Designing Silages for the Future

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Plant Breeding defined …….

- Plant Breeding is the art and science of the genetic improvement of plants. - Fehr, Principles of Cultivar Development: Theory and Technique, 1987

- Plant Breeding is the genetic improvement of plants for human benefit. - Bernardo, Breeding for Quantitative Traits in Plants, 2010

Plant breeding constantly adopts new techniques

~ 50 years ago

- Winter Nurseries
- Shuttle Breeding
- Mutation Breeding
- Plot Machinery

~25 years ago

- Molecular Markers
- Linkage Maps
- QTLs
- Genetic Transformation
- Computers

Currently

- Genome Sequencing
- Genomic Selection
- Bioinformatics
- Phenomics
- Phenomic Selection
- Gene editing

- *The technology and biology define what can be done.*
- *Ethics, market, and logistics define what will be done.*

Improvement is Conditional to Crop, Environment

- The environment effect is much larger than the genotype effect.
- Once adaptation is accomplished, rates of gain slow because the easy genes are "fixed". It take more effort to achieve a lower rate of gain.
- Biomass traits have lower rates of gain than Grain Traits.
- Simple genetic structure is more facile than Complex Genetic Structure.
- Annual crops have greater rates of genetic improvement than Perennials
- More commercially important crops have greater access to technology.

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Future Improvement of Silage - Technology

- Integration of genotyping and genomic analyses for MAS, genomic selection
- Integration of High Throughput phenotyping to generate larger more consistent phenotypic data
- Machine learning and Artificial Intelligence
- Faster Breeding Methodologies
  - Doubled Haploids
  - Speed Breeding
  - Tissue Culture
- Traits
  - Natural, Induced
  - Genetic Transformation (GM)
  - Gene Editing

Sorghum (*Sorghum bicolor*)

- Grain, Forage and Bioenergy
- Tropical to Temperate Production Areas in semi-arid regions with erratic hot and dry conditions
- Self-pollinated, but typically grown as a hybrid cultivar
- Diploid Genetics with Genomic Resources
- Modest Private Industry investment

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Texas A&M Agrilife has sorghum history

Current Program Objectives

- Develop improved germplasm to enhance/protect productivity
- Elucidate the genetic basis of important traits
- Educate students in plant breeding and genetics

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Agriculture Development in High Plains

- Homesteading the Western Great Plains
- Water was (and still is) the limiting factor and drought tolerant crops became the standard in the region.

- The Ogallala aquifer and the development of irrigation allowed the development of communities and stability.
- Production became reliant on the aquifer.

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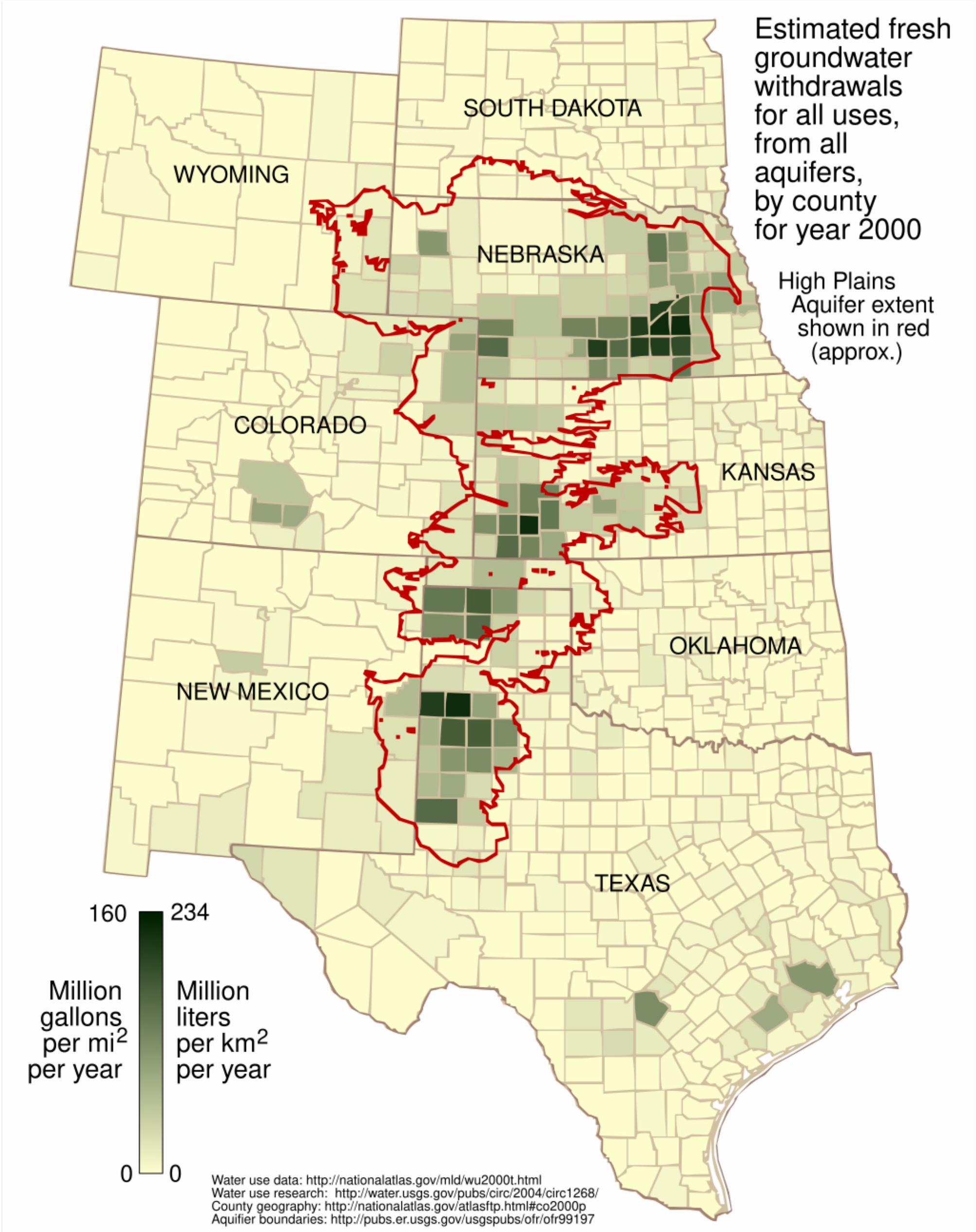

