College of
AGRICULTURE, FORESTRY
AND LIFE SCIENCES

CLEMSON
UNIVERSITY

USDA NIFA
United States Department of Agriculture
National Institute of Food and Agriculture

Going Organic: Breeding Biofortified Field Pea and Sorghum

Dil Thavarajah, PhD

Associate Professor,

Department of Plant & Environmental Science,

Clemson University, SC, USA

dthavar@Clemson.edu

United States Department of Agriculture
National Institute of Food and Agriculture

Project Team

PD and Co-PD

- **Dr. Dil Thavarajah**: Associate Professor, Pulse Quality and Nutritional Breeding, Department of Plant & Environmental Sciences, 113 BRC Complex, 105 Collings St., Clemson University, Clemson, SC 29634. dthavar@clemson.edu.
- **Dr. Rick Boyles**: Assistant Professor, Cereal Breeding and Genomics, Department of Plant & Environmental Science, Pee Dee Research and Education Center, 2200 Pocket Road, Florence, SC 29506, rboyles@clemson.edu.

CLEMSON UNIVERSITY

Senior Advisory

Stephen Kresovich
Robert and Lois Coker Trustees Endowed Chair of Genetics
Lead Genomic & Translational Experiments
skresov@clemson.edu

Faculty Profile | Group Website
Google Scholar | Research Gate

Rebecca McGee
Pulse Breeder & Research Geneticist (Plants)
Lead Field Pea Breeding
Rebecca.McGee@ars.usda.gov

Emerson Shipe
Emeritus Professor of Agronomy & Plant Breeder
Field Pea Breeding
eshipe@clemson.edu
Research Gate

Shiv Kumar Agrawal
Pulse Breeder at The International Center for Agricultural Research in the Dry Areas (ICARDA)
Field Pea Breeding
SK.Agrawal@cgiar.org
Research Gate

Students

Sarah Powers
PhD Student
Field Pea
spower2@g.clemson.edu

AJ Ackerman
PhD Student
Sorghum
arlyna@g.clemson.edu

Nathan Johnson
PhD Student
Field Pea
njohns9@g.clemson.edu

Boone Jones
Undergraduate
Field Pea
boonej@g.clemson.edu

Field & Lab Team

Brad Stancil
Director of SC Crop Improvement Association &
SC OVT Coordinator
Lead/Facilitate Planting, Production & Harvest
bstanci@clemson.edu
Crop Improvement Page | OVT Website

David Robb
Clemson Organic Farm Manager
Manage & Maintain Fields
drobb@g.clemson.edu

Tristan Lawrence
Research Associate & Field Technician
Manage & Evaluate Field Pea Trials
Website Administrator
tjlawre@clemson.edu

Adam Kay
Laboratory Technician
Quality Assessment
jakay@g.clemson.edu

Ryan Holmes
Ag Research Associate
rholmes@clemson.edu

William Caughman
Ag Research Associate
caughm2@g.clemson.edu

College of
AGRICULTURE, FORESTRY AND LIFE SCIENCES

Advisory Committee Members

Todd Scholz
USA Dry Pea & Lentil Council -Vice President of Research & Member Services

Gerald F. Combs, Jr
Senior Scientist, Jean Mayer USDA Human Nutrition Research Center on Aging, Tufts University
Professor of NutritionEmeritus, Cornell University
Program Website

Glenn Roberts
President & CEO, Anson Mills, LLC
President, The Carolina Gold Rice Foundation

