SORGHUM, A KEY TO BUILD OUR FUTURE.

CAMPAIGN FINANCED
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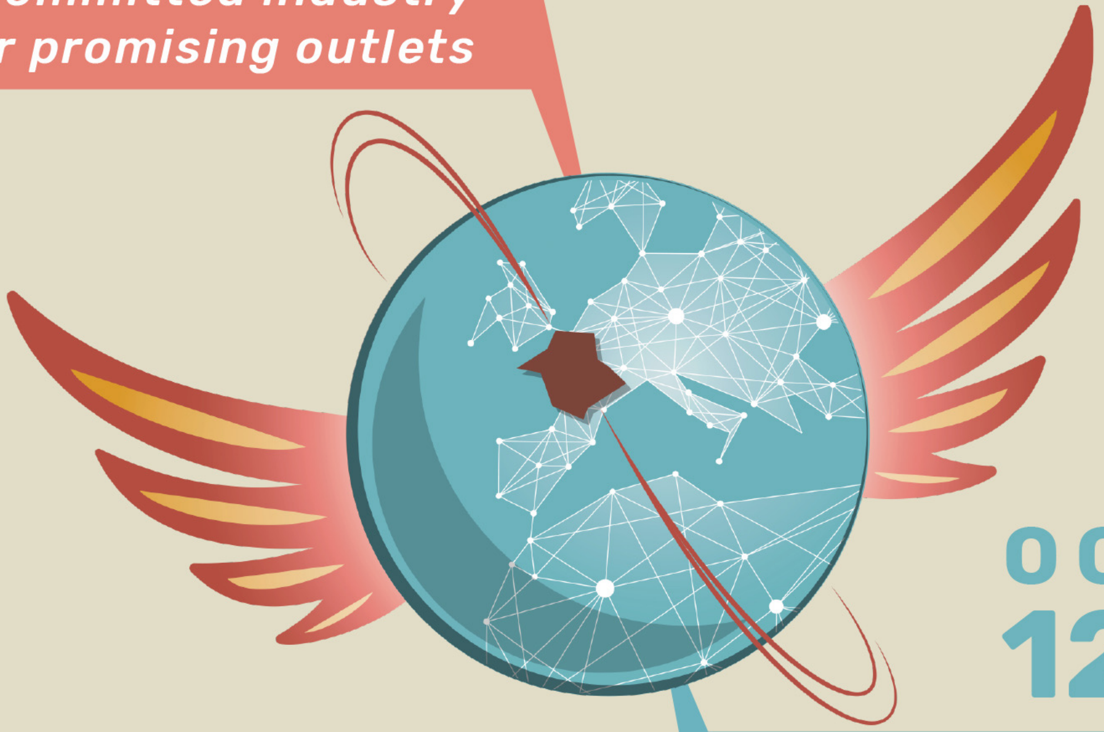
SEEDS FROM EUROPE

SORGHUM,
A KEY TO BUILD
OUR FUTURE.

3RD EUROPEAN SORGHUM CONGRESS

THE SORGHUM

*A committed industry
for promising outlets*



OCTOBER
12TH & 13TH

TOULOUSE
2021

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Breeding tools and traits for hybrid sorghum hybrid improvement.

William L. Rooney
Texas A&M University

Breeding programs adapt

Genomics/Phenomics

Improved Statistical Models

Bioinformatics

Machine Learning

Winter Nurseries

Plot Equipment

Computers

Traditional breeding schemes must change to adopt these technologies.

Sorghum is no different

What moves sorghum methodology?

1. Temporal Male Sterility Induction - TFMSA
2. Haploid Induction or Generation Advancement
   - Inducers at reasonable frequency
   - Phenotypic markers to identify Haploids
   - Methods to double chromosomes
3. Genomic Selection/Phenotyping
4. Traits to Add Value to Production/End Use
   - Specialty Food Sorghum "Onyx"
   - Herbicide Resistance
5. Mitigating Gene Flow

P1 x P2 → F1 → F2 → F3 → F4 → Phase I Hybrids

P1 x P2 → F1 x Inducer → Haploids, → DH Lines

TFMSA

Trifluoromethanesulfonamide

- maize (Loussaert, 2004, Sexual Plant Reproduction)
- sorghum (Hodnett and Rooney, 2018 Can. J. Plant Sci.)
  - Temporal induction of male sterility
  - No effect on female fertility
- suspected to interfere in transport of the amino acid proline to the anther
- Application
  - Breeding Crosses/Backcrossing
  - Testcrossing for Hybrid Evaluation
  - Seed Production?

Treatment	Selfed Seed Set %	Controlled Pollination g/panicle	Open pollination g/panicle	Days to anthesis d	Plant height cm
G-lines	0.1 a	13.7 a	13.0 b	80.5 b	93 b
A-lines	0.1 a	19.4 b	22.3 a	77.5 a	110 a
B-lines	100.0 b		20.4 a	77.3 a	106 a

- Kyanam and Rooney (2021, Crop Sci.)
- TFMSA treatment of inbreds
  - Induces male sterility like CMS
  - Delays anthesis ~3 days
  - Reduces plant height ~ 15 cm
  - Lowers seed yield ~30%
- G-LINE- or A-LINE Hybrids essentially equal

TFMSA is at inducing temporal male sterility in most sorghum genotypes

Experimental use - there is NO label for commercial use.

