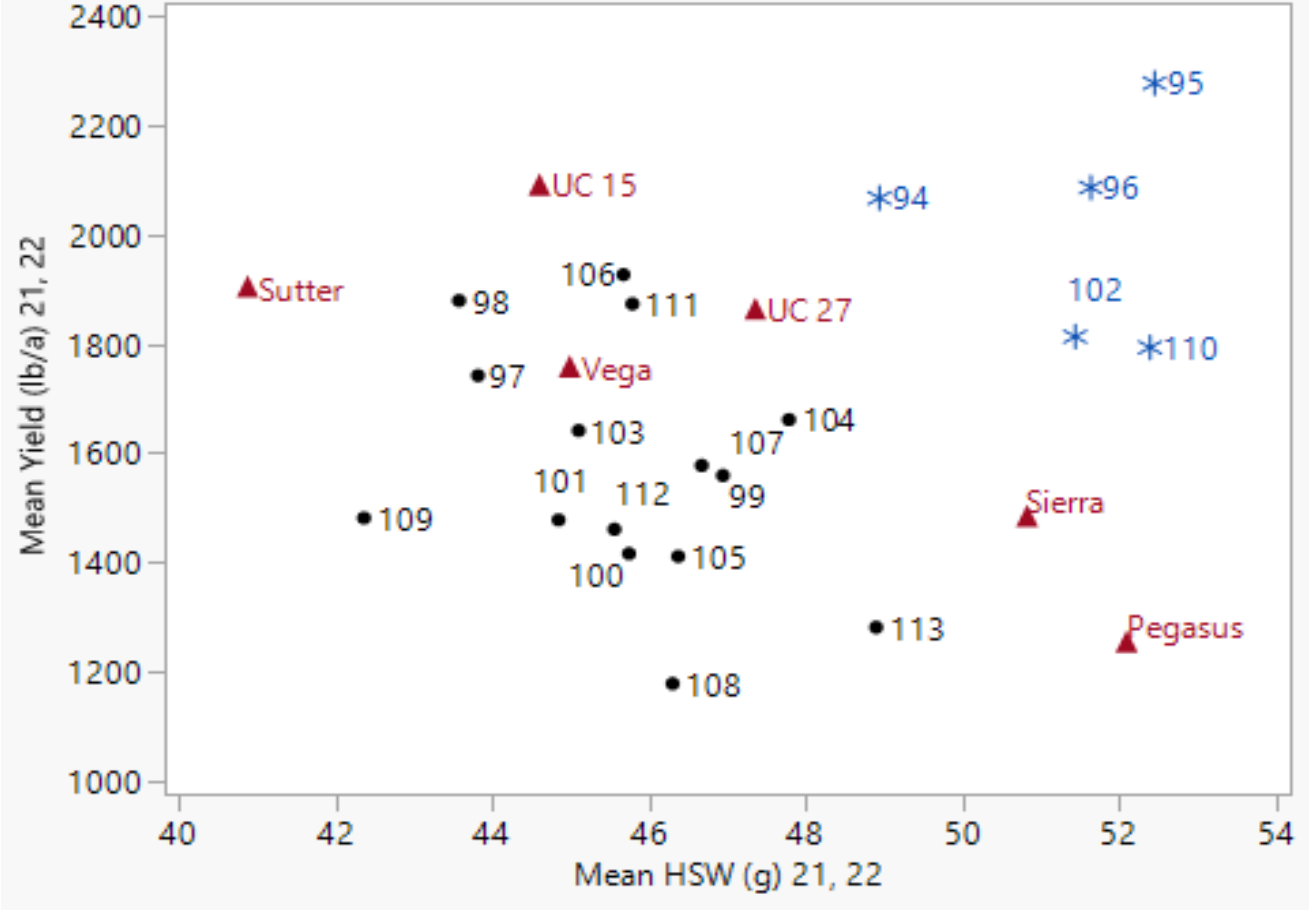
Photo credit: E. Kilmartin
anrcatalog.ucanr.edu/pdf/8505.pdf

Associate Specialist
Antonia Palkovic

Garbanzo breeding progress

Lines in blue are prioritized for testing in regional trials

Garbanzo Yield by Hundred Seed Weight Means with 2021 and 2022 Data



Blue entries with asterisks indicate high yielding and large seeded breeding lines.
Red entries with triangles are checks.

Lima breeding progress

- Large-seeded limas
  - Advanced-generation lines (F9+)
  - Mid- and early generation lines: F4 lines, UC 92 backcross populations
  - Checks: UC 92, Dompe 95
- Baby-seeded limas
  - F9+ and F6 lines
  - Checks: Beija Flor, Jackson Wonder (reasonably high-yielding, useful for verifying by-plot purity in harvesters)

Overview of lima bean production in the U.S.