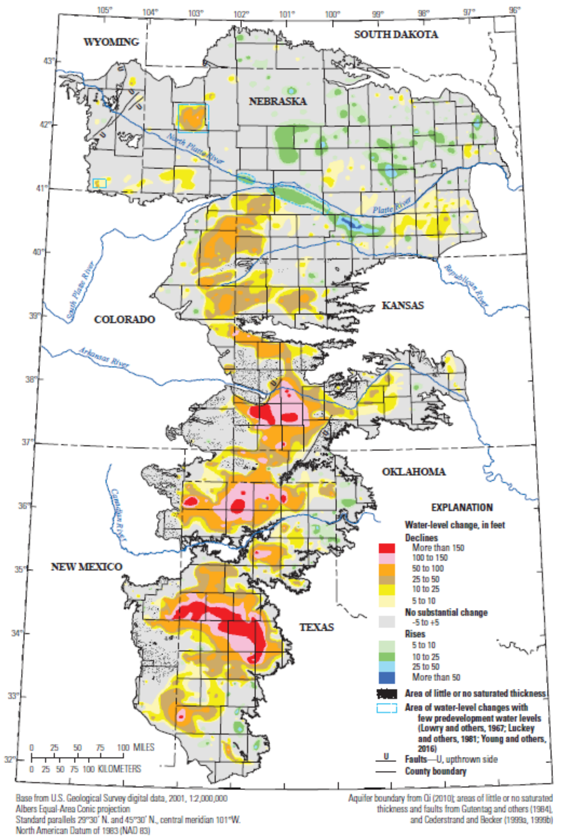

- Water is becoming scarce in some areas
- The cost of pumping it have many producers looking for alternatives