Sterility System	Self Progeny	Days to Anthesis	Plant Height	Test Weight	Monte Alto	Taft	College Station
	%	days	cm	kg hL^{-1}	kg/ha	kg/ha	kg/ha
A-lines	0.67^{A}	77^{A}	138^{A}	42.7^{A}	$2,584^{A}$	$6,899^{A}$	$7,318^{A}$
G-lines	0.71^{A}	77^{A}	136^{B}	43.1^{A}	$2,753^{A}$	$6,763^{A}$	$7,276^{A}$

Haploids in Sorghum

- Induction via *S. bicolor, S. halepense*
  - Low Induction rate (< 2%)
  - No seed/seedling phenotypic markers
  - Methods to double chromosomes
- Greenhouse phenotyping is more efficient than field
- TFMSA makes system possible
- Current focus
  - Increasing induction frequency
  - Integrating seedling phenotypinc markers into inducers

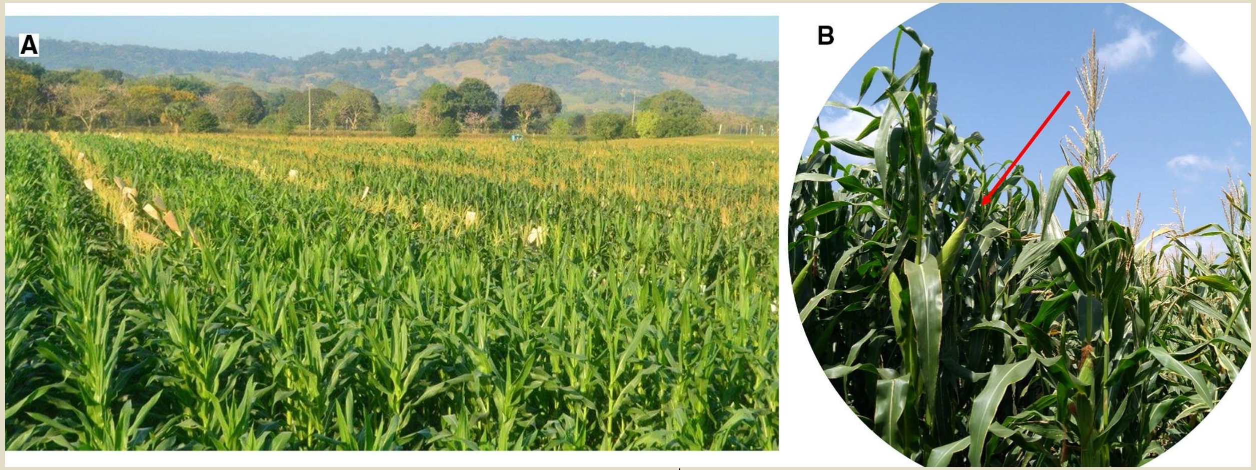
P1 x P2

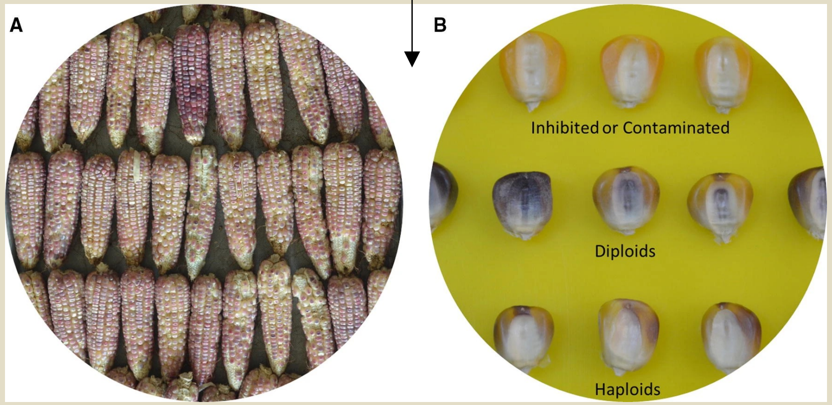