Two Harvest Stages

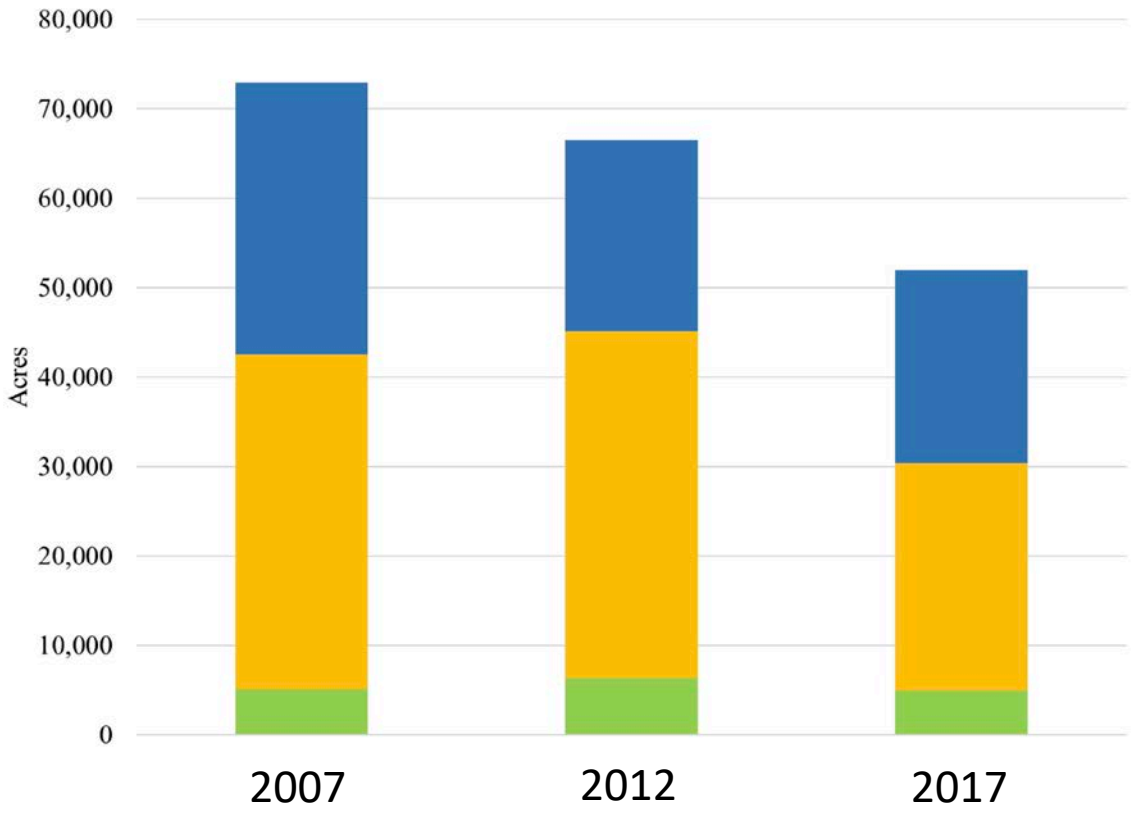
CA

Three Markets

Dry

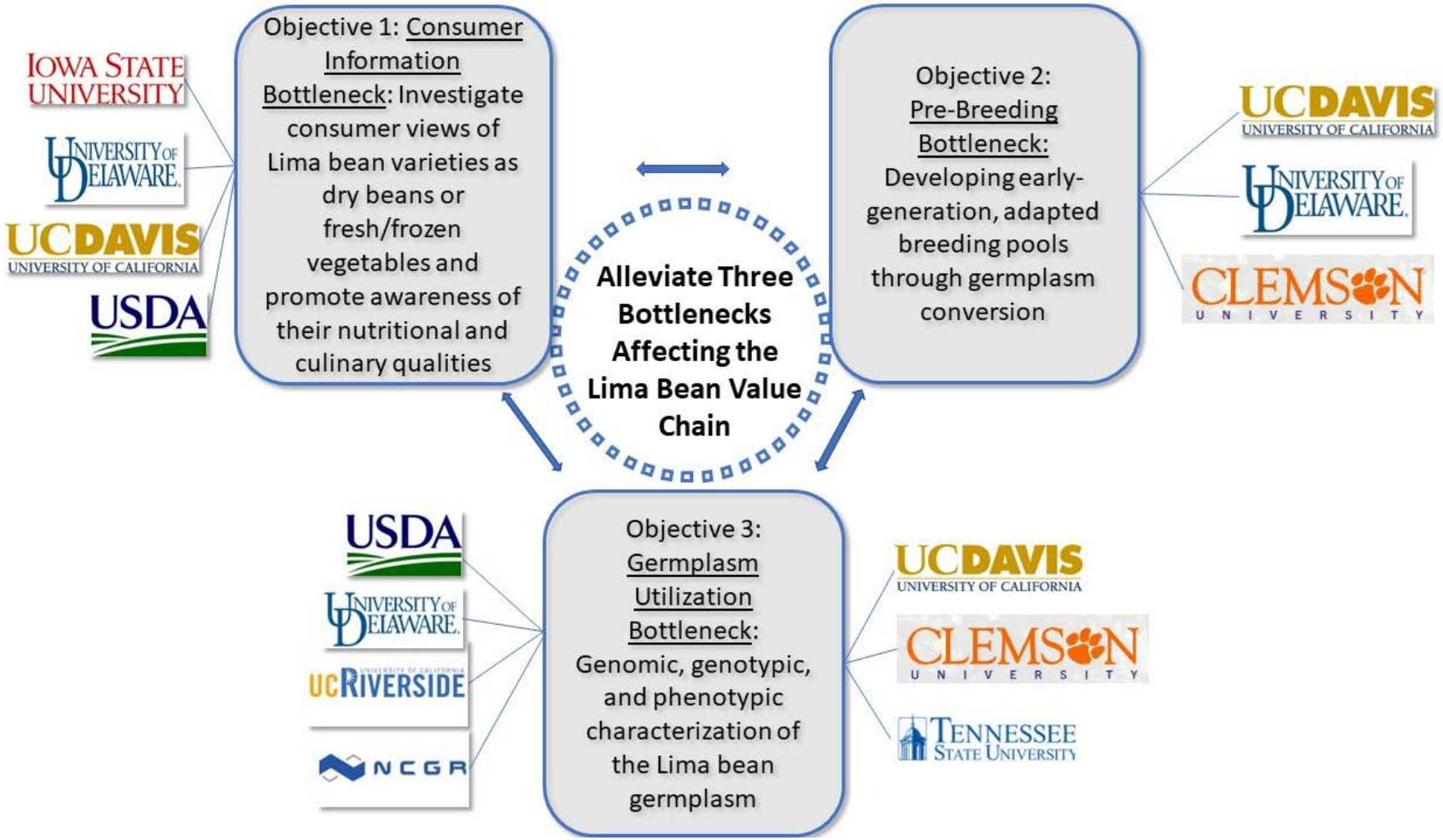
Processing (Dry/ Succulent)

Fresh Market (Succulent)



Graphic from Emmalea Ernest, Data from U.S. Censuses of Agriculture

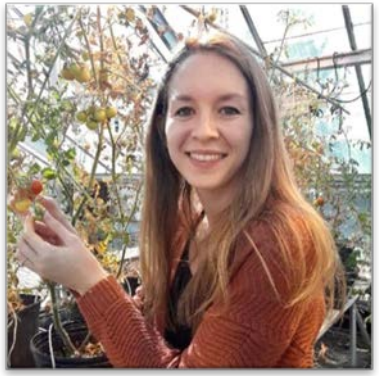
A large, four-year (USDA-funded) project working on improving lima beans for/with growers, processors, other ag. and food professionals, and consumers; led out of UC Davis by Disting. Prof. Emeritus Paul Gepts



Examples of the work going on in this project: addressing consumer information, pre-breeding, and germplasm information/utilization bottlenecks

- Lima beans cannot be crossed with common bean (‘quaternary gene pool’)
- >80% of major lima bean collections are thought to be photoperiod-sensitive
- Characterizing the USDA (National Plant Germplasm System) lima bean collection for adaptation, agronomic, nutritional quality, and nematode resistance traits

Postdoc.
Jaclyn
Adaskaveg



Assessing lima bean nutritional quality across varieties and environments to inform breeding

48 Genotypes

- California-relevant cultivars
  - E.g., UC Beija Flor, UC Haskell, Beija Flor, Dompe 95, UC 92
- Advanced breeding lines

Categorized into baby-seeded and large-seeded

Environments (so far)

Years:

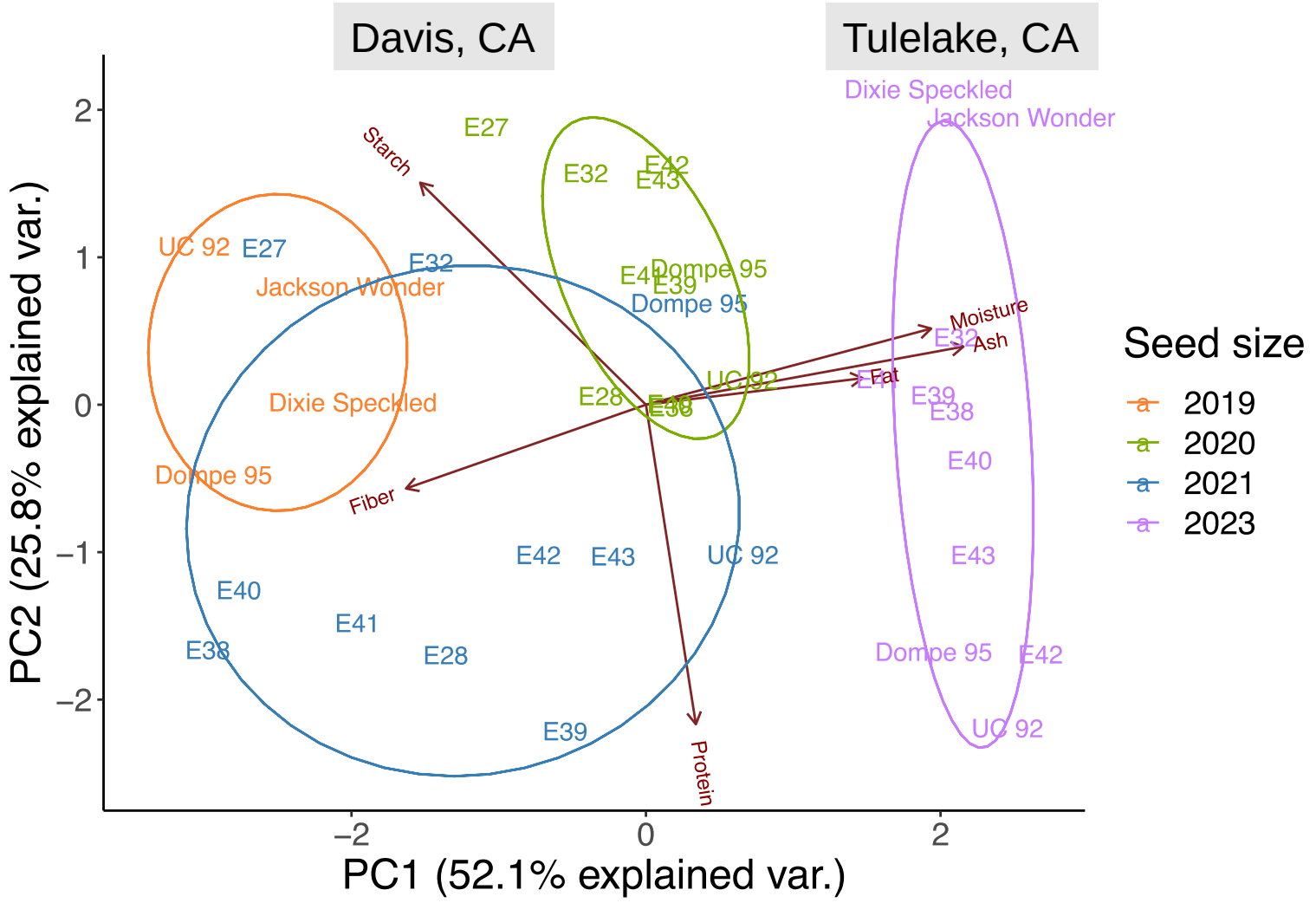
- 2019
- 2020
- 2021
- 2022
- 2023

CA Locations:

- Central Valley (Davis)
- Northern CA (Tulelake)
- Southern CA (Coachella)
  **Planted in late fall*

Nutritional traits look to be varying across environments within the same genotypes; follow-up studies still ongoing

Variation across environments for 13 genotypes with multiple locations and/or years

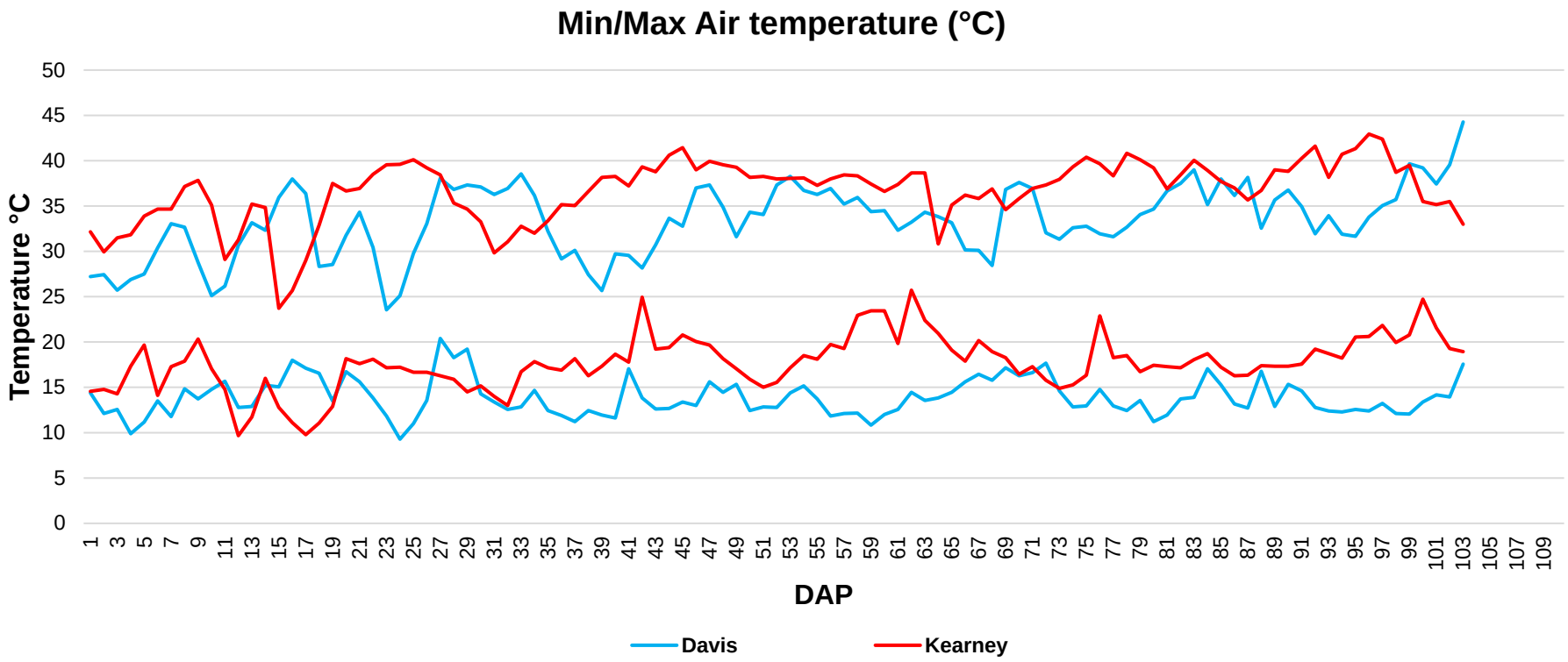


Testing of a common bean/tepary bean interspecific population in California, 2022 and 2023

