Organic Dry Pea and Lentil Adaptation to South Carolina for Plant-based Protein Production

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USDA NIFA

United States Department of Agriculture
National Institute of Food and Agriculture

Project Team

Research Team:

- Dr. Dil Thavarajah – The PI
- Tristan Lawrence – Project Manager
- Dr. Emersion Shipe – Breeding Pipeline
- Dr. Jon Lucas Boatwright – Bioinformatics Pipeline
- Dr. Pushparajah Thavarajah – Protein Pipeline
- Dr. Nathan Johnson – Postdoctoral
- Cory Tanner – Extension Outreach
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- Sonia Salaria – Doctoral Student
- Mark Dempsey – Doctoral Student
- Adam Kay – Lab Manager
- Richard Baker – Field Assistance
- Nathan Windsor – UPIC Intern
- Lindsey Moroney – Undergraduate intern
- Jacob Johnson - Undergraduate intern

Partnerships

- Meridian Seeds, ND
- Pulse USA, ND
- Walter P Rawl & Sons Inc
- ICARDA, Morocco
- CSI-Spain
- CDC, Canada
- AAFC, Canada
- Carolina Farm Stewardship Association
- The Good Food Institute
- FoodShot Global
- Clearwater Group
- e- Organic

Advisory Board

- Dr. Steve Kresovich – Clemson/Cornell
- Dr. Gerald F. Combs Jr. – USDA-ARS/Cornell
- Dr. Shiv Kumar – ICARDA, India
- Ashley Rawls – WP Rawls & Sons Inc
- Dough Moser – Clearwater Group
- Sara Eckhouse – FoodShot Global
- Dr. Erin Clayton – The GFI
- Dr. Diego Rubialus –CSI - Spain

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Outline

- Plant-based protein market
- Dry pea and lentil
- Stakeholder challenges
- Project long-term goals
- Organic field trials
- Summary results
- Closing remarks

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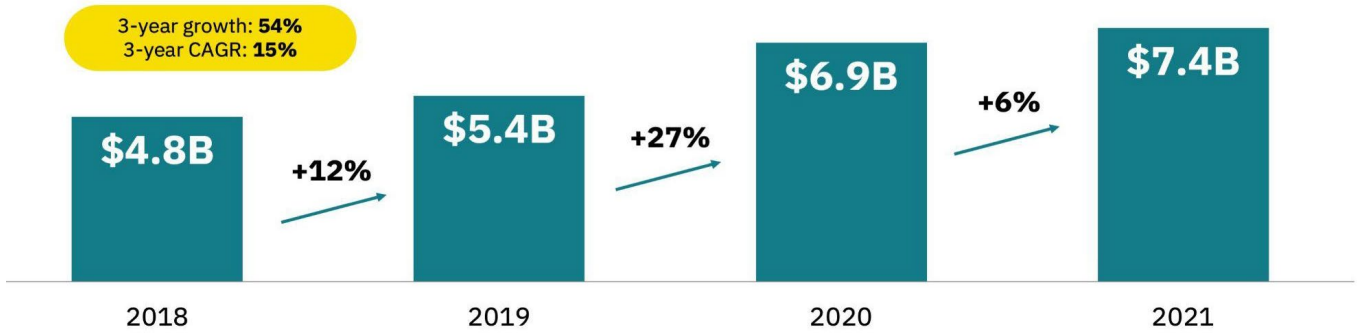
Total US Plant-based Protein Demand – 2018-2021

- Plant-based protein market will increase to $9.5B in 2025
- New choices in the market – “**Beyond Burgers**” and “**Impossible Burgers**”
- Soy protein is the most used, but health implications are conflicting
- Pulse crops (dry peas and lentils) are becoming popular as a non-allergenic gluten-free plant-based protein



Note: The data presented in this graph is based on custom GFI and PBFA plant-based categories that were created by refining standard SPINS categories. Due to the custom nature of these categories, the presented data will not align with standard SPINS categories.

Source: SPINS Natural Enhanced Channel, SPINS Conventional Multi Outlet Channel (powered by IRI) | 52 Weeks Ending 12-26-2021

SPINS

gfi Good Food Institute

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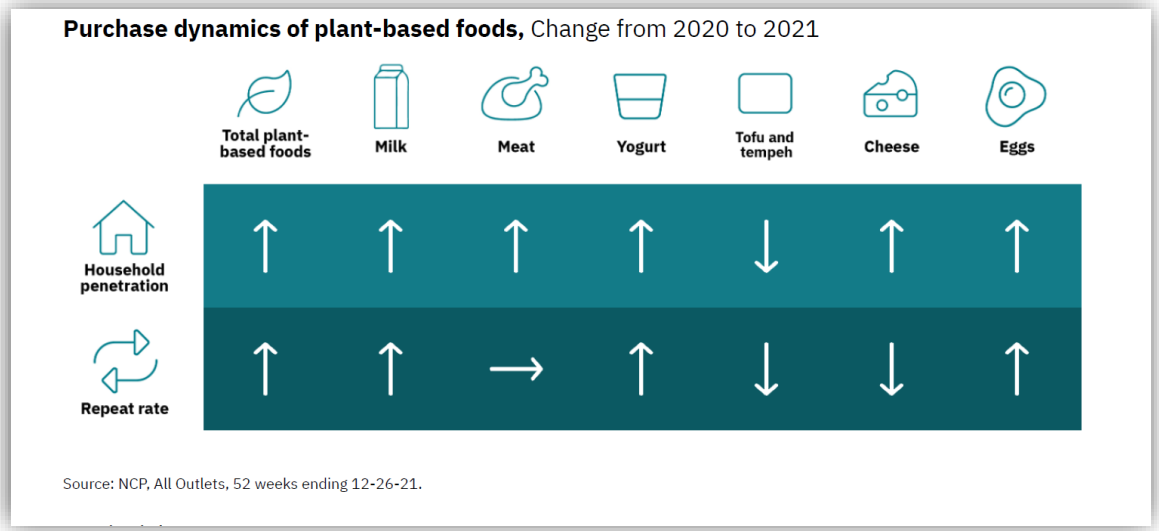
Purchasing Dynamics