Collaborators

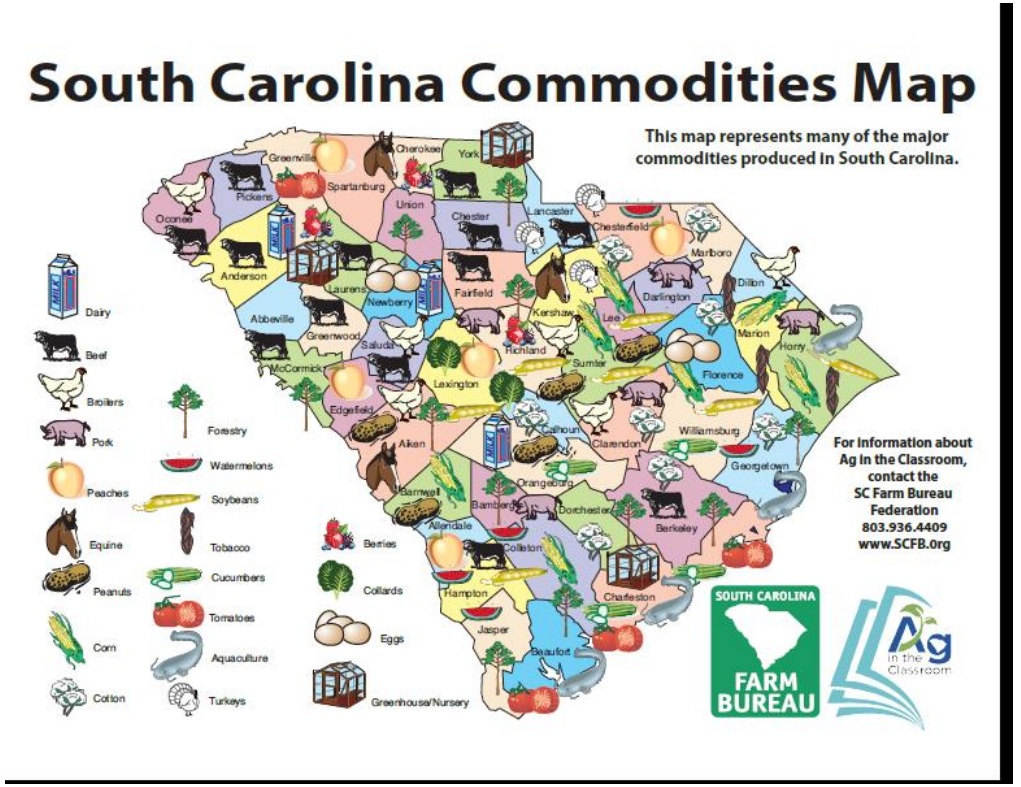
Tony Melton
Area County Extension Agent
Oversee On-Farm Extension Education Activities
AMELTON@clemson.edu

Denise Attaway
PSA Communications
Oversee Extension Education & Communication Activities
avaa@clemson.edu

Critical Need(s) of Organic Agriculture

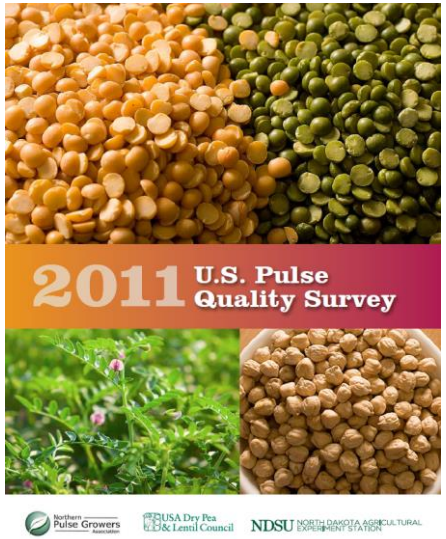
College of AGRICULTURE, FORESTRY AND LIFE SCIENCES

- Organic agriculture defines as "***an ecological production management system that promotes and enhances biodiversity, biological cycles, and soil biological activity***" (USDA, 1995)
- Pulse – cereal crop rotation provides the benefits - biological N fixation, P benefit, enhanced biodiversity, and healthy food system
- South Carolina is home to 25,000 farms totaling 4.9 million acres
- Increasing crop production costs and decreasing commodity prices have resulted in our growers exploring options
- Cool-season food legumes (pulse crops – field pea) and traditional cereals such as sorghum fits into existing cropping systems in SC



Critical Stakeholder Needs

1. **Production system**: breeding and selection for organic cropping systems
2. **Nutritional quality and grading**: 20-30% of protein for pulses and 10-14% for cereals
3. **Marketing and trade**: the organic grain market remains small, a limited number of buyers
4. **Current public research availability**: limited large data sets on organic pulse and cereal production, variety development, nutritional quality, and end-use as a whole food or an ingredient.