- Tepary bean is more drought- and heat-tolerant than common bean (also being tested as a forage)
- Tepary and common bean are in the same genus but different species (‘tertiary gene pool’)
- Tested 324 interspecific (common bean/tepary) lines and 12 tepary lines at Davis and Parlier

Field trials 2022, 2023

- Contrasting day and night temperatures
  - Davis, CA; cooler environment
  - Parlier, CA; heat stress environment (Kearney)



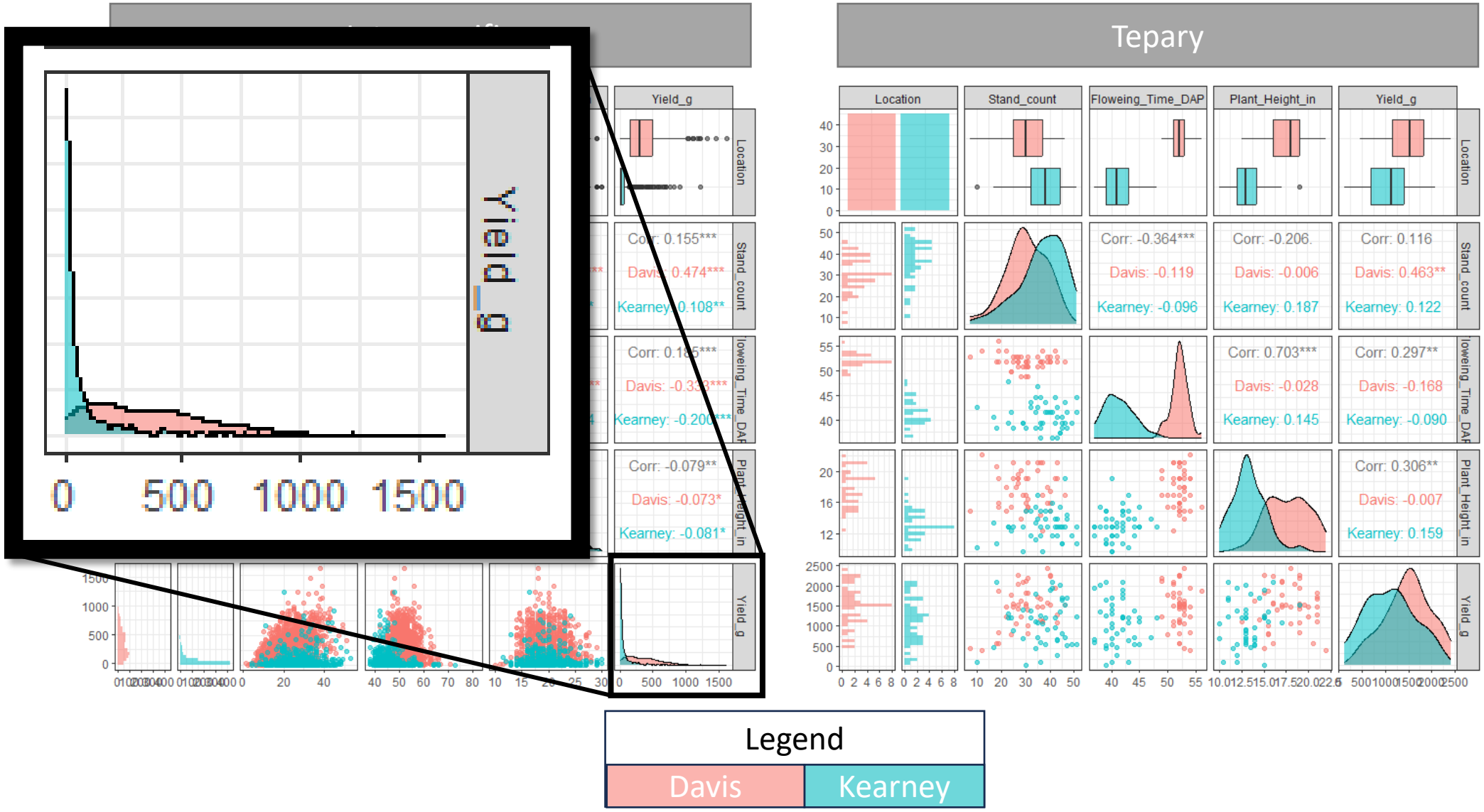
Traits being measured manually

for genetic analysis and for trait predictions from sensors

- In-field phenotypes
  - Stand count
  - Flowering time
  - Plant height
  - Yield

- After harvest
  - 100-seed weight
  - Seed protein, fat, starch, total phenolics, moisture
  - Seed mineral nutrients (focus on Fe, Zn, and Ca)
  - Anti-nutrients (phytic acid)
  - Seed coat color/patterning
  - Cooking time: Dr. Karen Cichy (USDA-ARS)

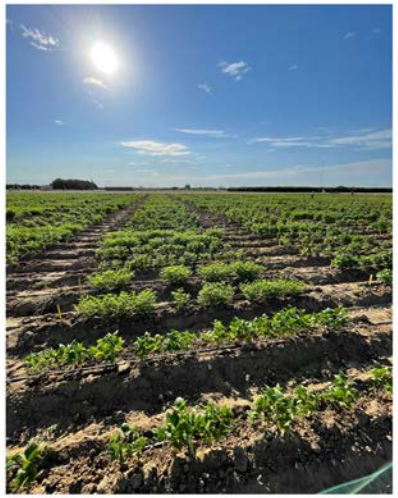
Agronomic trait correlations (2022)

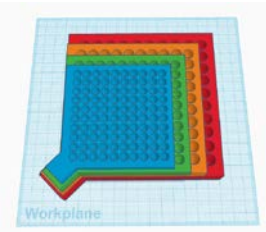


3D Crop Modeling

HELIOS

Pre-Breeding and Genomics





AI-Enabled Phenotyping

Example from cowpea (partnership with Lam Huynh at UC Riverside): traits being assayed from rover platform