↓

F1 x Inducer

↓ Haploids

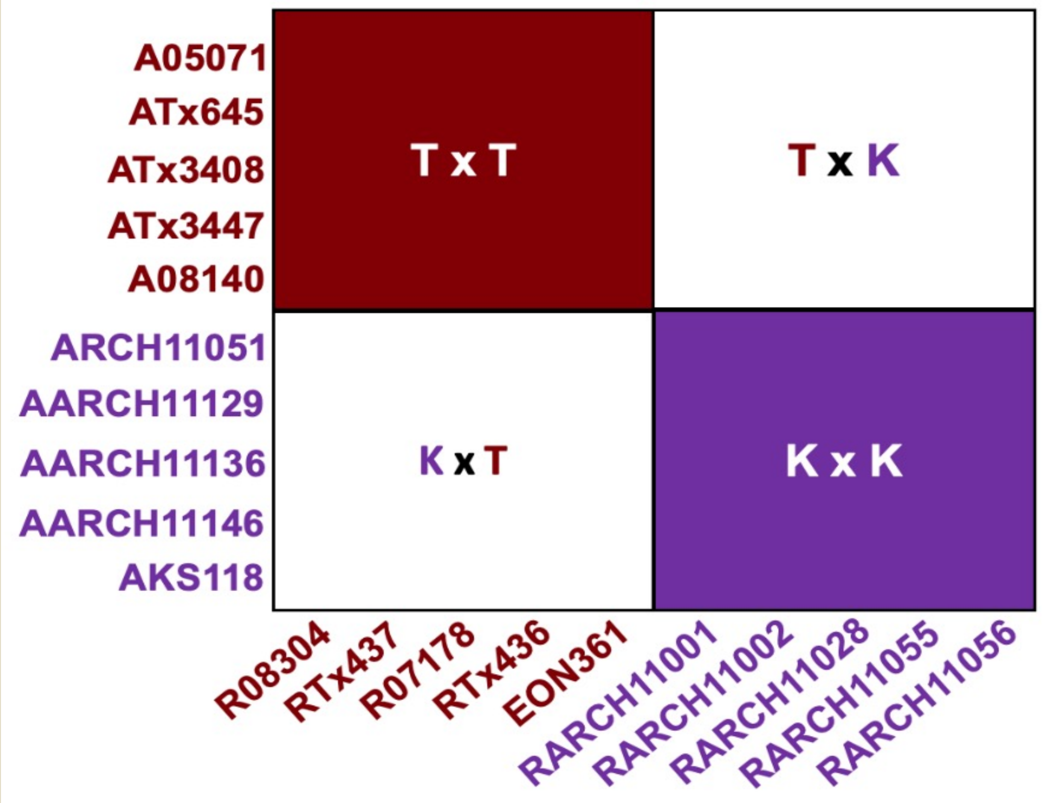
DH Lines





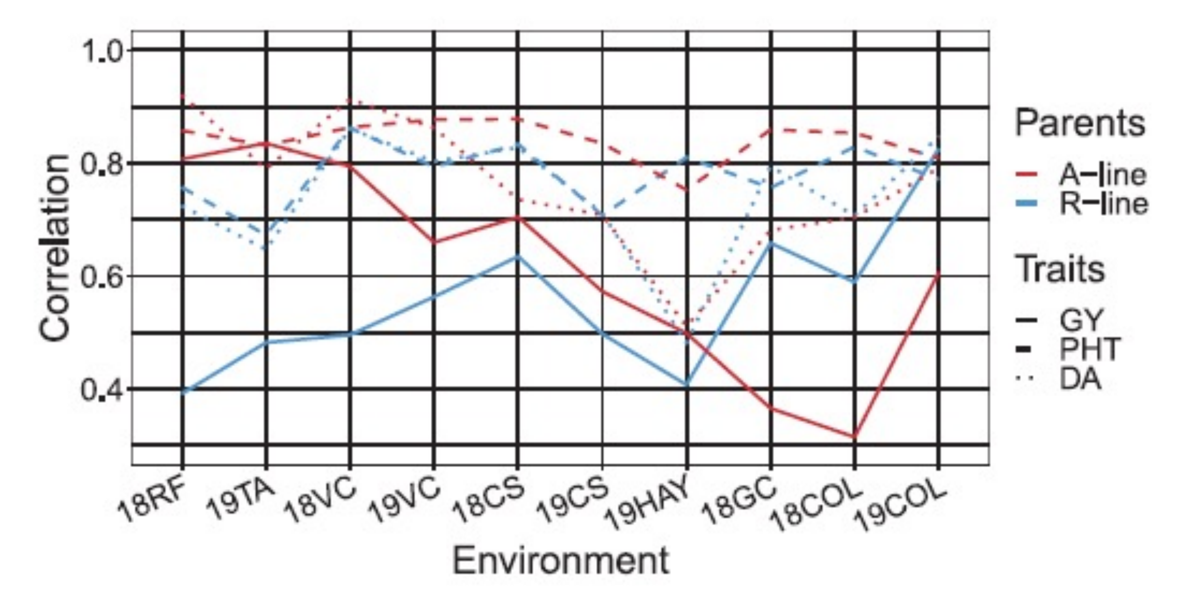
Genomic Selection in Sorghum

- Fonseca et al., 2021, Plant Genome
- Factorial Design (100)
- 10 environments
  - Texas (6)
  - Kansas (4)



Genomic Selection in Sorghum

Trait	Group	Single Environment	Multi environment	MMGE
Yield	Male Seed	.573 .498	.499 .420	.625 .571
Height	Male Seed	.835 .707	.789 .752	.843 .785



- Genomic and classical GCA-SCA models can predict agronomic traits in sorghum hybrids.
- Genomic models with G × E effects can increase the prediction accuracy of sorghum hybrids.
- Hybrids adapted to a target environment provide better predictions than unadapted hybrids.