- 6 out of 10 American households purchase plant-based foods
- Plant-base milk is a significant entry point, followed by plant-based meat
- 79% of buyers purchased multiple times in 2021
- Pulse crops are an economical nutritionally enriched protein ingredient
- A new opportunity for organic pulse crops



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Dry pea and Lentil

- Organic winter cash crops for SC, fix 40-60 kg N/ha
- Great candidates for organic crop rotations for N and P fertilizer management and soil health
- Consumer nutritional benefits
  - ✓ Rich sources of protein (20-25%)
  - ✓ prebiotic carbohydrates (10-20%)
  - ✓ Low digestible carbohydrates and resistant starch
  - ✓ Micronutrients – minerals and vitamins
  - ✓ Gluten-free, allergens free
- Pulse base diet will reduce malnutrition, obesity, and overweight

Nutrient (per 100 g)	Lentil	Chickpea	Rice	Wheat
Protein (g)	25	20	7	10
Total lipid (g)	1.1	6.0	0.7	2.0
Carbohydrate (by difference, g)	63	63	80	74
Fiber (g)	11	12	1	13
Sugars (g)	2.0	11	0.1	1.0
Iron (mg)	6.5	4.3	0.8	3.7
Potassium (mg)	677	718	115	394
Vitamin C (mg)	4.5	4.0	0.0	0.0
Thiamin (mg)	0.87	0.48	0.07	0.3
Niacin (mg)	2.61	1.54	1.60	5.35
Vitamin B-6 (mg)	0.54	0.54	0.16	0.19
Folate, DFE (µg)	479	557	8	28

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Stakeholder Needs

Organic Production

- Lack of suitable cultivars adapted to the Organic System
- *Misperception* that organic crops have *lower* protein
- Crop management, agronomy, and economic value

Food Processing and Nutrition

- Lack of some essential amino acids
- Proteins are often not fully digestible
- Changes in protein stability and function
- Chemicals, toxins, and pesticides are concentrated during extraction and drying
- ***How can we address these challenges?***

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Protein Quality

- Plant proteins are also harder to digest
- Sulfur-containing amino acids limit protein quality in pulses – Methionine and Cysteine
- Measuring protein quality is <u>not fun</u>
  - ✓ Protein content (N * 6.25) ~ $6-10 /sample
  - ✓ Amino acid profiles ~ $100/sample and 2–3 days per batch -HPLC
  - ✓ Digestibility requires an animal study or an *in vitro* method

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Project Goals (2021-2025)

- ***Long-term goal:*** *The long-term goal is to breed lentil and dry pea cultivars suitable for organic production with higher-quality protein, digestibility, color, texture, aroma, flavor, and better adaptation to protein isolation and blending.*

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ORGANIC LENTIL & FIELD PEA TRIALS

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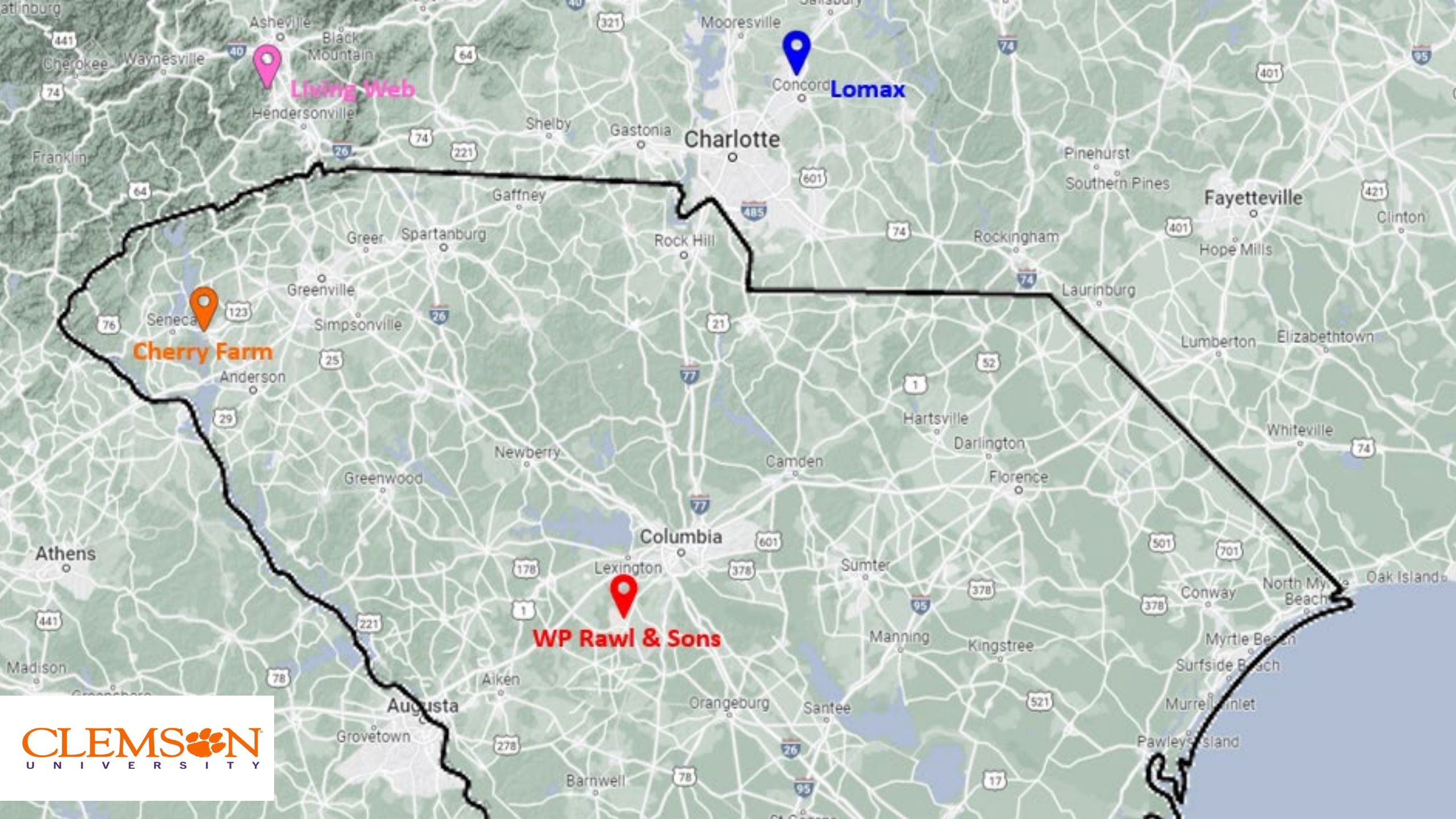