Leaf Detection

Observed: 66 | Predicted: 54

Pod Detection

Observed: 11 | Predicted: 8

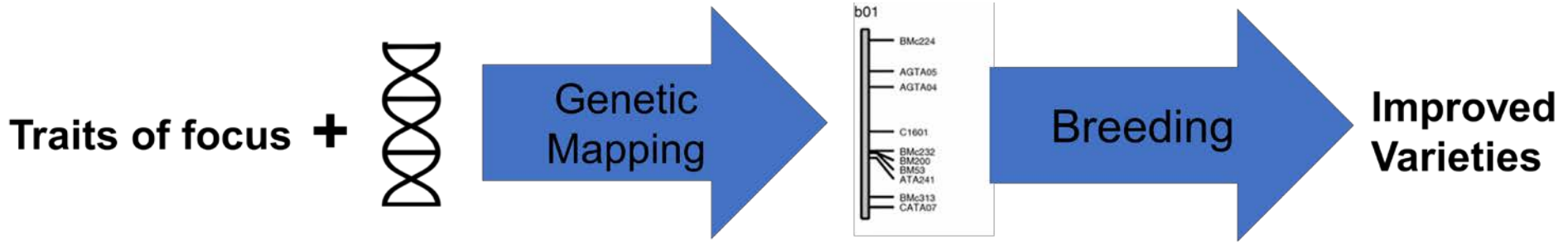
Flower Detection

Observed: 18 | Predicted: 23

Legend: Observed | Predicted

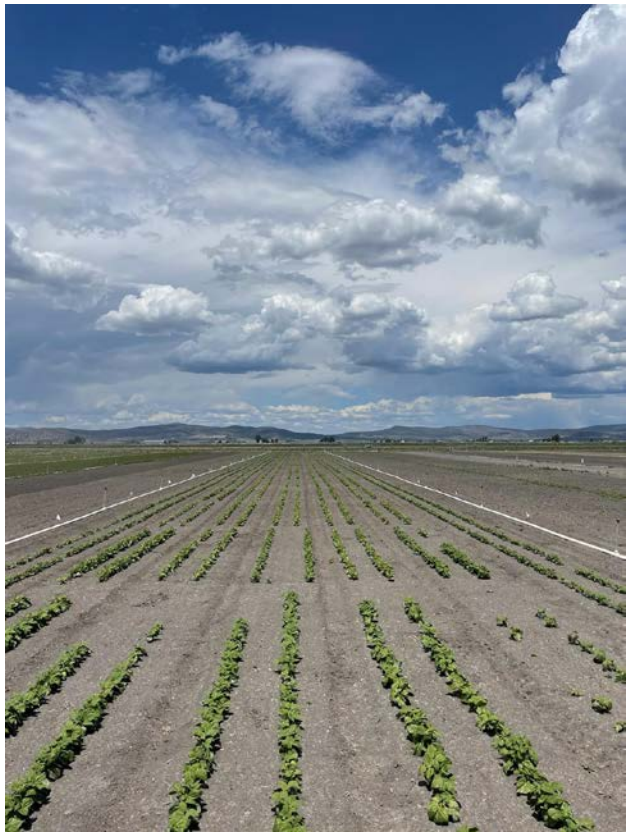
Planned analyses and outcomes

- Genetic mapping (uncover genetic regions that control priority traits)
- Genetic-by-environment interactions (how do we expect performance to vary across California environments?)
- Build easier methods to predict or measure (and understand the mechanisms behind) priority traits
- Accelerate breeding efforts (e.g., for heat-tolerant beans) by integrating genomics, 3-D crop modeling, and sensing



From farm to (robot) stomach: testing beans with diverse seed coat patterns in CA growing environments

Tayah Bolt, Margaret Riggs, Bhargavi Gidugu, Antonia Palkovic, Paul Gepts, Li Tian, Travis Parker,
Gail Bornhorst, Christine Diepenbrock



Field locations

2022 Planting Locations ★

Davis

San Gregorio

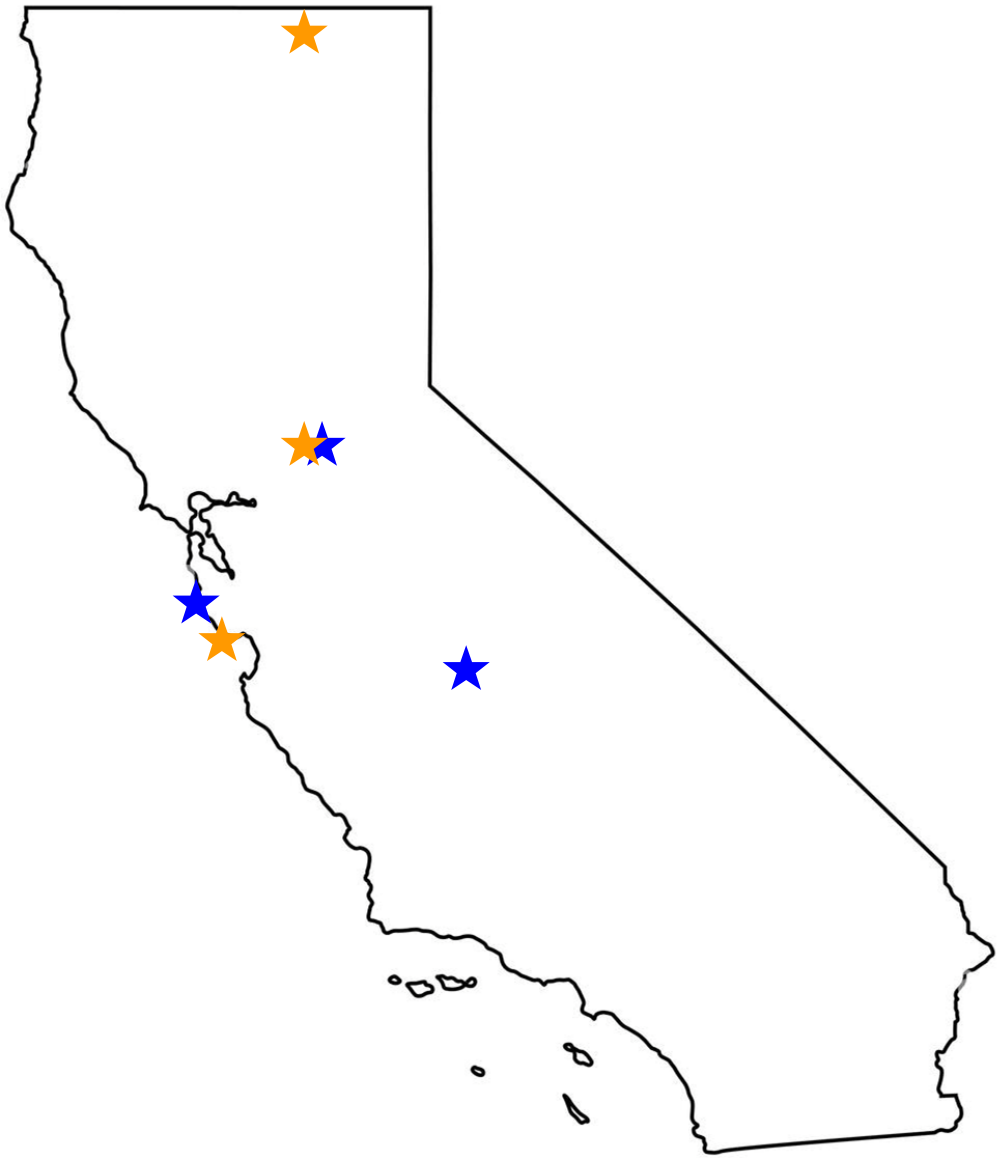
Parlier

2023 Planting Locations ★

Davis

Santa Cruz

Tulelake



Varieties tested

A

Variety / Location	UC Southwest Red	UC Southwest Gold
Davis, CA July mean high/low 33°C/15 °C		
Pescadero, CA July mean high/low 22°C/11 °C		

UC Southwest varieties by location. Extent of seed coat patterning (%) determined by ImageJ macro: 70.8% (± 0.4%, SE) in Davis and 21.0% (± 2.7%, SE) in Pescadero.