Genomic Selection and Envirotypes

Environmental Factor
Average downward longwave radiative flux
Average insolation incident on a horizontal surface
Top of atmostphere insolation
Altitude
Evapotranspiration*
Temperature effect on radiation use efficiency*
Atmospheric water deficit*
Precipitation
Relative air humidity 2 m above surface
Slope of saturation vapor pressure curve*
Global solar radiation*
Air temperature 2 m above surface-Maximum
Air temperature 2 m above surface-Minimum
Air temperature 2 m above surface-Average
Air temperature 2 m above surface-Range*
Dew point temperature
Vapor pressure deficit*
Wind speed 2 m above surface
*factors calculated using processWTH() from EnvRtype package

	Leave 1 Env Out)		70 all/30 none		70/30 all in ≥1 Env	
	Grain yield	Plant height	Grain yield	Plant height	Grain yield	Plant height
A	**0.119**	**0.209**	**0.462**	**-0.228**	**0.745**	**0.580**
	(0.035)	(0.016)	(0.041)	(0.026)	(0.013)	(0.017)
A, D	**0.511**	**0.842**	**0.819**	**0.864**	**0.823**	**0.891**
	(0.053)	(0.018)	(0.007)	(0.008)	(0.009)	(0.005)
A, D A*E, D*E	**0.506**	**0.842**	**0.869**	**0.902**	**0.878**	**0.923**
	(0.051)	(0.018)	(0.005)	(0.009)	(0.009)	(0.004)
A, D Envirotype	**0.511**	**0.842**	**0.821**	**0.875**	**0.817**	**0.891**
	(0.053)	(0.018)	(0.009)	(0.008)	(0.010)	(0.005)

Winans et al., 2021 submitted to Frontiers

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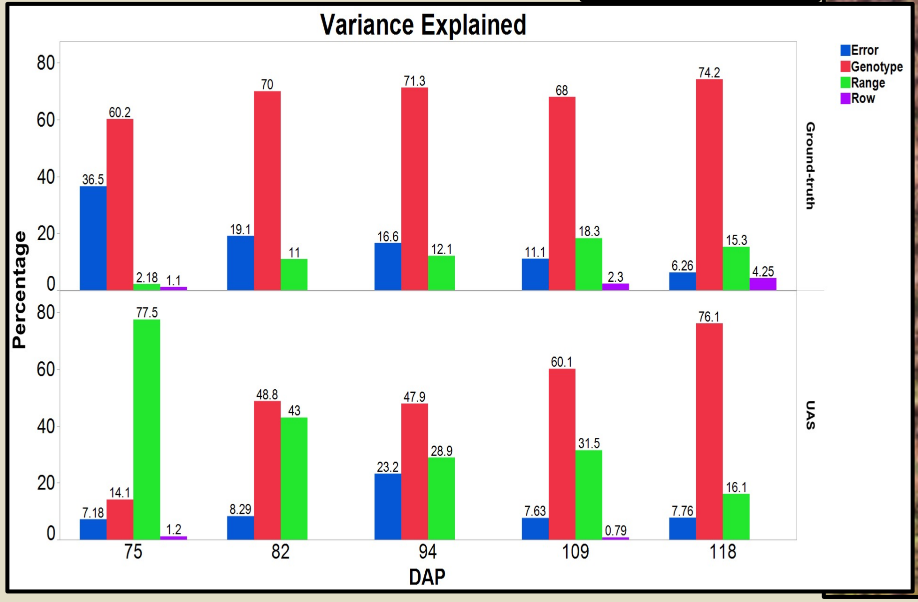
UAV Phenotyping – Plant Health