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Growing Conditions
Dry pea

- All locations are USDA-Certified Organic on-farms
- Fields were conventionally tilled using a disc harrow
- Soil samples were taken at 0-6"
- No irrigation was provided
  - WP Rawl and Sons, Pelion, SC; sandy loam
  - Clemson, SC; clay loam soils
- Seeding rates were 90 seeds/m^2
- Using a cone plot planter, cultivars were sown in 1.4×6 m plots (8.4 m^2) containing seven rows spaced 20 cm apart, with a seeding depth of 5-7 cm

Year	Location	Source	Jan	Feb	Mar	Apr	May
2019	**Clemson**	**Temp (°C)**	**6.1**	**10.0**	**10.8**	**16.9**	**23.1**
		Precipitation (in)	**5.5**	**7.6**	**3.5**	**4.6**	**0.76**
	Pelion	**Temp (°C)**	**9.4**	**12.8**	**13.6**	**19.4**	**25.6**
		Precipitation (in)	**3.6**	**1.7**	**2.6**	**4.3**	**2.7**
2020	**Pelion**	**Temp (°C)**	**9.6**	**11.0**	**16.6**	**17.6**	**20.8**
		Precipitation (in)	**2.7**	**6.8**	**3.3**	**3.2**	**9.3**
2022	**Clemson**	**Temp (°C)**	**4.4**	**8.3**	**11.7**	**14.4**	**21.1**
		Precipitation (in)	**4.1**	**4.9**	**6.4**	**4.9**	**3.1**
	Pelion	**Temp (°C)**	**5.8**	**10.8**	**13.6**	**16.4**	**23.1**
		Precipitation (in)	**3.8**	**2.1**	**2.2**	**5.8**	**1.4**

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Growing Conditions – Lentil

Year	Location	Source	Jan	Feb	Mar	Apr	May	June
	Lomax	Temp (°C)	2.8	6.4	10.8	14.7	20.0	24.2
		Precipitation (in)	4.35	2.38	4.54	4.64	3.17	1.77
	Pelion	Temp (°C)	5.8	10.8	13.6	16.4	23.1	-
		Precipitation (in)	3.8	2.1	2.2	5.8	1.4	-

- All locations are USDA-Certified Organic on-farms
- Fields were conventionally tilled using a disc harrow
- Soil samples were taken from at 0-6.”
- No irrigation was provided

Three locations

- WP Rawl & Sons – Pelion, SC
- Lomax – Concord, NC
- Living Web (Organic transition) – Mills River, NC

- Dimensions (L x W): 10’ x 5’ – 50 ft2
- Rows: 7; 7 ½ inch spacing
- Seeding Rate: 130 seeds/m^2
- Spacing: 14” alley

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Field Management: Before Planting

- Disk Harrow – 1 month
- Chisel Plow – 3 weeks
- Cultivate – 2 weeks
- Pre-planting Soil Amendments – 1-4 days
- Cultivate – 1 day

✓ Cultivation is crucial

✓ Stale Bed Fallow

  ✓ Allow weeds to germinate (rain or irrigation) before cultivation

✓ Apply fertilizer/soil amendments at the last cultivation

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Field Management: After Planting

- Interrow Cultivation (Tine Cultivator) – based on-farm
- Cultivate 1-4 times in the first 14 days
  - Controls ~80% of weed pressure
- Cultivate 5-6 times before canopy closure
- Plant – straight and uniform
  - Allows for easy cultivation
  - Lowers risk of damaging plants