Source: U.S. Geological Survey (USGS) http://ne.water.usgs.gov/ogw/ hpwlms/

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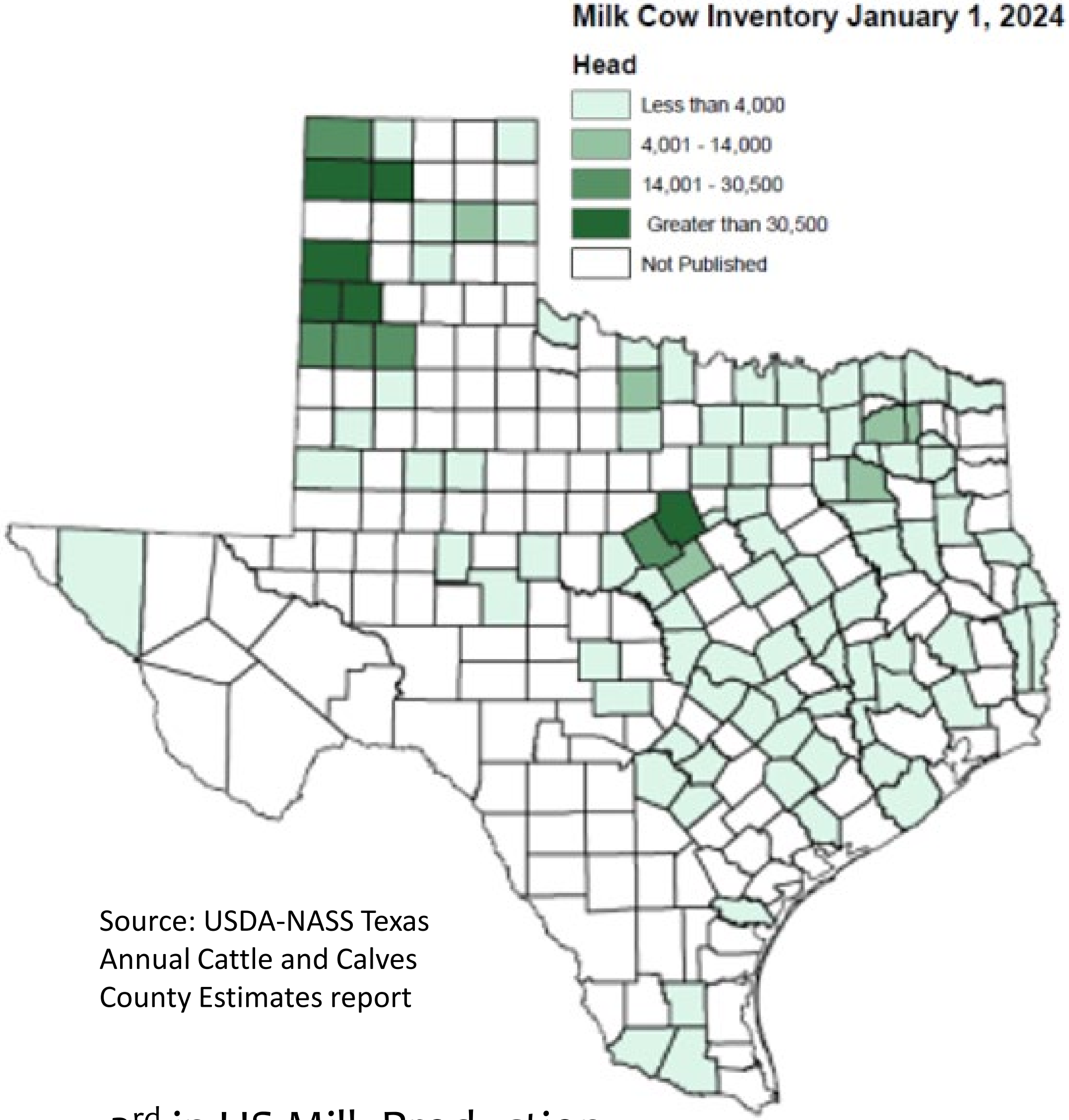
Texas Cooperative EXTENSION
The Texas A&M University System

MKT-3557L
05/07

The Economic Benefits of Forage Sorghum Silage as an Alternative Crop

Dean A. McCorkle, Dan Hanselka, Brent Bean, Ted McCollum,
Steve Amosson, Steven Klose and Mark Waller*

There is also a growing dairy industry in the Panhandle, with some projections showing that the number of dairy cattle could reach 225,000. The dairy industry also generates a large demand for silage. Corn has been the traditional source of silage for the beef and dairy industries, but the scarcity of water in some areas and the cost of pumping it have many producers looking for alternatives.



Source: USDA-NASS Texas Annual Cattle and Calves County Estimates report

3rd in US Milk Production
645,000 Head Total Inventory

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Looking Forward

- Very few producers can fully irrigate.
- Production on limited irrigation is the current reality
- In this region, priorities must be placed on water use
  - Feed grain can be imported
  - Forages cannot be imported

- Forages that produce high yield, good quality with lower water requirements are essential.

Forage Sorghum comes in many forms

- Grain Sorghum
- Silage Sorghum
- Forage Sorghum (includes sudangrass types)
- Bioenergy Sorghum

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Forage Testing in Texas A&M AgriLife

- Testing is coordinated through the Variety Testing Program
- Public Forage Sorghum/Silage Hybrid Trial (20+ years)
  - Agronomic and Composition Data are collected
  - Comparison to Silage Corn Hybrids
  - Data published annually
  - Commonly used in comparison analyses
- Goal is to provide relevant production information to producers, companies and agencies to maximize water use and production efficiency

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Forage Testing General Observations

- Select Forage and Silage Sorghum hybrids can produce yields comparable or better than corn using 65% of the water required for corn.
- Delayed Maturity of forage sorghum is correlated to yield but require more water.
- Hybrid Selection is Crucial
  - Maturity (yield, water use)
  - Height (yield, lodging)
  - Brown Midrib (quality, lodging)
- New traits and specific classes of forage sorghum have developed.
- Tests have been crucial to adoption and to the availability of crop insurance.