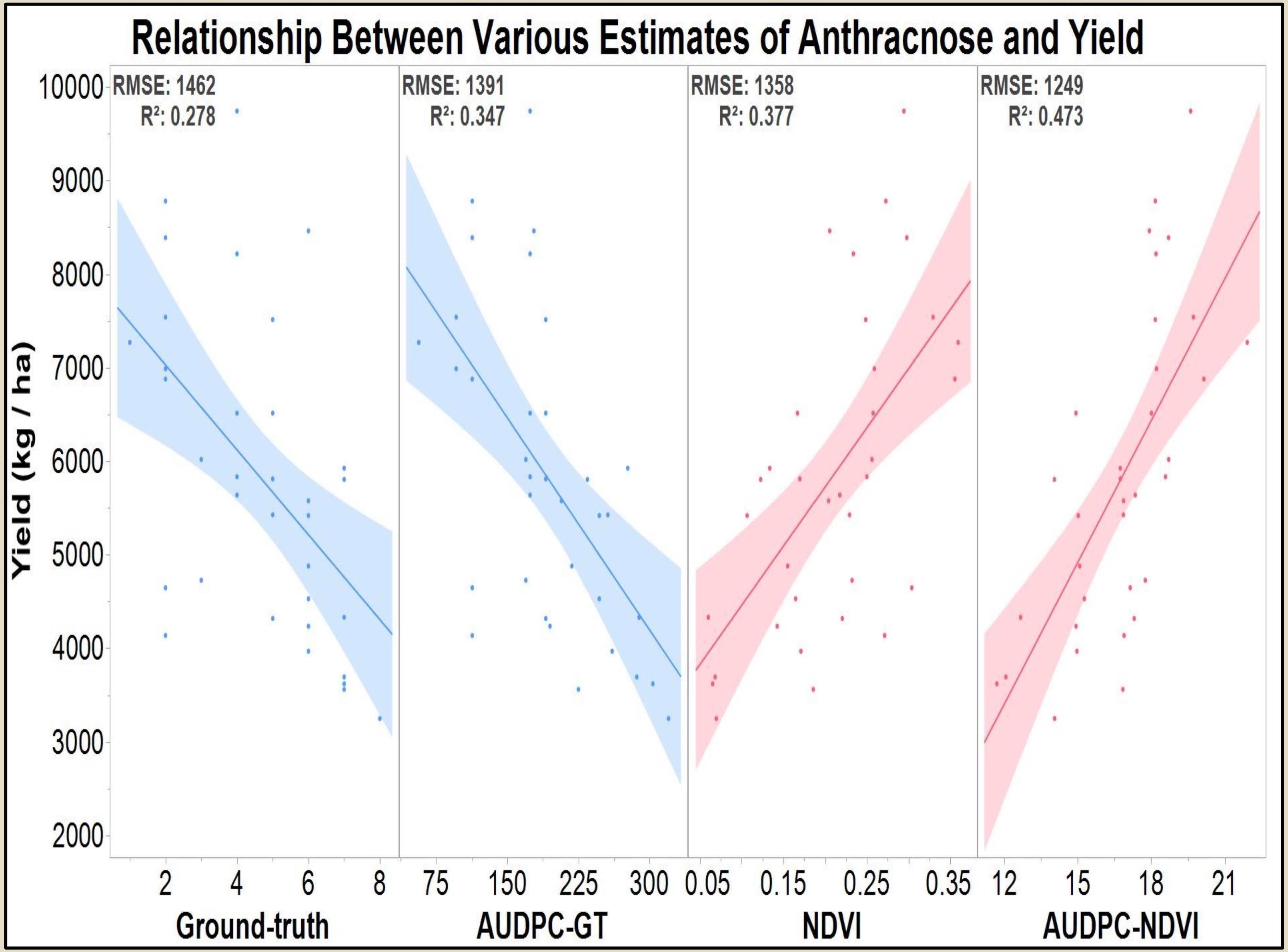
Anthracnose (*Colletotrichum sublineola*) - fungal disease in sorghum

Repeatability Estimates

DAP	Ground-truth	NDVI
75	0.62	0.66
82	0.77	0.86
94	0.81	0.67
109	0.86	0.89
118	0.92	0.91

$$R = \frac{\sigma_g^2}{\sigma_g^2 + \frac{\sigma_e^2}{r}}$$

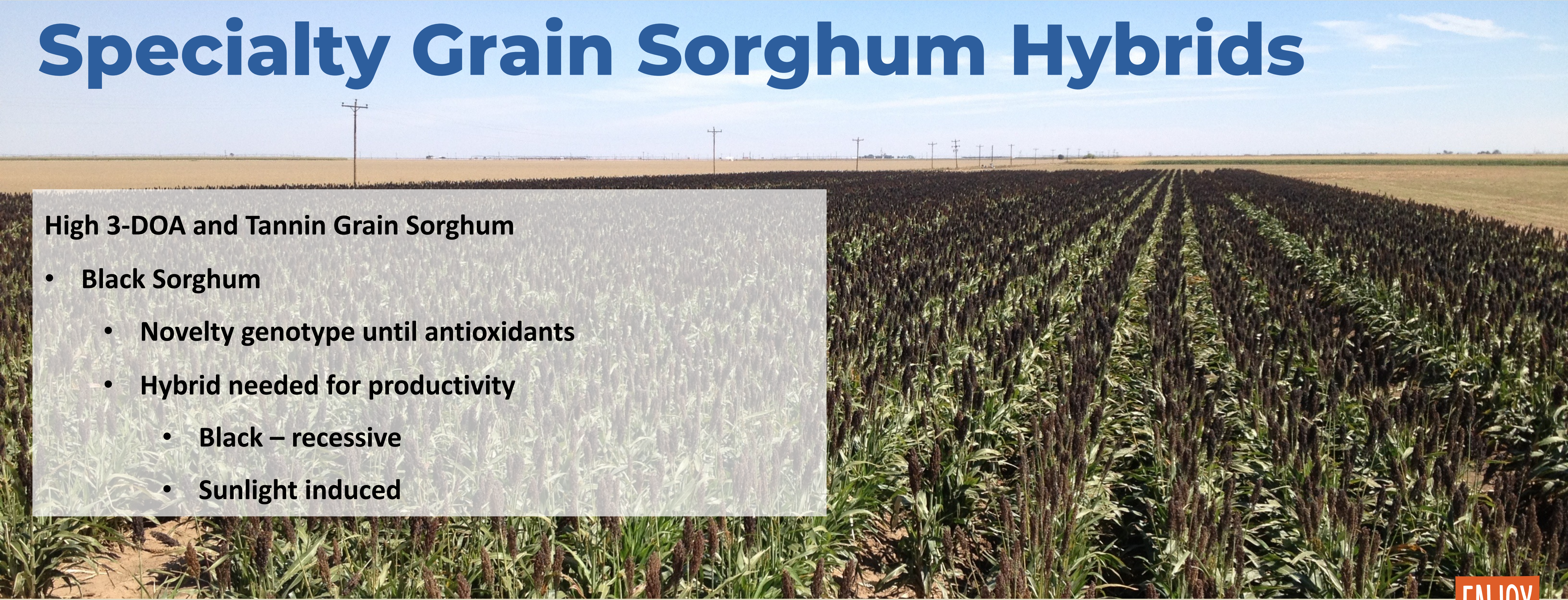




Pugh, NA, et al., 2018. J Crop Improvement https://doi.org/10.1080/15427528.2018.1535462