B

UC Southwest Red 	UC Southwest Gold 	Anasazi 
Orca 	Black Nightfall 	Raven 
Othello 	Viva 	CELRK 

Commercially relevant cultivars with partially colored seed coat patterns, and one of each of the following major market classes of dry bean: pinto (Othello), black (Raven), navy (Viva), kidney (California Early Light Red Kidney (CELRK)).

(Also, a subset of lines from a biparental population)

Which traits are we measuring?

At harvest:

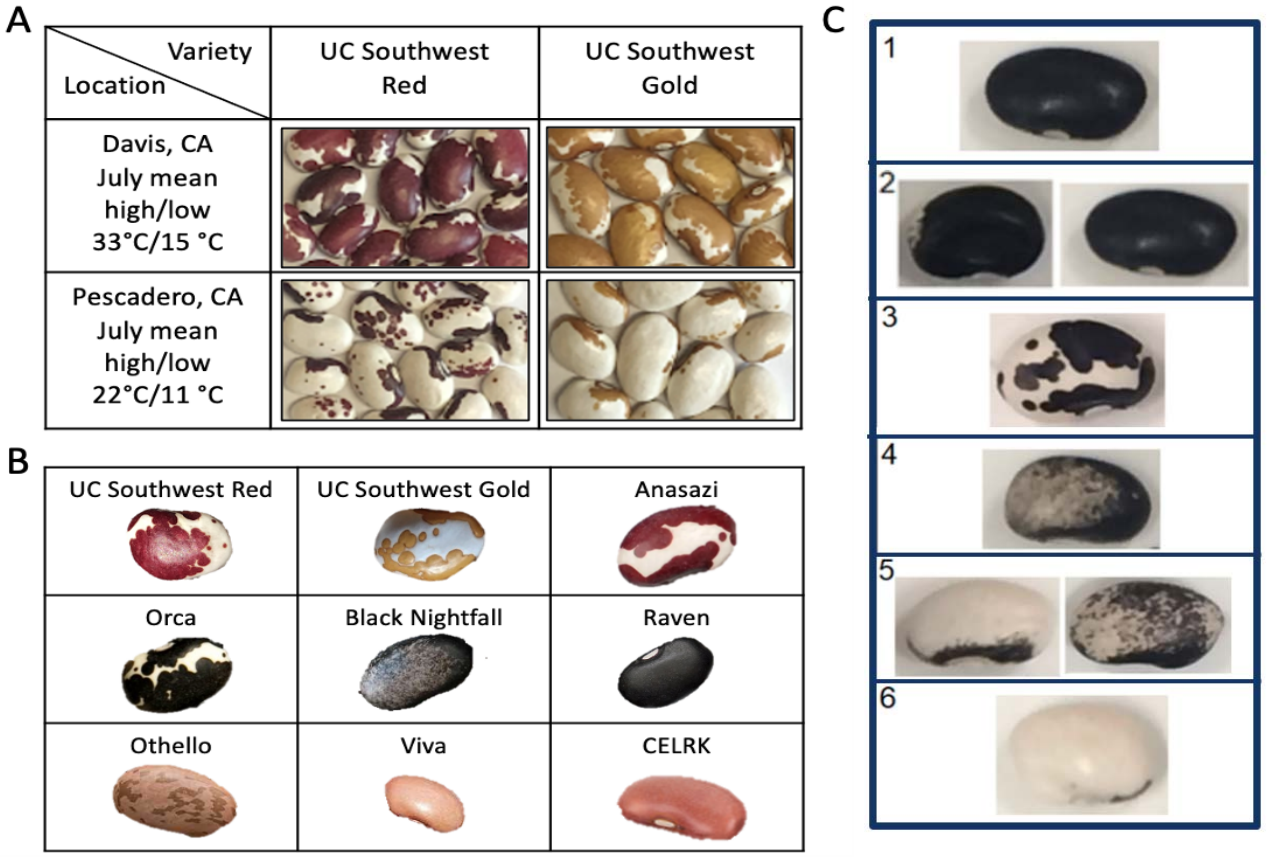
- Seed coat patterning, starch, fiber, protein, fat, moisture, total phenolics

In cooked beans (and broth) and during/after digestion:

- Breakdown of protein and starch, total phenolics

2022 seed coat patterning

Values indicate the average seed coat color % for each genotype in Davis and San Gregorio



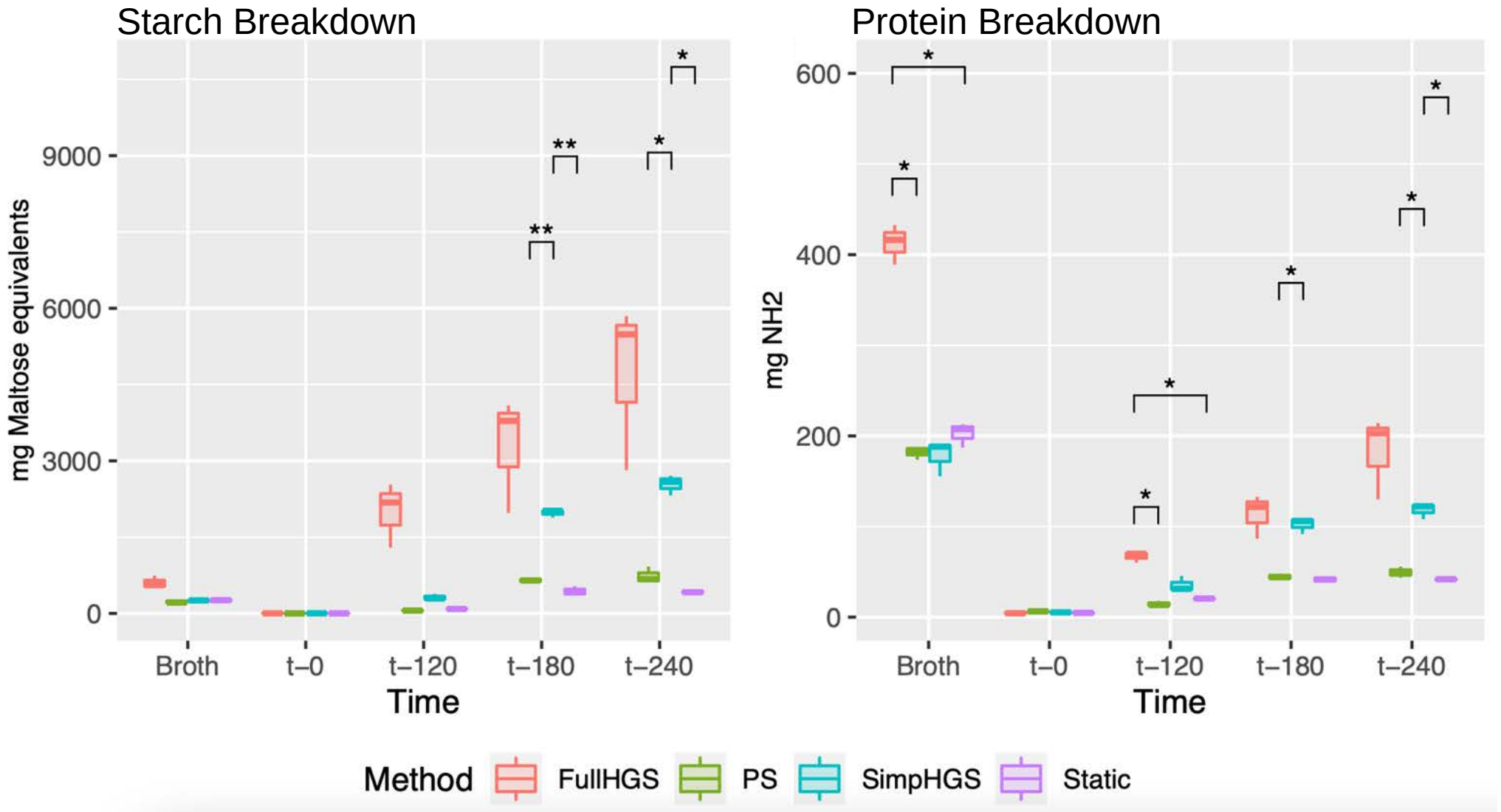
Genotype	Davis	San Gregorio
Southwest_Gold	0.648	0.170
Southwest_Red	0.773	0.240
Anasazi	0.866	0.447
Black_Nightfall	0.310	0.515
Orca	0.833	0.069
BXO-030_PH1	0.992	0.935
OXB-098_PH1	1.022	1.003
OXB-100_PH1	1.009	0.968
OXB-178_PH1	1.020	1.002
BXO-119_PH2	0.958	0.726
BXO-144_PH2	1.013	1.006
OXB-086_PH2	0.880	1.012
BXO-158_PH2	0.890	0.943
BXO-052_PH3	0.784	0.076
BXO-139_PH3	0.844	0.165
BXO-145_PH3	0.569	0.076
OXB-094_PH3	0.818	0.065
BXO-145_PH4	0.556	0.888
BXO-040_PH4	0.530	0.614
BXO-049_PH4	0.791	0.912
BXO-055_PH4	0.459	0.741
BXO-100_PH5	0.416	0.201
BXO-118_PH5	0.190	0.183
OXB-117_PH5	0.161	0.170
BXO-159_PH5	0.333	0.425
BXO-013_PH6	0.035	0.029
BXO-075_PH6	0.061	0.034
OXB-139_PH6	0.085	0.036
OXB-179_PH6	0.035	0.049
Raven	1.007	1.033
CELRK	0.872	0.927
Viva	0.835	0.891
Othello	0.588	0.556