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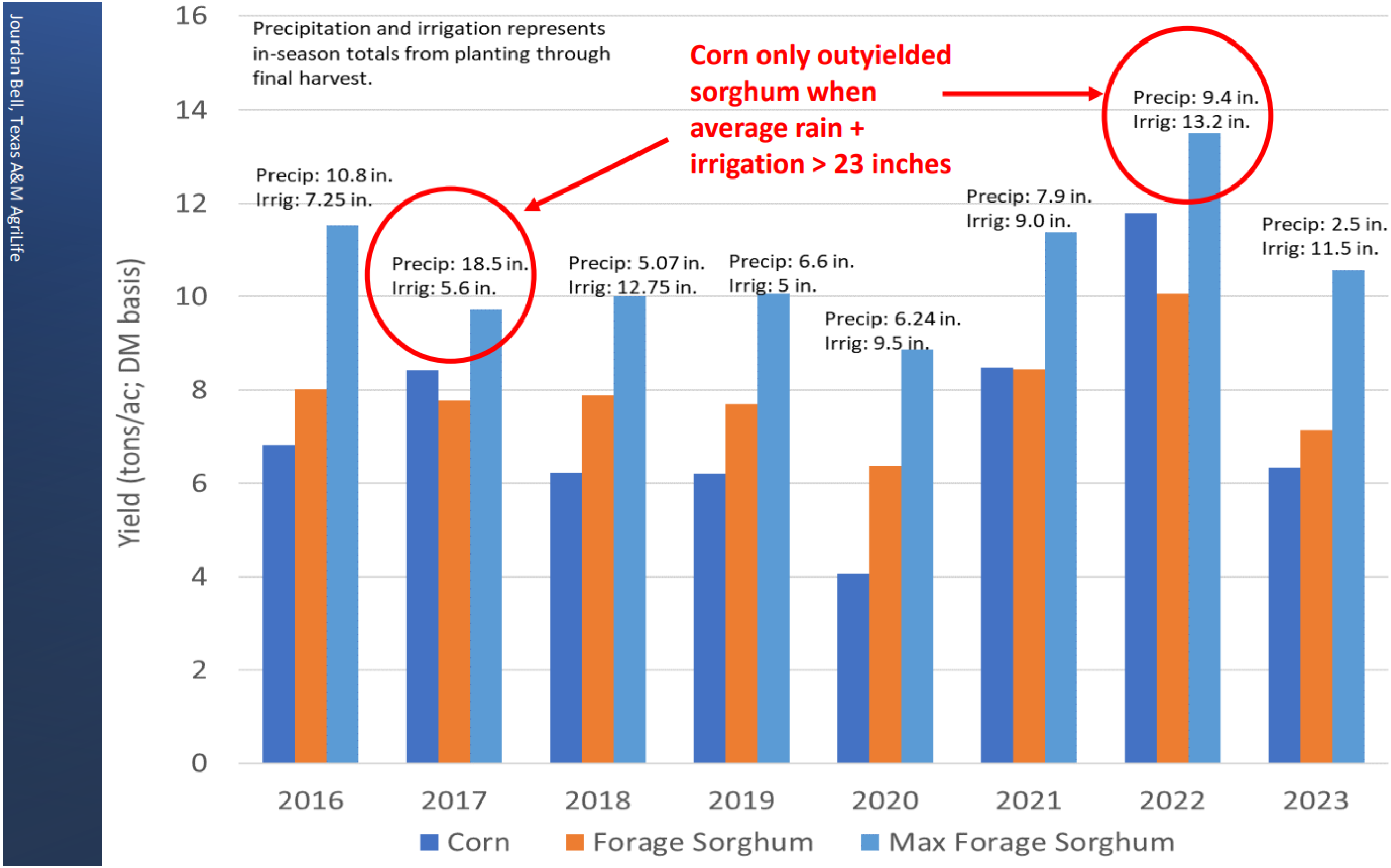
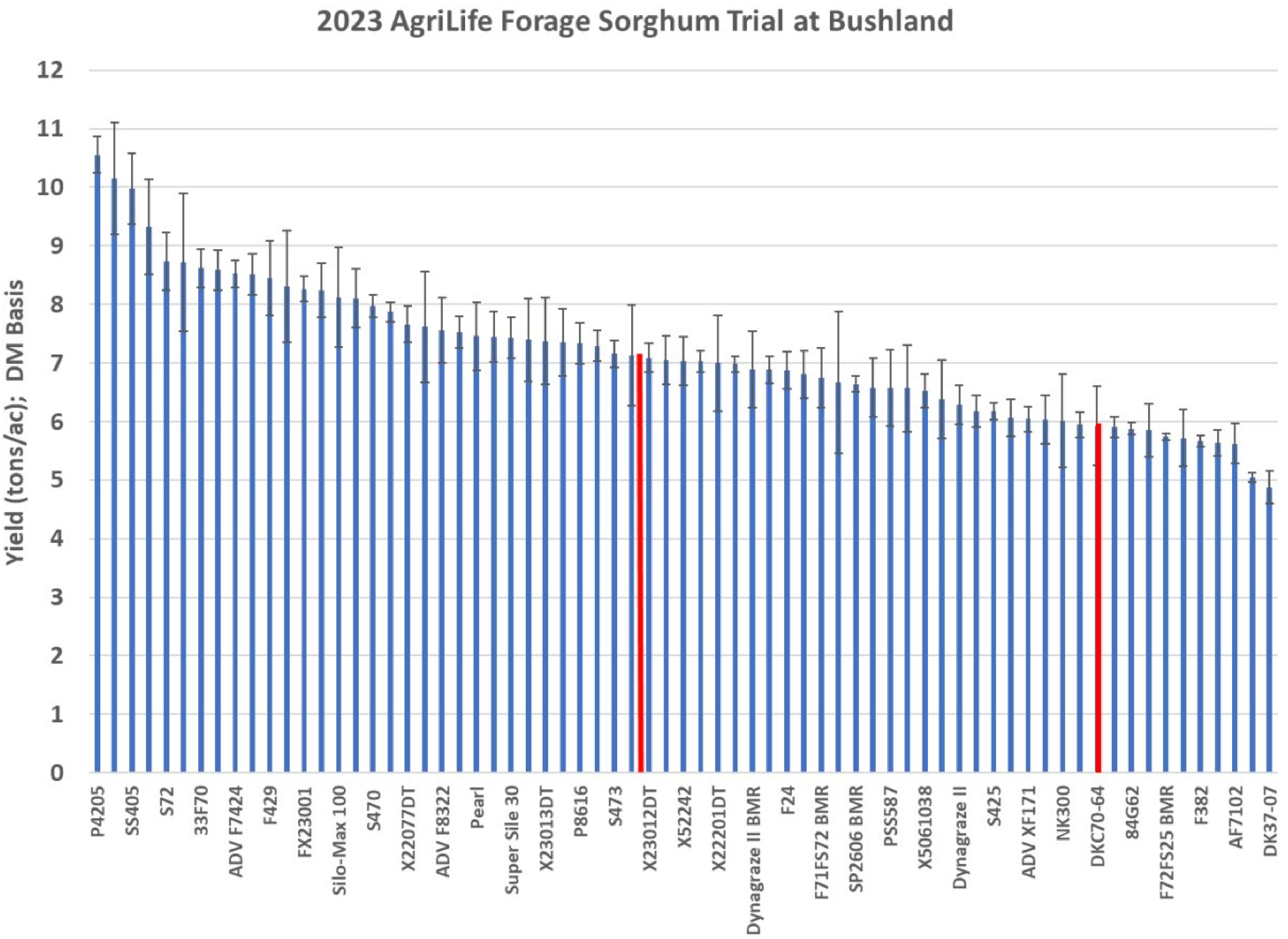