- NDVI from UAS effectively mimic visual score for anthracnose in sorghum
- UAS estimates are better late season, ground-truth is better early
- Estimates are leaf health; not possible to discriminate multiple pathogens

Specialty Grain Sorghum Hybrids



High 3-DOA and Tannin Grain Sorghum

- Black Sorghum
  - Novelty genotype until antioxidants
  - Hybrid needed for productivity
    - Black – recessive
    - Sunlight induced

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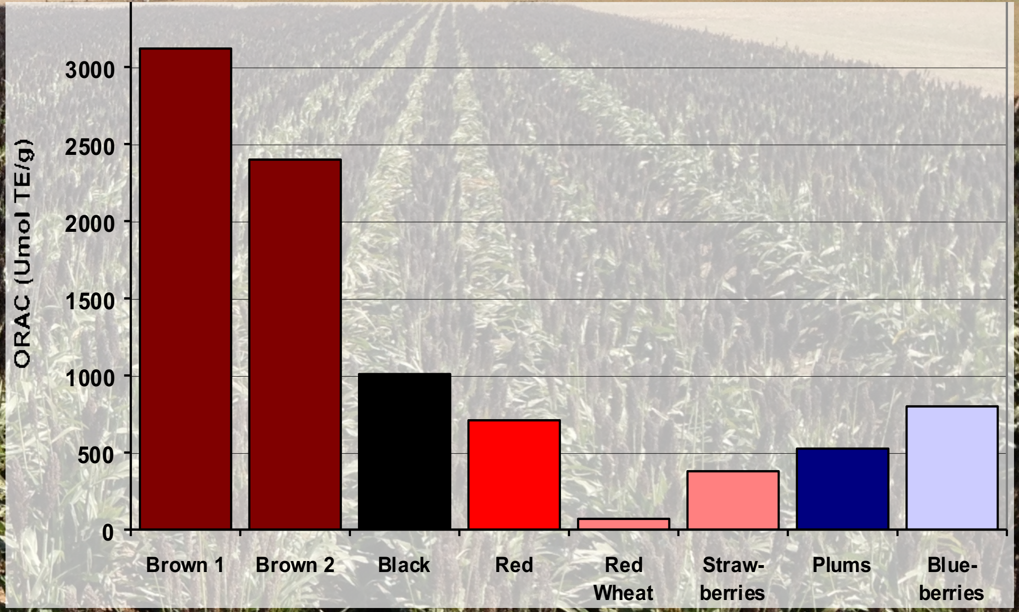