College of AGRICULTURE, FORESTRY AND LIFE SCIENCES

Food System

- ***Nutritional Breeding*** *– "A greener revolution that will provide not just more food but more nutritious food, ending reliance on the supplements, and food fortification programs*

- ***Biofortification***
  - *Make human health as a clear goal*
  - *Improve yields with nutritional quality*
  - *Increase access to healthy foods*
  - *Food utilization – cooking*
  - *True nutrient bioavailability*
  - *Education: nutrition - family health*

- ***Improved health can be addressed by changing the paradigm for Agriculture***

College of AGRICULTURE, FORESTRY AND LIFE SCIENCES

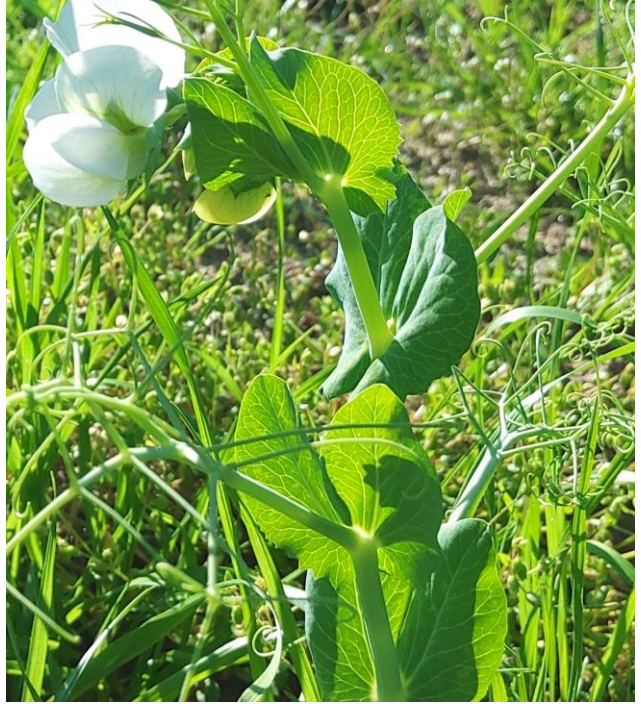
Project Goals

Long-term goal: Develop biofortified organic field pea and sorghum cultivars for organic cropping systems

- ✓ Grain yield and agronomic adaptability
- ✓ Nutritional quality
- ✓ Genomic and bioinformatic tools
- ✓ On-farm education
- ✓ Consumer education

College of
AGRICULTURE, FORESTRY
AND LIFE SCIENCES

Field Pea - *Pisum sativum* L.



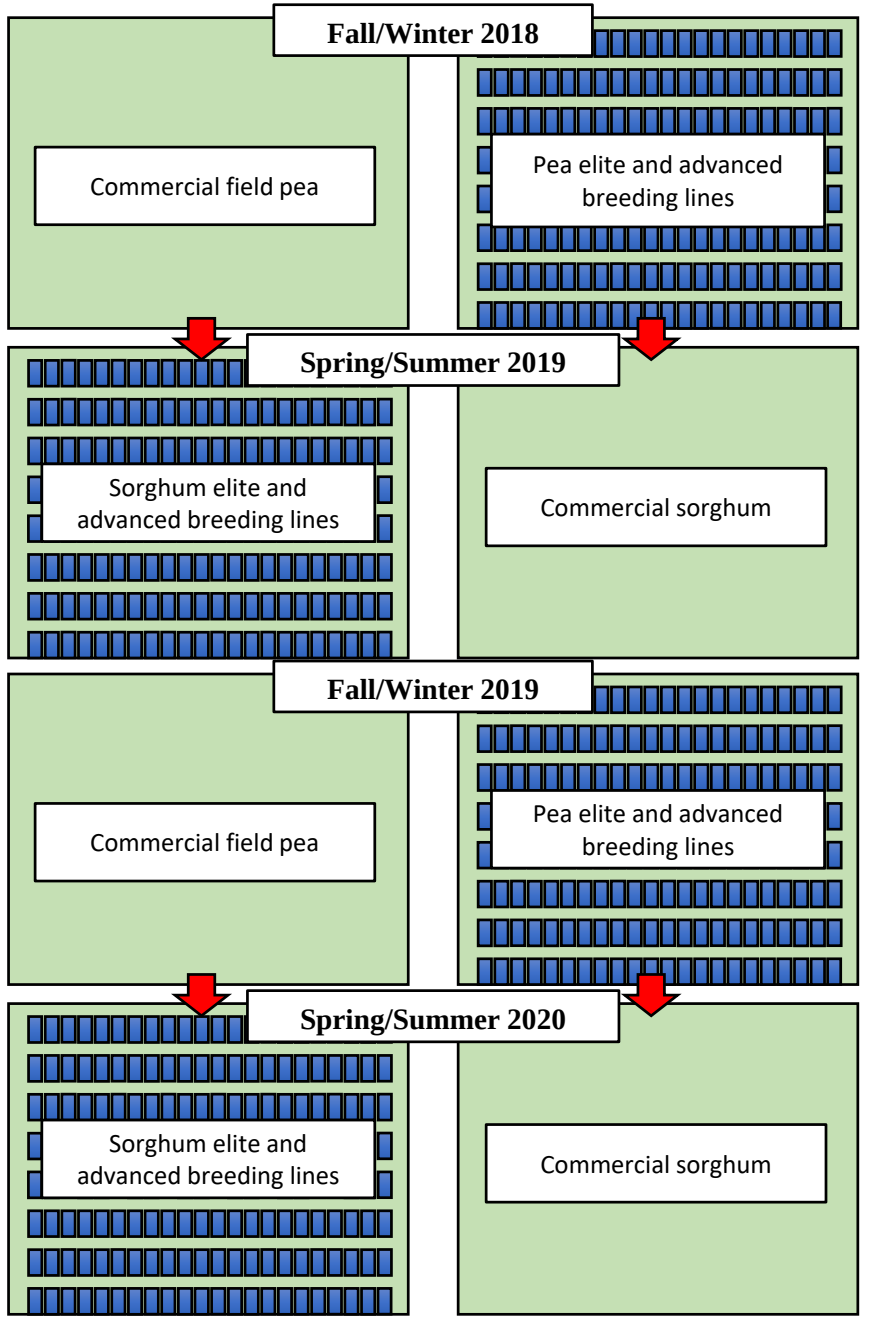
Pea - *Pisum sativum* L.