2022 at-harvest nutritional quality

	2022 Davis Harvest						2022 San Gregorio Harvest					
Genotype	Moisture	Fat	Starch	protein	Ash	fiber	Moisture	Fat	Starch	protein	Ash	fiber
Anasazi	11.67	1.73	16.34	23.91	5.84	5.55	11.26	2.99	20.69	18.17	6.14	6.80
Black Nightfall	8.72	1.60	16.66	26.70	4.74	4.45	13.12	3.23	20.05	19.36	5.91	3.71
BXO-013_PH6	8.58	2.04	18.69	25.96	4.73	11.76	10.85	2.89	19.05	17.46	6.16	6.71
BXO-030_PH1	9.04	3.21	17.53	25.49	4.90	7.13	NA*	NA*	NA*	NA*	NA*	NA*
BXO-040_PH4	8.56	2.94	17.01	26.64	4.48	7.21	12.71	4.73	20.80	19.09	6.00	5.99
BXO-049_PH4	10.18	2.34	17.30	25.33	4.99	5.53	14.11	3.70	18.64	20.45	6.61	5.80
BXO-052_PH3	8.00	3.10	19.45	24.81	4.16	8.42	11.77	3.12	19.76	20.67	5.92	4.58
BXO-055_PH4	10.01	1.48	16.60	25.03	5.47	3.99	16.03	1.88	17.35	20.57	8.58	6.10
BXO-075_PH6	8.78	1.76	18.66	26.08	4.58	4.72	11.67	3.43	20.92	18.71	6.13	5.84
BXO-100_PH5	7.96	2.41	18.76	24.78	4.49	8.58	12.23	2.80	20.68	17.87	6.26	4.83
BXO-118_PH5	9.07	1.87	18.11	25.18	4.61	4.44	12.50	2.74	19.72	20.43	5.95	4.25
BXO-119_PH2	8.37	3.51	18.34	25.18	4.35	7.18	13.33	4.14	19.70	20.22	6.30	5.94
BXO-139_PH3	8.25	3.58	20.17	23.73	4.78	8.51	11.83	2.72	20.10	19.34	6.04	3.77
BXO-144_PH2	8.99	2.96	18.58	24.78	4.49	6.28	13.73	4.43	21.59	19.63	7.74	5.85
BXO-145_PH3	7.74	2.66	18.66	25.59	4.54	8.52	11.39	2.56	18.94	20.85	5.79	7.21
BXO-145_PH4	8.35	2.98	17.44	26.18	4.93	8.42	13.57	4.41	18.45	18.72	6.31	7.15
BXO-158_PH2	7.64	3.23	18.15	27.07	4.41	7.26	13.60	4.03	18.67	20.54	6.41	6.53
BXO-159_PH5	8.01	2.95	18.69	24.95	4.59	8.14	12.49	3.86	20.63	19.30	6.00	5.89
CLERK	8.11	2.19	20.47	23.59	4.54	15.13	11.60	2.56	21.19	20.20	5.39	6.24
Ocra	7.96	3.27	19.49	25.23	4.08	8.27	11.91	2.68	18.87	20.84	6.29	5.87
Othello	9.06	1.58	18.97	23.28	4.93	7.37	11.81	2.49	21.96	17.55	5.43	6.11
OXB-086_PH2	7.97	3.29	18.58	25.80	4.24	7.98	13.17	5.31	19.58	20.26	5.88	5.60
OXB-094_PH3	7.61	3.60	19.71	23.58	4.37	9.04	11.44	2.28	21.78	19.02	5.69	6.49
OXB-100_PH1	7.93	3.03	18.18	27.96	4.21	7.38	13.07	5.17	20.76	19.22	6.40	5.86
OXB-117_PH5	9.09	3.14	17.52	25.04	4.62	6.77	14.53	3.94	19.74	20.57	8.36	6.48
OXB-139_PH6	7.88	2.02	18.86	24.26	4.56	7.87	13.49	2.79	17.48	18.83	6.26	5.00
OXB-178_PH1	8.47	1.82	19.18	24.40	4.82	6.44	11.69	3.26	22.28	18.01	6.20	5.26
OXB-179_PH6	8.25	3.54	18.99	25.36	3.89	7.07	11.54	2.84	20.23	19.34	6.45	6.22
OXB-98_PH1	9.73	1.65	16.03	28.09	5.42	3.98	12.30	5.14	21.47	19.65	5.94	5.80
Raven	8.27	2.69	19.78	23.48	4.42	6.36	15.31	3.74	15.08	24.06	6.03	4.69
UC Southwest Gold	8.48	2.57	21.74	22.78	4.54	14.54	11.57	3.97	21.18	17.86	6.26	6.45
UC Southwest Red	8.56	2.08	18.82	24.99	4.65	13.27	11.57	4.04	20.53	19.17	5.93	5.44
Viva	8.14	2.39	22.21	22.04	4.77	15.75	11.89	3.04	21.45	17.44	6.25	6.43