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Field Pea – PSP

3/5/22 – Cherry Farm

4/2/22 – Cherry Farm

4/4/22 – Cherry Farm

Lentil – Advanced

3/3/22 – WP Rawl

3/25/22 – WP Rawl

4/15/22 – WP Rawl

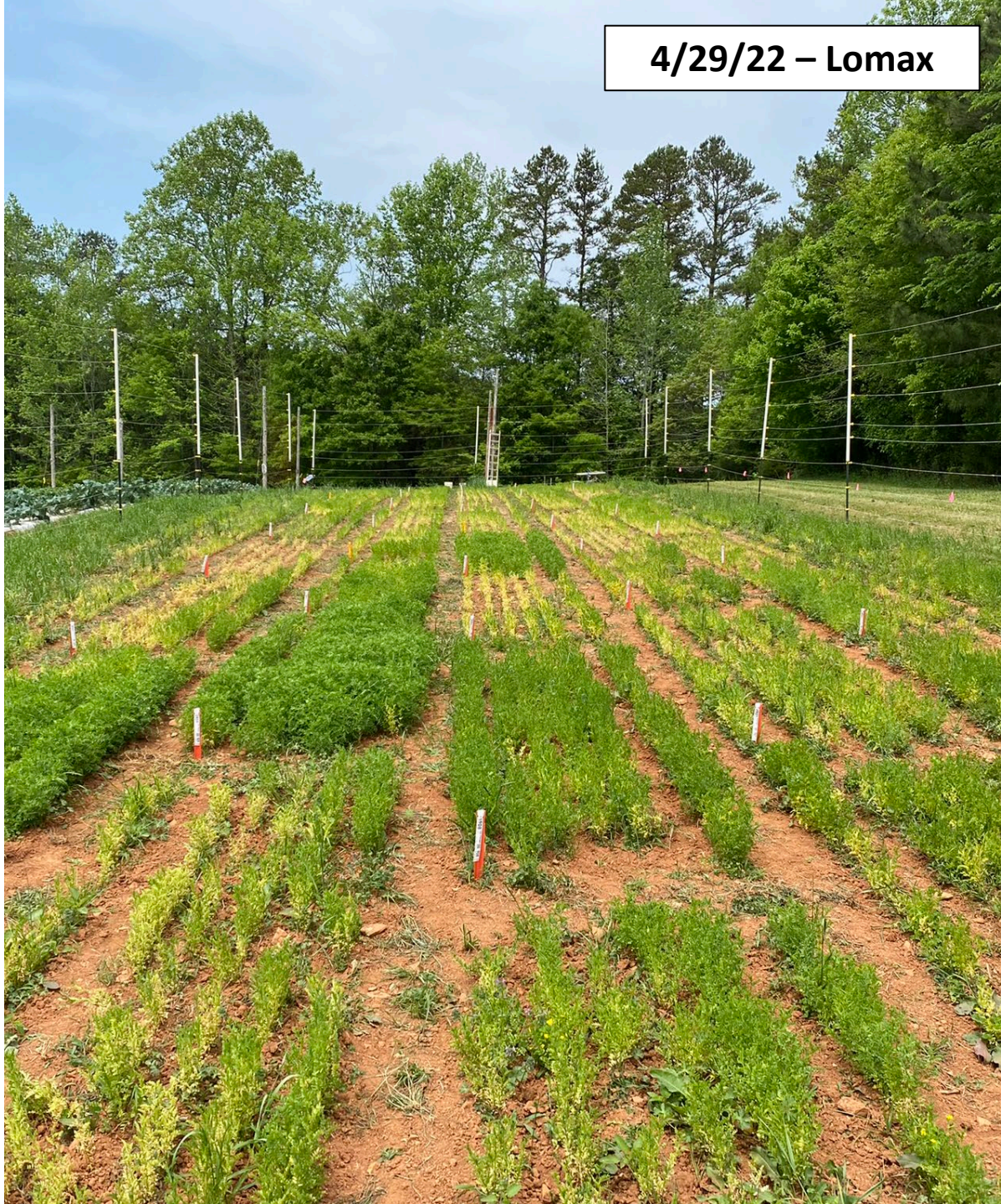
Lentil – LSP

4/15/22 – WP Rawl

5/13/22 – WP Rawl

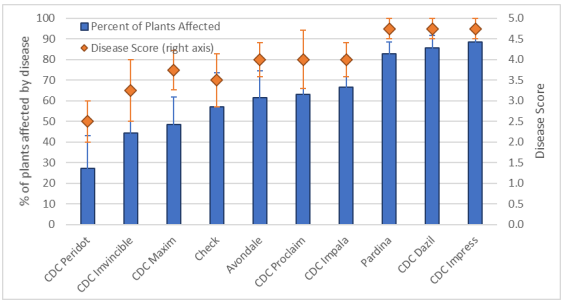
4/20/22 – WP Rawl

Lentil – Advanced



Lomax on-farm trial

- Suspected for Aphanomyces root rot (Aphanomyces euteiches)
- Confirmed for Unspecified pathology (Fusarium sp./spp.)
- Heavy clay wet soils
- ***Recommendations*** – clean field, delay planting, seed treatment, weed management, avoid pulses for 5-10 years



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PLANTING DATE STUDY: 2020-21 & 2021-22

Year 1: 2020-21

Planting Dates: 4
- October 20, 2020
- November 5, 2020
- November 18, 2020
- January 20, 2021

Location: Clemson Organic Farm – Clemson, SC

Entries: 5 – Advanced Cultivars: Late & Early
- Late: AAC Comfort & Flute
- Early: AAC Carver & Banjo
- Control: CDC Inca
- Border: Hampton

Replicates: 3

Year 2: 2021-22

Planting Dates: 4
- October 27, 2021
- November 10, 2021
- November 30, 2021
- February 1, 2022

Locations: WP Rawl & Sons – Pelion, SC

Entries: 5 – Advanced Cultivars: Late & Early
- Late: CDC Greenwater & Flute
- Early: AAC Carver & Banjo
- Control: CDC Inca
- Border: Hampton