- Peas are grown and consumes as either fresh or dry seed
- Edible legume or pulse crop – one of the oldest cultivated plants (7000-6000 B.C.)
- Diploid with a chromosome number of x=7
- Two species within the genus – *P. arvense* (colored flower) and *P. sativum* (white flower)
- Two classes of cultivars - garden and field pea
- Different growth habits – determinant and indeterminant
- Annual or winter annual herbaceous plant

College of
AGRICULTURE, FORESTRY
AND LIFE SCIENCES

Experimental Design

Year (location)	**2019 (Clemson; Pelion), 2020 (Pelion)**
Location	Clemson, SC; Pelion SC
Replicates (Year)	2 (2019); 3(2020)
Cultivars/ Breeding lines	**Cultivars (25):** AAC Carver, AAC Comfort, AC Agassiz, AC Earlystar, Banjo, CDC Amarillo, CDC Gwater, CDC Inca, CDC Saffron, CDC Spectrum, CDC Striker, Delta, DS Admiral, Durwood, Fiddle, Flute, Hampton, Jetset, Korando, LG Koda, Matrix, Mystique, Nette 2010, SW Arcadia, SW Midas **Breeding lines (19):** PS01100925, PS03101445, PS05100735, PS08100582, PS08101004, PS08101022, PS12100047, PS14100079, PS1410B0003, PS1410B0006, PS1410B0065, PS1410B0073, PS1514B0002, PS16100003, PS16100038, PS16100085, PS16100086, PS16100096, PS16100127
Total	**308**