Jourdan Bell, Texas A&M AgriLife
Precipitation and irrigation represents in-season totals from planting through final harvest.
Corn only outyielded sorghum when average rain + irrigation > 23 inches
Precip: 10.8 in.
Irrig: 7.25 in.
Precip: 18.5 in.
Irrig: 5.6 in.
Precip: 5.07 in.
Irrig: 12.75 in.
Precip: 6.6 in.
Irrig: 5 in.
Precip: 6.24 in.
Irrig: 9.5 in.
Precip: 7.9 in.
Irrig: 9.0 in.
Precip: 9.4 in.
Irrig: 13.2 in.
Precip: 2.5 in.
Irrig: 11.5 in.
Yield (tons/ac; DM basis)
16
14
12
10
8
6
4
2
0
2016
2017
2018
2019
2020
2021
2022
2023
Corn
Forage Sorghum
Max Forage Sorghum



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Maturity Class and Yield - 2024

Hybrid	Maturity	Days to HB	HB Date	Days to Harvest	Days to Harvest	Yield (tons/ac) 65% Moist.[ǂ]	WUE lbs/inch
F71FS72 BMR	Early	65	8/10/2024	84	8/29/2024	14.8 ± 0.7	1215
23015+	Med-Early	71	8/16/2024	90	9/4/2024	17.4 ± 1.0	1332
F27	Medium	84	8/29/2024	102	9/16/2024	26.9 ± 2.8	2002
SS405	Late	102	9/16/2024	113	9/27/2024	25.0 ± 3.0	1699
S473	PS	125		125	10/9/2024	27.5 ± 1.7	1863