Replicates: 3

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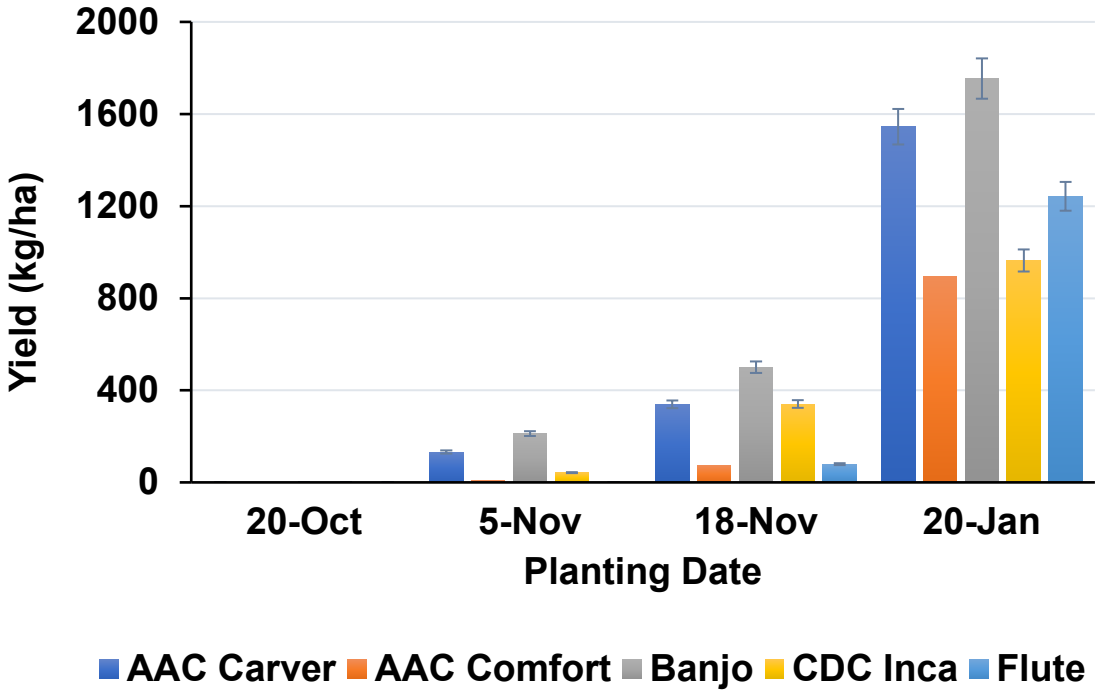
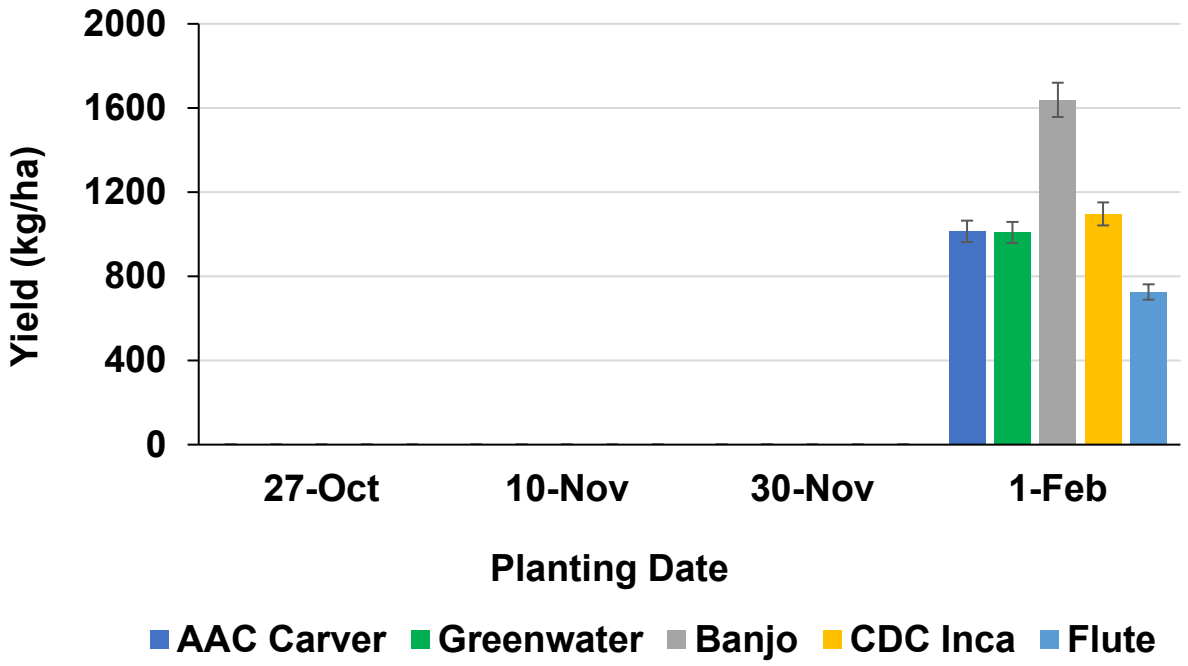
2021-2022: Pelion, SC

Planting Date Study: 2020-21 & 2021-22

Yield Comparison for Dry peas





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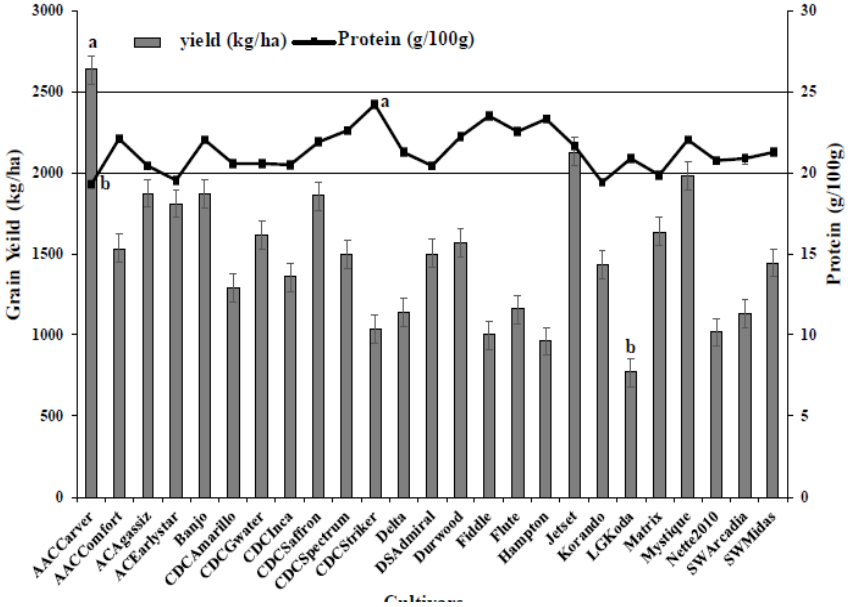
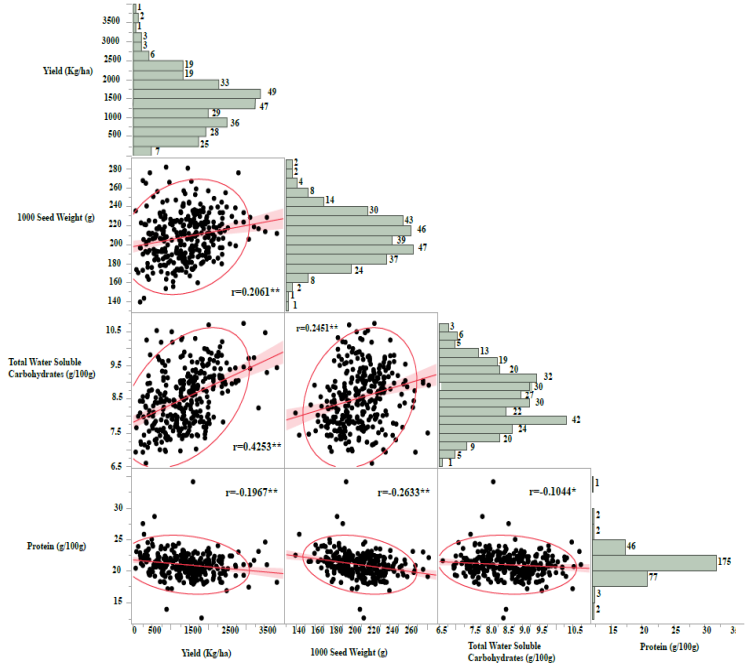
Dry pea