College of AGRICULTURE, FORESTRY AND LIFE SCIENCES

Growing Conditions

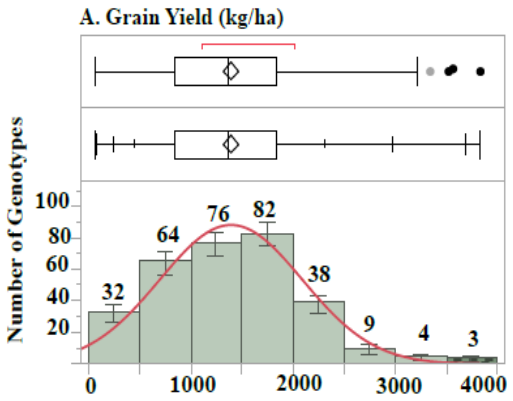
Field Preparation

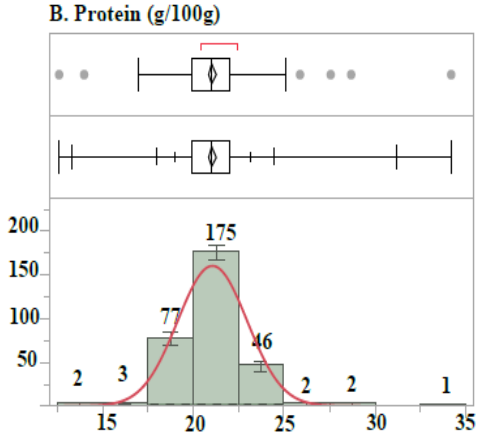
- All field locations are USDA Certified Organic
- Fields were conventionally tilled using a disc harrow
- Each field plot was marked (barcoded)
- Soil samples were taken from each location at 0-6"
- No irrigation was provided
  - WP Rawl and Sons, Pelion, SC; sandy loam soils
  - Clemson, SC; clay loam 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 7 rows spaced 20 cm apart, with a seeding depth of 5-7 cm
- A conventional grain drill was used for “Hampton” with a row spacing of 15.2 cm and a seeding depth of 5-7 cm

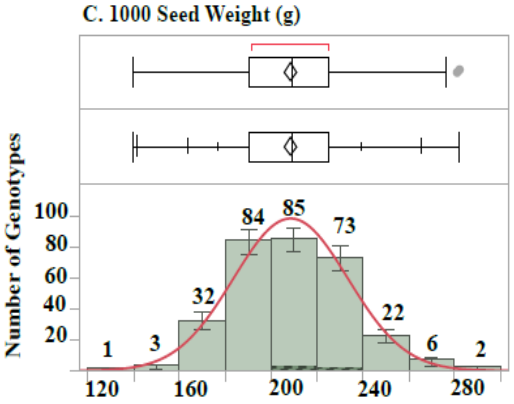
College of AGRICULTURE, FORESTRY AND LIFE SCIENCES

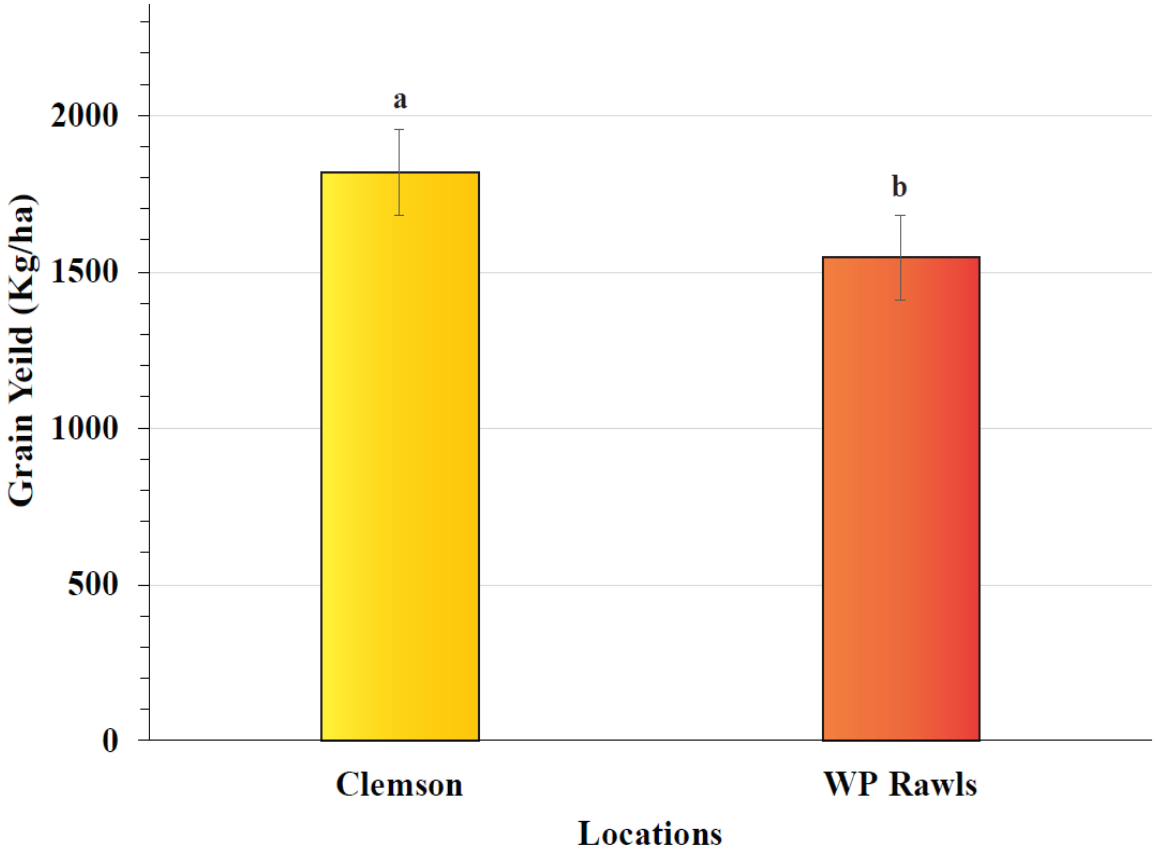
Year	Location	Source	Jan	Feb	Mar	Apr	May
2019	Clemson	Temp (°C)	6.1	10.0	10.8	16.9	23.1
		Precipitation (in)	5.5	7.6	3.5	4.6	0.76
	Pelion	Temp (°C)	9.4	12.8	13.6	19.4	25.6
		Precipitation (in)	3.6	1.7	2.6	4.3	2.7
2020	Pelion	Temp (°C)	9.6	11.0	16.6	17.6	20.8
		Precipitation (in)	2.7	6.8	3.3	3.2	9.3