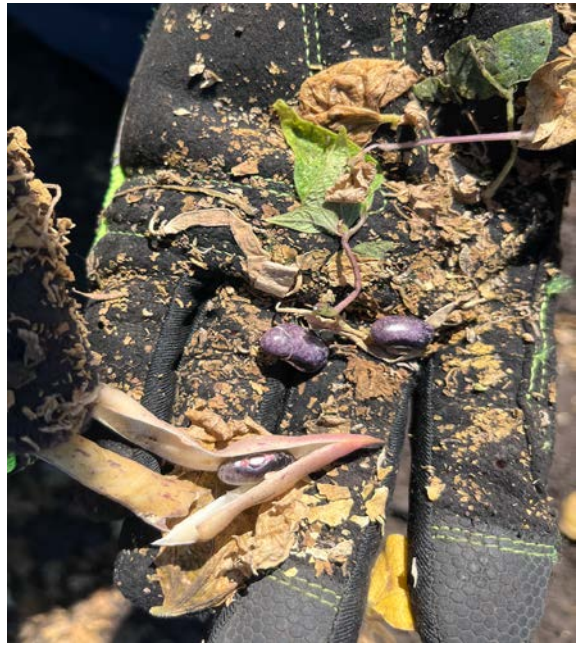
* This genotype did not reach full maturity and thus had too much moisture to measure on the NIRS

Brief mention: digestion method comparisons



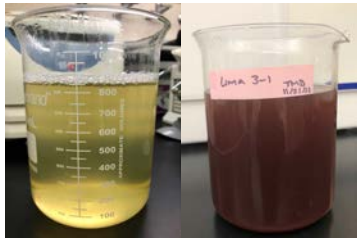
How can this work be applied?

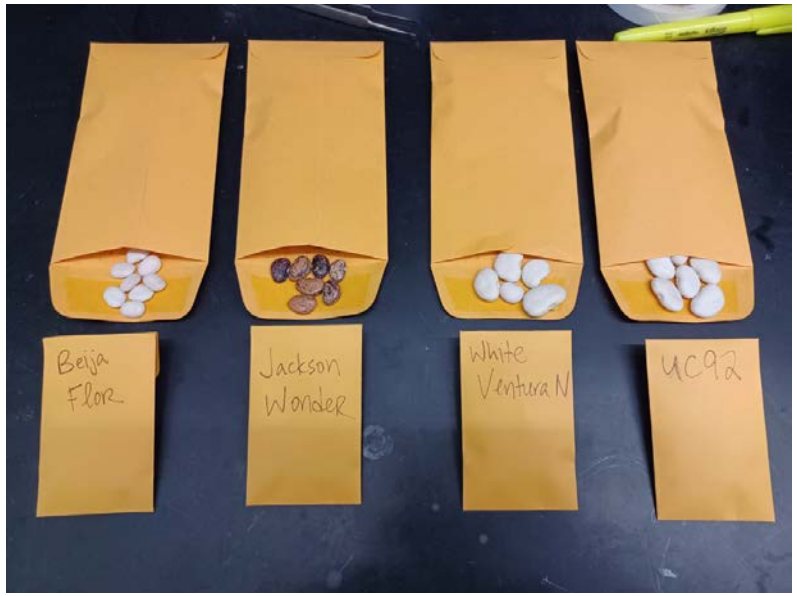
- Breeding for more nutritious beans
- Predicting seed coat patterns based on growing location



What are we doing next?

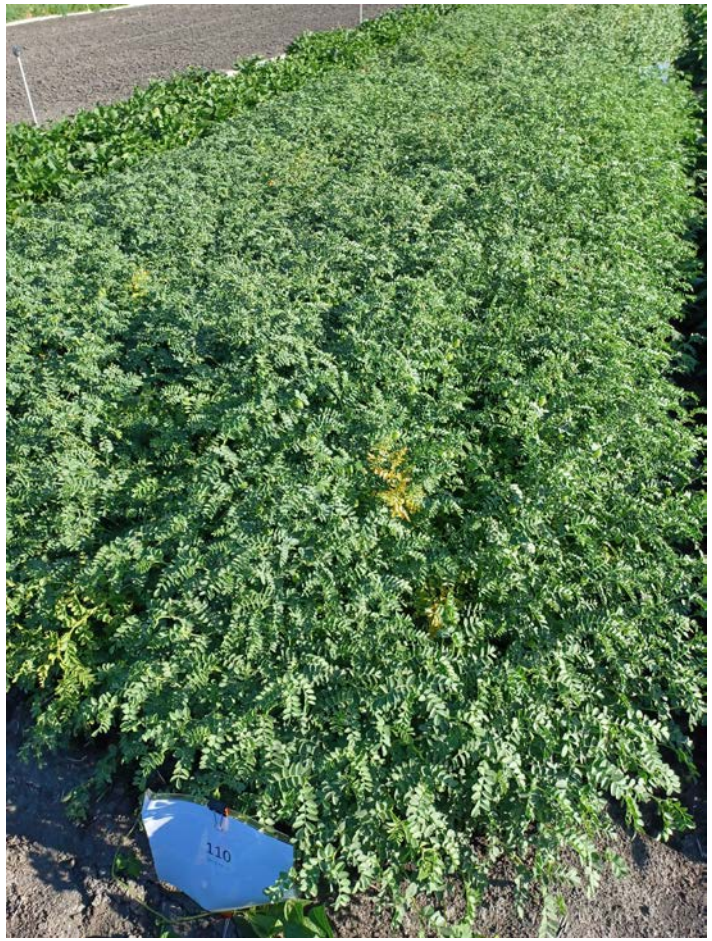
- Small-plot research combine arrived in December!
- Partnering with food scientists for potential product development; also testing canning quality
- New crosses in garbanzo to create early-generation material and start a ‘recurrent selection’ strategy
- Speed breeding in limas to increase the number of cycles per year (and/or produce more seed)





Finally: testing viability of seed increases at the UC Intermountain Research & Extension Center and/or Coachella Valley Ag. Research Station to generate seed for trials in more locations

thanks to Darrin Culp, Rob Wilson, Peggy Maux, and Mike Cardey



Potential ways to interact (namely in the field)

- **UC Dry Bean Field Day** in Davis, co-organized with Michelle Leinfelder-Miles; typically in mid-August, or you are welcome anytime earlier in the year.

AND/OR

- We would be interested in coming to you! Please let Michelle or me know if you produce beans and would be up for a visit by the UCD breeding team.

Thank you!

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