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Maturity	Silage Yield	(Range)	Grain Yield	(Range)	IVTD	(Range)	Hybrids Tested	Hybrids Specs*	
	% of Fully Irrigated Corn						No.	No.	USE
Early	81	(69 - 93)	52	(39 - 70)	99	(95 - 102)	7	1	SILAGE
Med-Early	92	(74 - 126)	61	(31 - 85)	97	(90 - 106)	16	3	SILAGE
Medium	98	(78 - 141)	46	(27 - 80)	97	(89 - 105)	13	4	SILAGE
Late	106	(86 - 126)	36	(12 - 66)	92	(84 - 104)	8	1	SILAGE
V Late (PS)	109	(82 - 129)	1	(0 - 10)	87	(83 - 97)	14	0	GREENCHOP
Conventional	97	(74 - 126)	57	(12 - 85)	91	(84 - 101)	38	5	SILAGE
Brown Midrib	86	(69 - 102)	34	(0 - 61)	100	(91 - 106)	20	4	SILAGE

Specs*- Hybrid yielded 90% with 95% IVTD of corn and < 10% lodging
Adapted from Bean and McCallum (2006)

Conclusions:
Select silage sorghum hybrids have yield and quality comparable to silage corn hybrids.
PS sorghum hybrids are better suited for greenchop.
Hybrids with brown midrib have improved quality, but do not guarantee quality.

500,000 acres of Silage Sorghum are now grown annually in the Southern High Plains

Breeding Forage Sorghums

- All improved Forage Sorghums are Hybrids
  - Seed parents are usually more grain types
  - Pollinator parents define the type of forage
- All types are amenable to breeding but improvement is typically focused on the
  - Sudangrass
  - Sorghum Sudangrass
  - Silage types
  - Photoperiod Sensitive types
    - Greenchop
    - Bioenergy
- Traits (native) are important

Changing the Program

- Doubled Haploid Technology
  - Frequency of Induction
  - Logistics of Production (temporal sterility)
- Genomics
  - Genomic Selection
  - Marker Assisted Selection
- Phenotyping
  - UAV for height, maturity and biomass yields
  - On board NIR for composition analysis
  - Phenomic Selection is being tested
- Traits
  - Natural, Induced
  - Transgenic, Gene Editing

SEASON	YEAR	TRADITIONAL	PROPOSED
Summer	0	P1 x P2	P1 x P2
Winter	0	F_1	F_1
Summer	1	F_2 Phenotypic selection	F_2 Phenotypic selection
Fall	1		F_3 Greenhouse Single seed descent
Winter	1		F_4 Greenhouse - Genotypic and genomic prediction (replaces 1st stage hybrid evaluation) - Seed from 1 plant
Summer	2	F_3 Phenotypic selection	F_5 Phenotype - Self to increase - Produce testcross hybrids
Summer	3	F_4 Phenotypic selection	2nd Stage Hybrid Evaluation
Winter	3	F_5 Self to increase - Produce testcross hybrids	
Summer	4	1st Stage Hybrid Evaluation	
Summer	5	2nd Stage Hybrid Evaluation	

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Breeding Forage Sorghums

- All improved Forage Sorghums are Hybrids
  - Seed parents are usually more grain types
  - Pollinator parents define the type of forage
- Traits (native to date) are important
  - Insensitive or Photoperiod Sensitive
  - Normal or Brown midrib
  - Brachytic or Tall
  - Dry or Juicy Stalk
  - Male Sterility or Male Fertile
  - Herbicide Resistance
  - Low/No Dhurrin
  - Sorghum/Sugarcane Aphid Resistance

Silage Sorghum

- Similar specification as corn
- In sorghum this means a taller, grain type sorghum
  - High Grain Yield
  - Moisture Content between 65-68% at harvest
  - More Leaf than Typical Grain Sorghum
  - Preferable to have larger seed but….

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Photoperiod Sensitive (PS) Sub-type

- Vegetative growth until day length < 12’ 20”’ .
- Very high yield produced per acre
- Hard to dry
- Use is primarily
  - Sorghum/sorghum
    - greenchop or bioenergy
  - Sorghum sudangrass
    - grazing or baling