Specialty Grain Sorghum Hybrids

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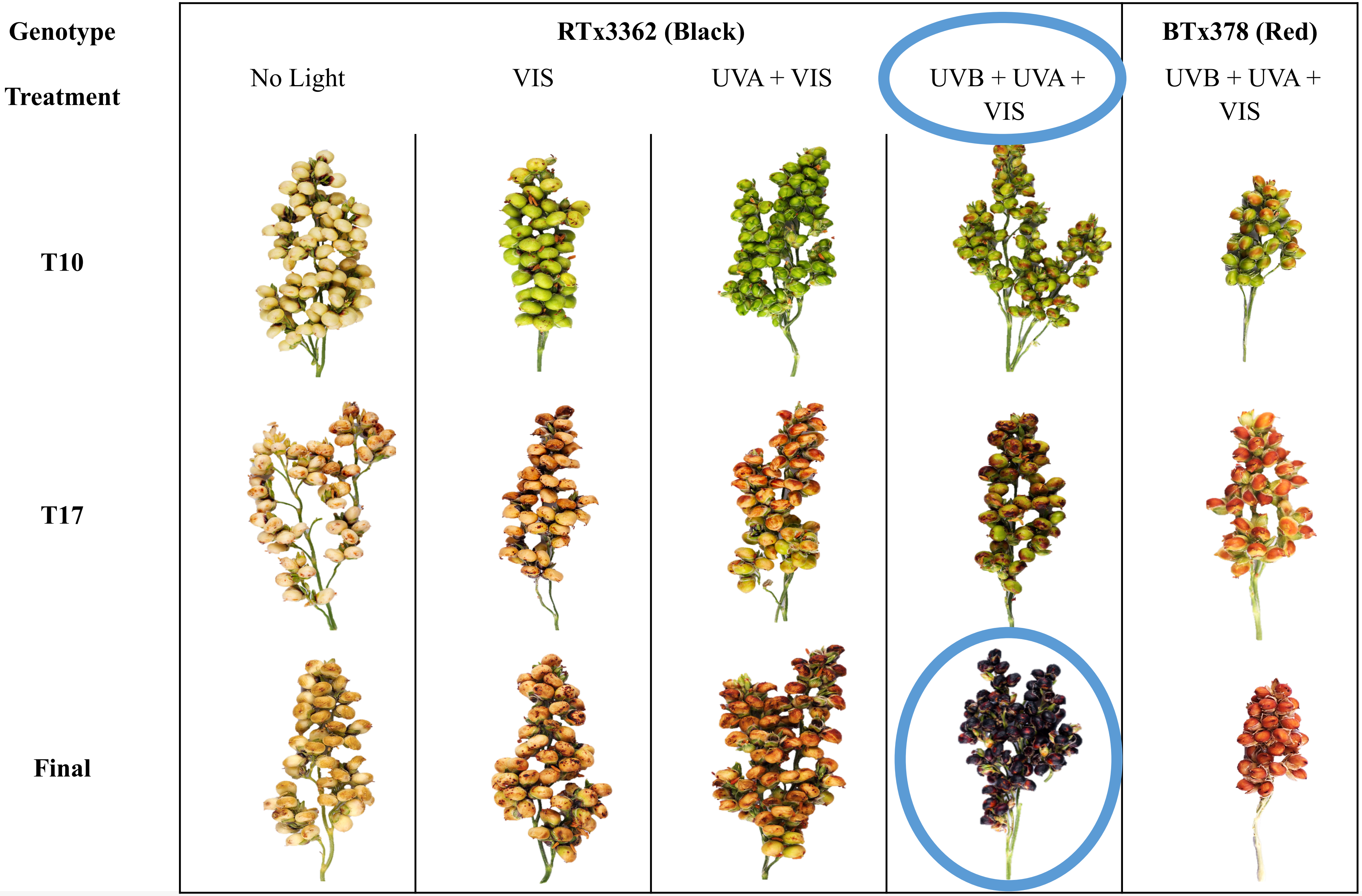
Fedenia et al., 2020
J. Ag and Food Chem.



Specialty Grain Sorghum Hybrids

High 3-DOA and Tannin Grain Sorghum

- Onyx 1 – 2013; Onyx 2 - 2019
- Licensed to Silver Palate Industries
- 1st commercialized specialty sorghum hybrid
- Identity Preservation Challenging

Specialty Grain Sorghum Hybrids

- Popping
- Waxy Endosperm
- High Protein
- Energy Hybrids

Gene Flow Sorghum to Johnsongrass

- Traits currently under commercialization
  - Inzen™ (ALS)
  - Igrowth™ (ALS)
  - DoubleTeam™ (ACCase)
- Other Traits under development
- Should we be concerned if they moved to Johnsongrass?
  - Sorghum/Johnsongrass
  - Johnsongrass/sorghum

Outcrossing occurring in both directions

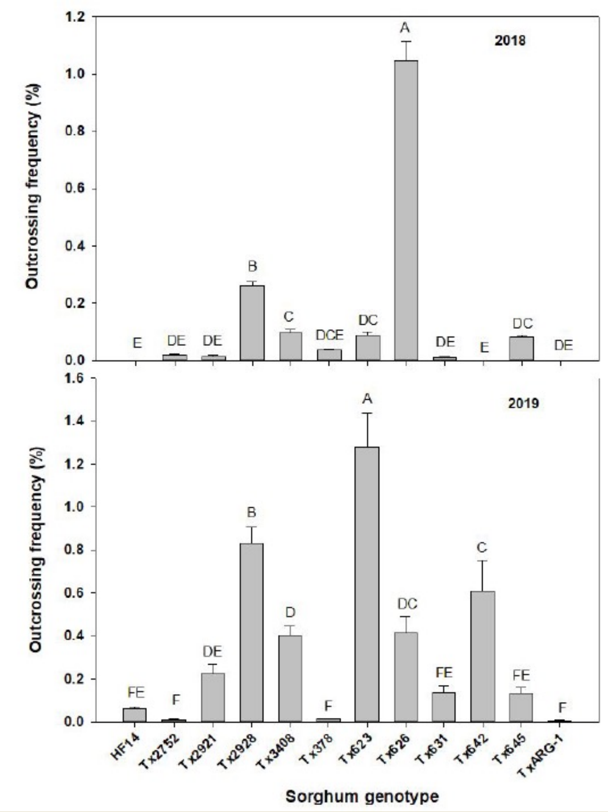
Volunteers (in fields after harvest)

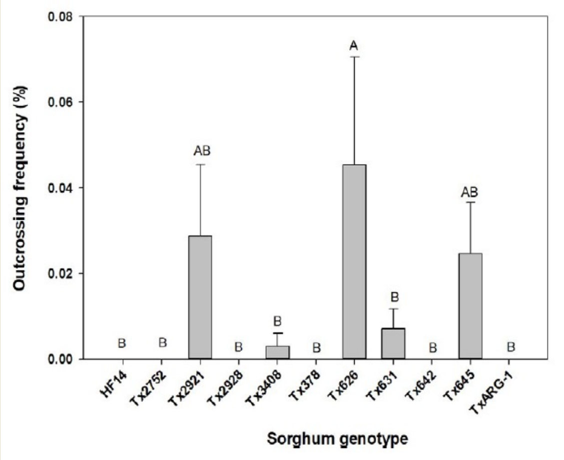
Feral sorghum (roadsides)