Distribution of (A) grain yield, (B) protein, and (C) 1000 seed weight among the genotypes









Protein and Prebiotic Carbohydrates

Nutrient	Organic		Conventional Range (Mean)
	Range	Mean	
Protein (g/100g)	12.6-34.2	21.1	15.6-28.3 (23.1)
% RDA of protein (women – age 10-70+)	27.4-74.3	45.9	33.9-61.5 (50.2)
% RDA of protein (men – age 19-70+)	22.5-61.1	37.7	27.9-50.5 (41.3)
Sugar Alcohols (mg/100g)			
Myo-Inositol	98-399	244	
Xylitol	2.5-31.7	15.7	
Galactinol	91.3-425	163	
Sorbitol	8.4-115	34.9	
Mannitol	0.9-23.8	5.9	
Simple Sugars (mg/100g)			
Glucose	14.6-137	62	330-650 (440)
Fructose	1.7-30.7	6.4	
Sucrose	1530-3043	2156	1850-3620 (2590)
Arabinose	3.3-13.1	7.2	
Maltose	2.1-289	26.3	
RFO and FOS (mg/100g)			
Sta+Raf	2111-4077	3128	
Ver+Kes	1548-3929	2688	
Nystose	1.6-9.1	3.4	
Starch Polysaccharides (g/100g)			
Resistant starch	5.6-18.0	12.2	5-10
Soluble starch	10.0-68	43.4	-
Total starch	17.0-76	52.9	41.1- 46.3 (42.2)
Total prebiotic carbohydrates (g/100g)	14.7-26.6	20.7	10-25 (20.5)
% RDA of prebiotic carbohydrates	73.5-133	103.5	70-130

College of
AGRICULTURE, FORESTRY
AND LIFE SCIENCES

Minerals and Phytic acid

College of AGRICULTURE, FORESTRY AND LIFE SCIENCES

Accession	Yield (kg/ha)	Ca (mg/100g)	Fe (mg/100g)	K (mg/100g)	Mg (mg/100g)	P (mg/100g)	Zn (mg/100g)	PA (mg/100g)
AAC Carver*	2149.9	57.2	3.1	588.7	86.6	232.9	1.8	107.7
AAC Comfort	1655.8	72.7	6.1	1113.5	111.1	360.9	3.5	143.4
AC Agassiz	1781.8	82.6	5.3	958.6	126.2	342.6	3.2	170.5
AC Earlystar	1793.6	83.9	6.8	1121.5	133.0	412.5	3.4	199.2
Banjo	1661.3	116.1	7.1	1200.2	141.4	431.9	3.5	166.6
CDC Amarillo	1303.0	86.8	5.0	909.1	133.5	387.6	3.0	190.4
CDC Inca	1736.5	87.6	4.6	852.4	123.2	331.3	2.9	147.2
CDC Saffron	1841.9	89.6	5.5	1003.2	137.8	396.2	3.0	165.7
CDC Spectrum	1571.4	79.4	5.9	1032.3	115.0	376.6	3.7	140.1
CDC Striker	938.4	93.0	5.8	1068.6	127.4	388.3	3.1	172.9
Delta	1357.6	80.0	6.8	1094.1	125.7	392.8	2.8	153.8
DS Admiral	1441.0	75.6	5.8	939.3	136.7	394.1	3.6	209.8
Durwood	1733.8	58.3	4.1	733.0	100.8	293.1	2.7	175.4
Fiddle	1002.8	130.5	7.4	1204.7	137.1	442.6	3.5	147.7
Flute	1318.6	77.2	6.0	1096.3	125.5	383.4	3.2	320.3
Hampton	1116.6	117.7	5.4	1005.8	120.2	390.1	3.1	123.8
Jetset	1999.9	105.2	6.2	1109.1	122.1	389.8	3.3	225.5
Korando	1559.2	114.1	5.6	916.5	126.0	319.7	2.9	179.0
LG Koda	1113.3	81.3	4.4	943.7	118.9	369.6	2.8	143.2
Matrix*	1335.5	106.6	5.6	870.9	116.7	326.6	3.0	155.7
Mystique	1886.8	97.3	6.2	948.2	130.0	377.1	3.5	140.8
Nette 2010	1036.7	106.0	6.4	1106.5	140.6	408.8	3.3	166.7
SW Arcadia	1317.3	87.4	6.3	1147.1	121.1	355.4	3.2	162.5
SW Midas	1162.0	85.7	5.2	993.9	105.7	381.9	2.8	199.5