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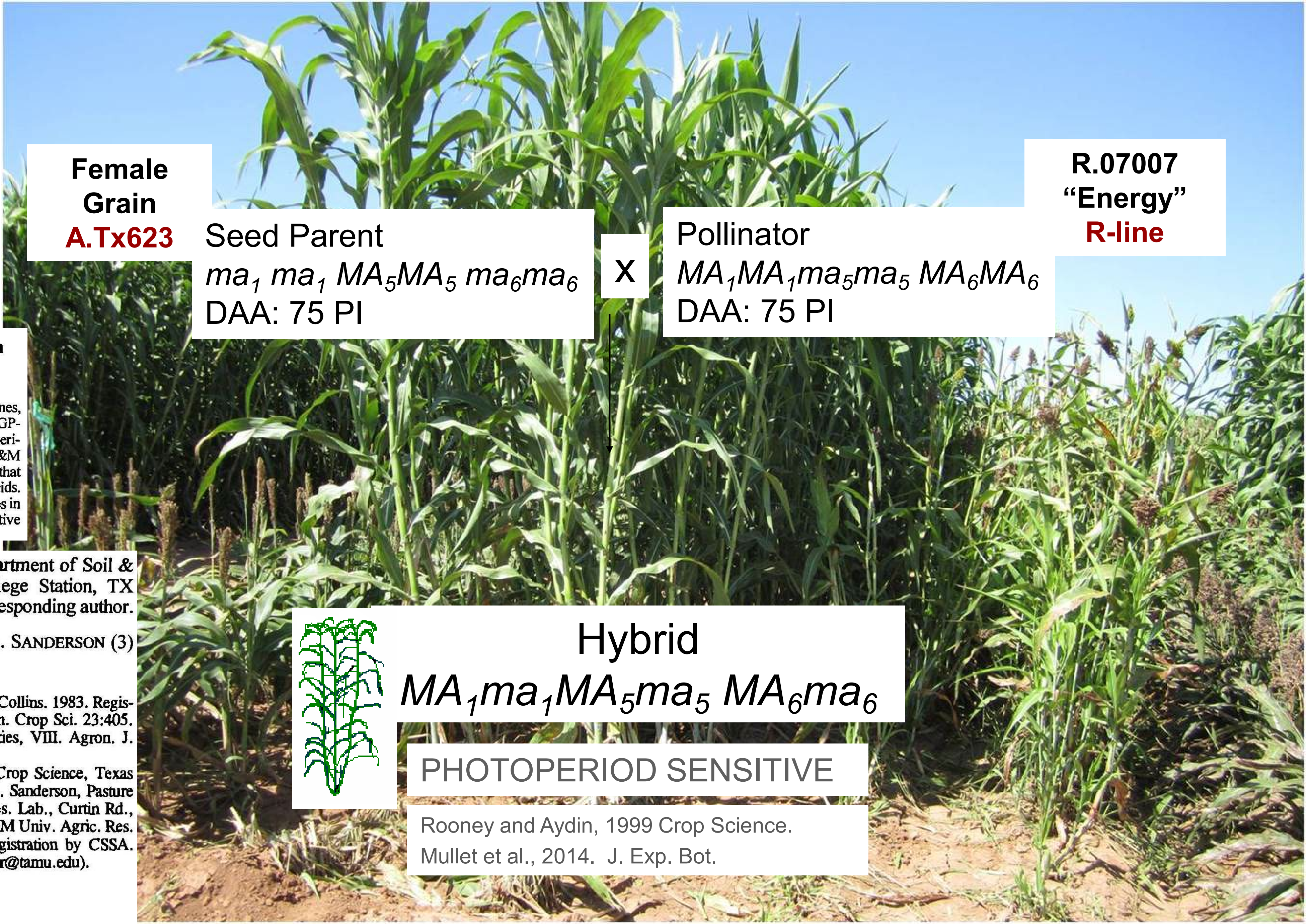
Development of Photoperiod Sensitive Hybrids



Female Grain
A.Tx623

Seed Parent
$ma_1\ ma_1\ MA_5MA_5\ ma_6ma_6$
DAA: 75 PI

X

Pollinator
$MA_1MA_1ma_5ma_5\ MA_6MA_6$
DAA: 75 PI

R.07007
“Energy”
R-line

Hybrid
$MA_1ma_1MA_5ma_5\ MA_6ma_6$

PHOTOPERIOD SENSITIVE

Rooney and Aydin, 1999 Crop Science.
Mullet et al., 2014. J. Exp. Bot.

Registration of Tx2909 and Tx2910 Sorghum Germplasm (Sudangrass Type)

Two sorghum [*Sorghum bicolor* (L.) Moench] germplasm lines, Tx2909 (Reg. no. GP-518, PI 598069) and Tx2910 (Reg. no. GP-519, PI 598070), were developed by the Texas Agricultural Experiment Station, Department of Soil and Crop Sciences, Texas A&M University at College Station, TX. These are sudangrass lines that can be used for the production of sorghum–sudangrass hybrids. Because of a unique combination of photoperiod response genes in these lines, Tx2909 and Tx2910 will produce photoperiod sensitive hybrids with most U.S.-developed A-lines.

Breeder seed will be maintained at the Department of Soil & Crop Sciences, Texas A&M University, College Station, TX 77843-2474. Seed can be obtained from the corresponding author.