Gene Flow Sorghum to Johnsongrass

ms sorghum x johnsongrass

fertile sorghum x johnsongrass





Gene Flow Sorghum to Johnsongrass

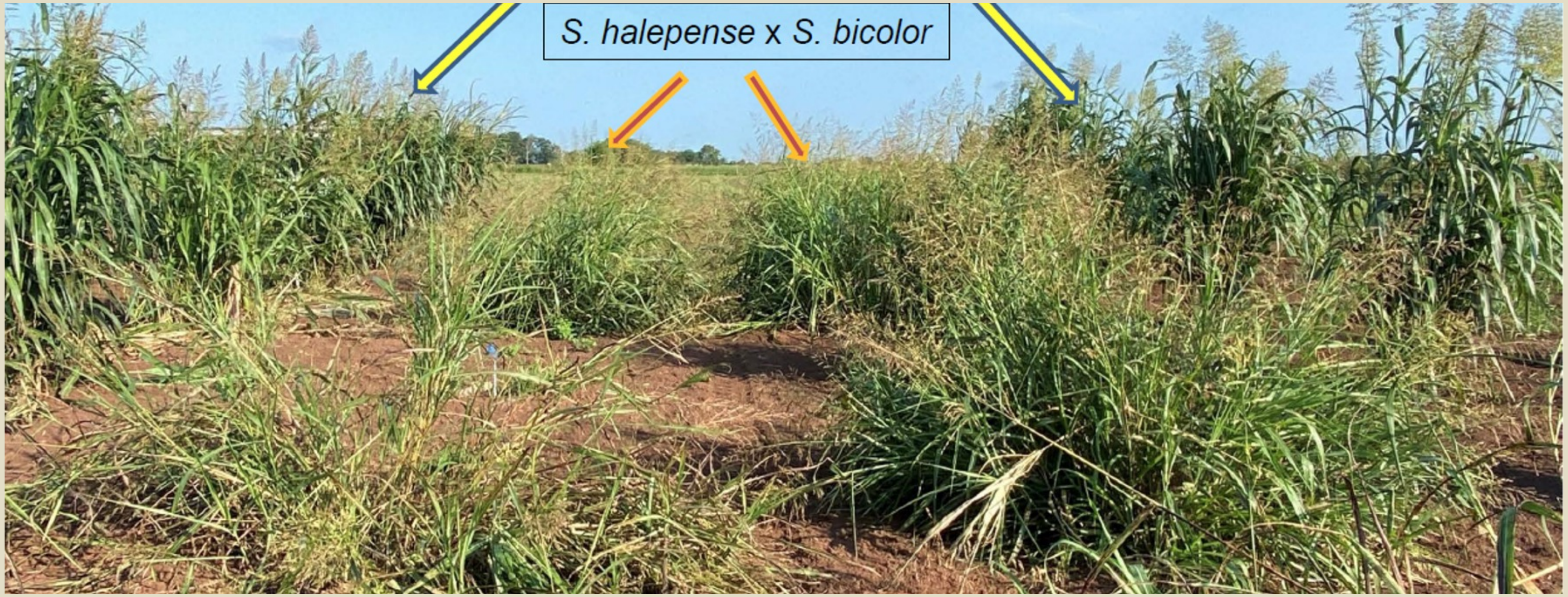
F_1 hybrids: ms sorghum x johnsongrass

Parent ID	Progeny No.	%haploid*	%triploid	%tetraploid
HF14	0	0	0	0
Tx2752	6	17	17	67
Tx2921	6	0	0	100
Tx2928	11	0	0	100
Tx3408	3	0	33	67
Tx378	9	0	0	100
Tx623	15	0	0	100
Tx626	34	3	0	97
Tx631	2	0	50	50
Tx642	0	0	0	0
Tx645	20	0	0	100
TxARG-1	0	0	0	0
Total/Avg	106	2	3	95

- Johnsongrass/Sorghum (Inzen)
  - 23 survivors/1993 seedlings: ~1% gene flow (experiment 1)
  - 9 survivors/1809 seedlings: ~0.5% frequency (experiment 2)
- All progeny were tetraploid

Gene Flow Sorghum to Johnsongrass

S. bicolor x S. halepense



- 2n gametes are the primary means of interspecific hybridization
- Variation among inbred for 2n gamete formation
- Very difficult to phenotypically detect JG/SB hybrids

Sorghum Breeding Evolves

- Adoption of new technology
  - will vary among programs
  - will require modifications to the process
  - Should improve efficiency; reduce cycle time
- Traits bring potential added value
  - Higher prices for grain (value added)
  - Reduce management costs (lower inputs)
- Traits also bring challenges
  - Identity preservation and supply chain management
  - Risk of traits to weedy wild relatives

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  - KSU-CSIP