- Average grain yield ranged from 769 to 2638 kg ha^{-1}
- Protein ranged from 12.6 to 34.2 g/100 g
- For both traits show low heritability estimates – 0.21-0.24
- Total prebiotic carbohydrates ranged from 14.7 to 26.6 g/100 g
- Organic dry peas are rich in minerals [iron: 1.9-26.2 mg/100 g; zinc: 1.1-7.5 mg/100 g and have low phytic acid (18.8-516 mg/100 g)
- "AAC Carver," "Jetset," and "Mystique" were the best-adapted cultivars with high yield
- "CDC Striker," "Fiddle," and "Hampton" had the highest protein concentration





Thavarajah D, Lawrence TJ, Powers SE, Kay J, Thavarajah P, Shipe E, et al. (2022) Organic dry pea (Pisum sativum L.) biofortification for better human health. PLoS ONE 17(1): e0261109. https://doi.org/10.1371/journal.pone.0261109

Dry Pea Protein Quality

- Seed total AA and protein for dry pea ranged from 11.8 to 22.2 and 12.6 to 27.6 g/100 g, respectively, with heritability estimates of 0.19 to 0.25.
- *In vitro* protein digestibility and protein digestibility corrected AA score (PDCAAS) ranged from 83 to 95% and 18 to 64, respectively.
- Heritability estimates for individual AAs ranged from 0.08 to 0.42

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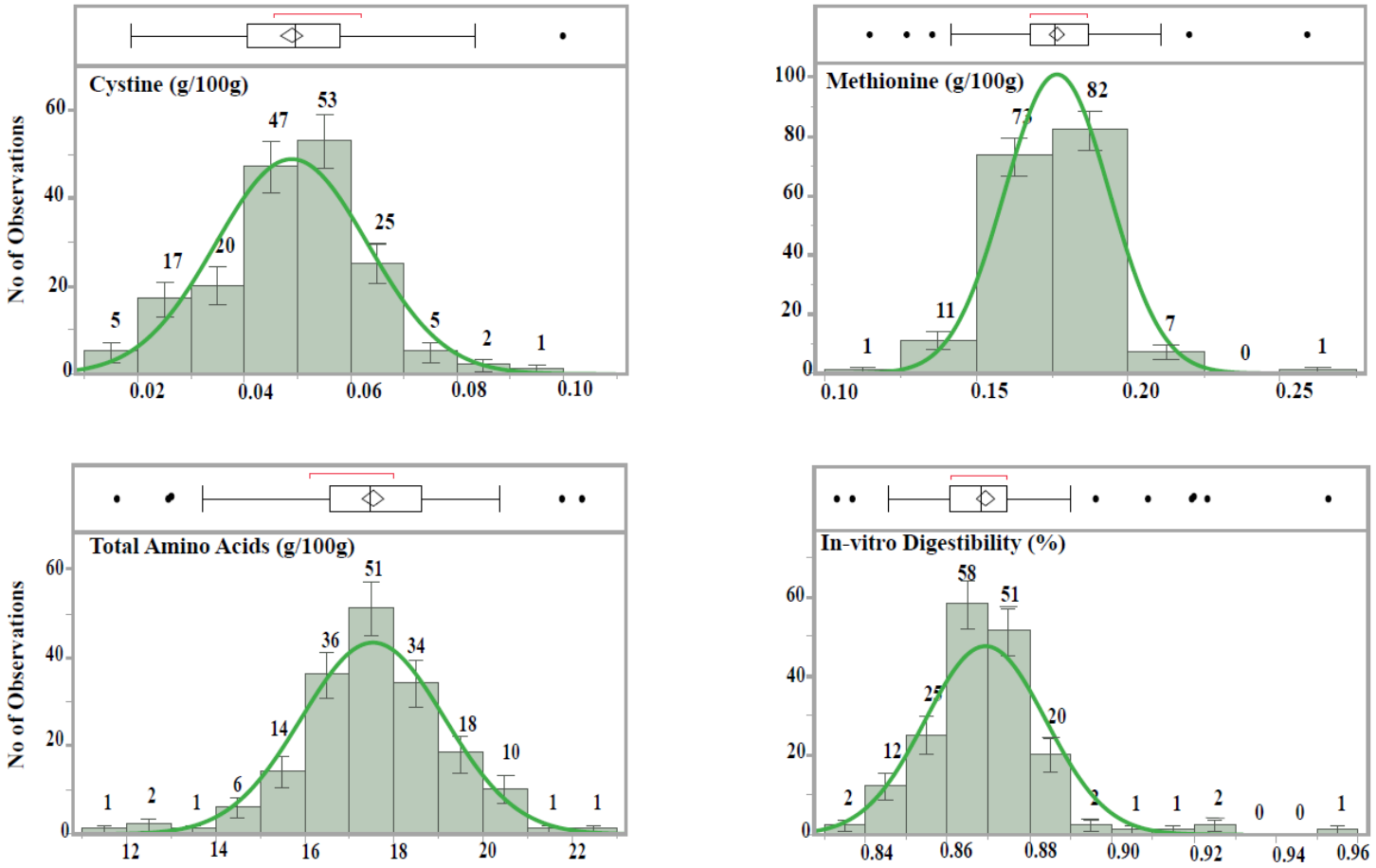
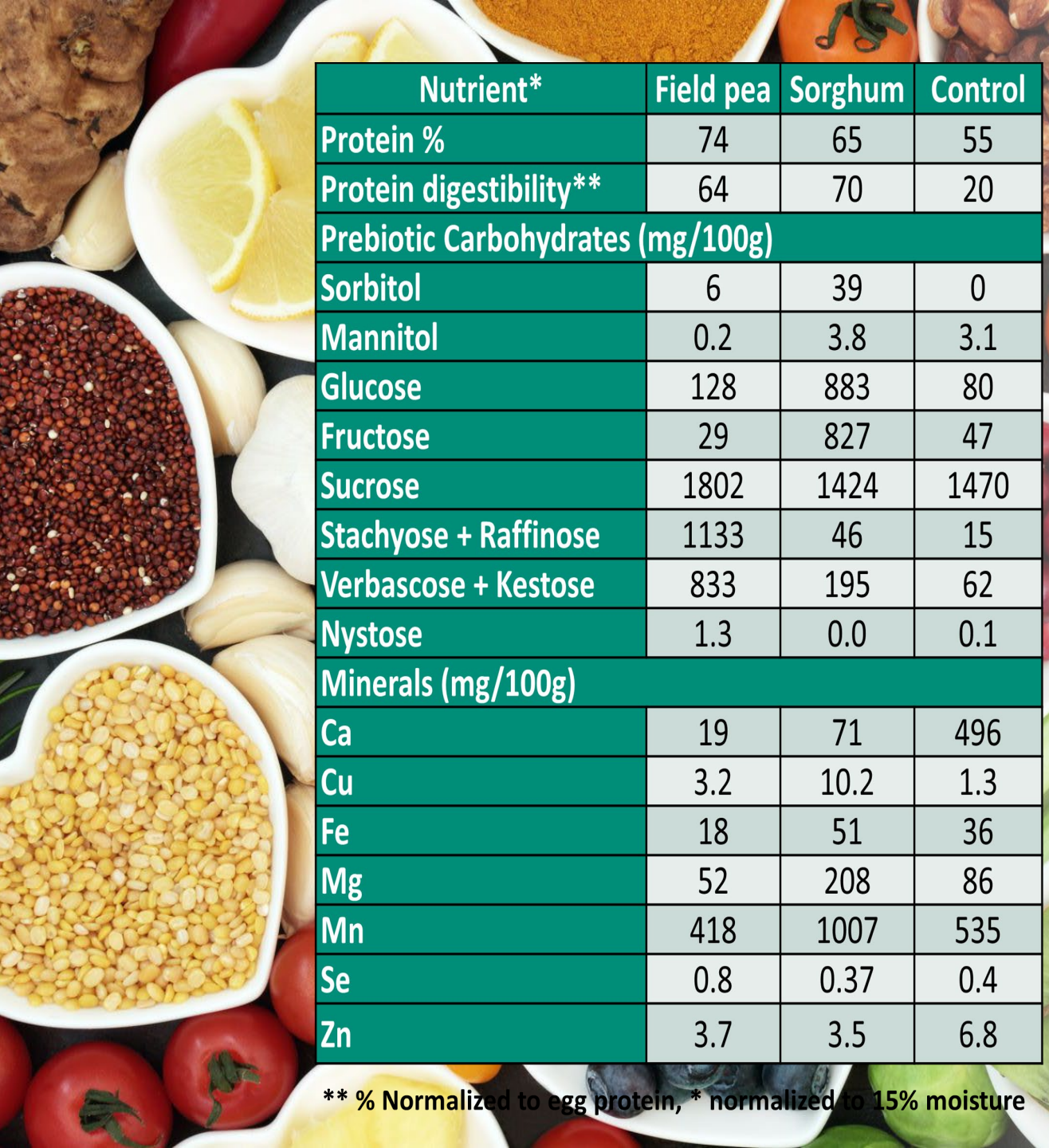
Thavarajah et al., 2022 PLOS ONE- under review