Promising Cultivars

2019

Variety	Cotyledon	Source[1]	Days to Flower	Days to Maturity	Canopy Height	Resistant Starch	Total Starch	Seed Protein	1000 Seed Weight	Seed Yield
			DAP[2]	DAP[2]	cm	g/100g	g/100g	g/100g	g	kg/ha
CDC Inca	Yellow	Meridian	72	111	69	13	53	20	217	2480.5
AAC Carver	Yellow	Meridian	68	107	60	14	49	18	220	2122.2
AAC Comfort	Green	Meridian	77	111	51	14	52	19	257	2069.6
PS16100085	Yellow	USDA	70	111	51	16	53	18	237	2049.0
Durwood	Yellow	Pulse USA	70	112	69	12	49	20	235	2048.5
CDC Spectrum	Yellow	Meridian	75	111	49	15	55	18	219	1965.7
AC Earlystar	Yellow	Meridian	69	108	62	14	51	19	212	1938.4

2020

Variety	Cotyledon	Source[1]	Days to Flower	Days to Maturity	Canopy Height	Resistant Starch	Total Starch	Seed Protein	1000 Seed Weight	Seed Yield
			DAP[2]	DAP[2]	cm	g/100g	g/100g	g/100g	g	kg/ha
PS17100022	Yellow	USDA	68	102	68	15.2	45.3	19.3	224	1973
AAC Carver	Yellow	Meridian	67	102	56	15.5	50.0	20.7	192	1946
LG Sunrise	Yellow	Pulse USA	63	103	62	15.2	54.1	19.8	224	1789
AC Agassiz	Yellow	Meridian	68	103	54	15.2	53.2	19.8	189	1744
DL Apollo	Yellow	Pulse USA	68	103	64	16.5	58.9	20.3	191	1584
Matrix	Green	Pulse USA	72	103	50	14.4	58.2	20.4	196	1525
Jetset	Yellow	Meridian	63	101	52	15.5	46.6	20.6	193	1519
CDC Inca	Yellow	Meridian	68	103	61	14.1	46.7	21.0	177	1511

Going Forward....

- Organic pea production is possible in SC
- Elite cultivars, advanced breeding lines, the USDA Pea Single Plant plus Collection will be tested on-farm locations
- The highest yielding entries and PI lines incorporated into the breeding pipeline
- Along with phenotypic characterizations, marker-trait associations will be identified via GWAS
- Planting date studies are on-going
- Nurseries are planted for selection in the on-farm location in SC

College of AGRICULTURE, FORESTRY AND LIFE SCIENCES

Acknowledgements

- Pulse Quality and Breeding lab team
- Sorghum Genetics and Breeding team
- CU Advanced Plant Technology
- PES, CAFLS, Clemson University
- WP Rawls and Sons, Pelion, SC
- ICARDA, Morocco
- Meridian Seed
- Pulse USA
- Dr. Tom Warkentin, Crop Development Centre, Saskatchewan, Canada
- Dr. Dengjin Bing, AAFC/AAC, Alberta, Canada
- USDA-ARS, WSU
- SC Department of Agriculture
- NIFA – OREI
- GFI
- USAID Feed the Future Innovation