Dry Pea Protein Quality

Thavarajah et al., 2022 PLOS ONE- under review



Nutrient*	Field pea	Sorghum	Control
Protein %	74	65	55
Protein digestibility**	64	70	20
Prebiotic Carbohydrates (mg/100g)			
Sorbitol	6	39	0
Mannitol	0.2	3.8	3.1
Glucose	128	883	80
Fructose	29	827	47
Sucrose	1802	1424	1470
Stachyose + Raffinose	1133	46	15
Verbascose + Kestose	833	195	62
Nystose	1.3	0.0	0.1
Minerals (mg/100g)			
Ca	19	71	496
Cu	3.2	10.2	1.3
Fe	18	51	36
Mg	52	208	86
Mn	418	1007	535
Se	0.8	0.37	0.4
Zn	3.7	3.5	6.8

** % Normalized to egg protein, * normalized to 15% moisture

Organic Pulse Protein Isolates

- A complete and easily digestible
- Enriched with micronutrients
  - Nutritionally superior to anything on the market
  - Gluten-free and non-allergenic
- A protein free of pesticides and chemical residues
  - Sodium
  - Chlorine
- 70-90% organic protein yield
- Better taste and flavor

  - No beany flavor

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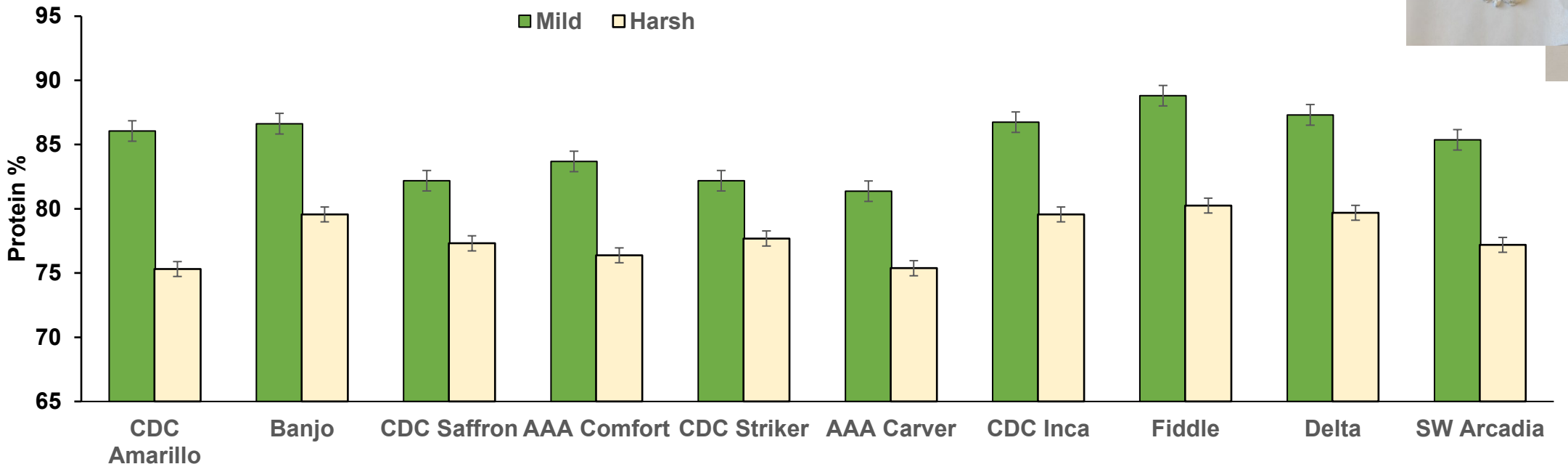
Dil Thavarajah and Pushparajah Thavarajah, **2021**. The United States Patent Application **No.17/512,136**. Filed: October 27, 2021. "Methods of Isolating Plant Protein and Related Compositions." The patent application was published as US20220125071 on April 28, 2022.

Cultivar vs. Organic Protein Isolation



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2022 Lentil Variety Trial - WP Rawl & Sons

Variety	Cotyledon	Source[1]	Days to Flower	Days to Maturity	Vine Length	Total Starch	Seed Protein	1000 Seed Weight	Seed Yield
			DAP[2]	DAP[2]	cm	g/100g	g/100g	g	kg/ha
Avondale	Green, Medium	Pulse USA	87	115	38	31.4	24.2	46	905
CDC Proclaim	Red, Small	Pulse USA	87	113	33	32.6	24.4	39	808
CDC Imvincible	Green, Small	Pulse USA	86	113	31	30.8	25.6	32	788
CDC Maxim	Red, Small	Pulse USA	87	114	33	31.1	23.5	36	758
CDC Peridot	French Green	Pulse USA	86	116	32	32.4	25.5	34	715
Pardina	Brown, Small	WSU-CI	88	114	32	32.7	25.6	36	605
CDC Impala	Red, Extra-Small	Pulse USA	87	113	30	30.6	24.8	28	602
CDC Impress	Green, Medium	Pulse USA	88	114	33	34.8	26.1	43	406
CDC Dazil	Red, Small	Pulse USA	89	116	31	33.5	24.2	31	382
Trial Mean			87	114	33	32	25	35	674
CV						5.6	4.8	3.0	18.0
LSD 5%						2.6	1.7	2	180

[1] *Source*
Pulse USA: Pulse USA, Inc.
WSU-CI: Washington State University Crop Improvement

[2] *Days after planting*

Planted: 2/1/22
Harvested: 6/1/22

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Breeding Pipeline

- Breeding objectives are to develop dry pea cultivars adapted to low-input organic on-farms with increased nutritional quality
- Three breeding cycles are on the way
- 800-1000 F6 breeding populations will be on-farm tested in the 2023 winter
- Two dry pea and lentil protein mapping populations will be field tested in the 2023 winter
- Target traits – yield, plant architecture, short duration, protein quality, prebiotic carbohydrates, and minerals
- Breedbase for breeding management and analysis software https://cupulses.breedbase.org/
- Target dry pea organic cultivar release - 2025

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Closing Remarks

- Organic pulse crop production in SC is feasible
- Field management is critical – before and after planting
- Make sure to add rhizobium and watch for previous cover crop
- Watch for the planting date – not too wet and not too frozen soil
- Disease identification – contact Clemson University diagnostic lab or Montana State University
- **“AAC Carver”** is the best-adapted cultivar with high yield
- **“CDC Striker”** is the best–adapted cultivar for high protein
- Seeds are available from **Meridian** and **Pulse USA**
- Clemson University will be releasing Organic cultivars soon
- Check **CU Pulse Breeding Social Media** for updates
- **Field day is scheduled for April 13, 2023, at WP Rawls Farm**

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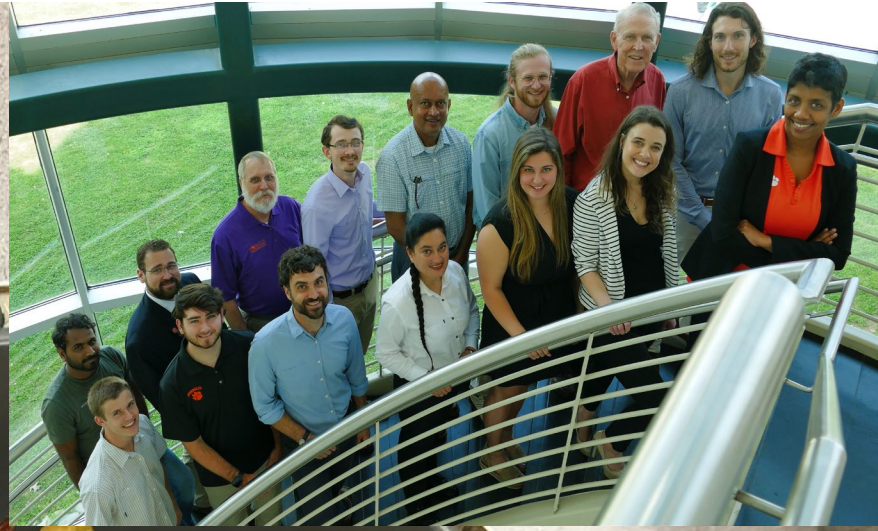
Social Media Outlets



Website

- Update & Redevelopment in progress
- clemson.edu/cafls/organic-breeding/orei/

YouTube

- Channel: 'Clemson Pulse Breeding'
- https://www.youtube.com/channel/UCvfFSQSuo12_tNy7qZFATwg

Twitter

- Handle: @CpulsesBreeding
- https://twitter.com/Cpulsesbreeding

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Funding – Thank you!

1. NIFA-OREI
2. The GFI
3. FoodShot Global Protein Price
4. SC Department of Agriculture
5. USDA-ARS
6. CAFLS, Clemson University, SC

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