W. L. Rooney,* M. A. Hussey, and M. A. Sanderson (3)

References and Notes

1. Frederiksen, R.A., D.T. Rosenow, L. Reyes, and D. Collins. 1983. Registration of Tx2784 and Tx2785 sudangrass germplasm. Crop Sci. 23:405.
2. Karper, R.E. 1955. Registration of Sorghum Varieties, VIII. Agron. J. 47:540.
3. W.L. Rooney and M.A. Hussey, Dep. of Soil & Crop Science, Texas A&M Univ., College Station, TX 77843-2474; M.A. Sanderson, Pasture Systems & Watershed Management, USDA-ARS Res. Lab., Curtin Rd., University Park, PA 16802-3702 (formerly Texas A&M Univ. Agric. Res. Ctr., Rt. 2, Box 00, Stephenville, TX 76401). Registration by CSSA. Accepted 30 Sept. 1997. *Corresponding author (wlr@tamu.edu).

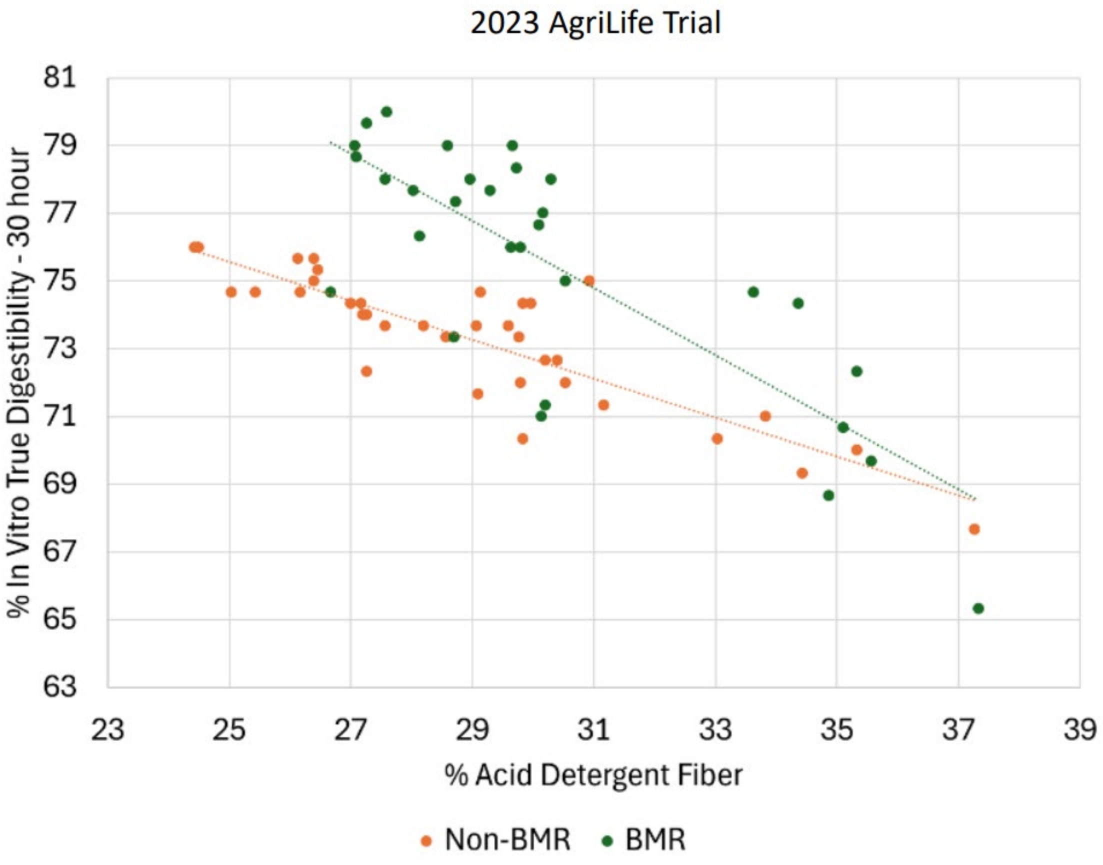
Published in Crop Sci. 38:566 (1998).

Brachytic Dwarf Sorghum

- Reduced internode length by increased number of recessive dwarfing genes
- Increases the Leaf to Stem Ratio.
- Shorter Height reduces lodging risk.
- Often paired with Brown Midrib.
- Typically incorporated into Silage Sorghum Types

Brown Midrib Sorghum

- Mutations in genes in the lignin biosynthesis pathway. The most common are
  - *bmr6*
  - *bmr12*
- Lower lignin content in leaves and stalks
  - Higher forage digestibility
  - More palatability
  - Greater grain rates
- Lodging can be a problem
- In Silage and Grazing/Baling Types



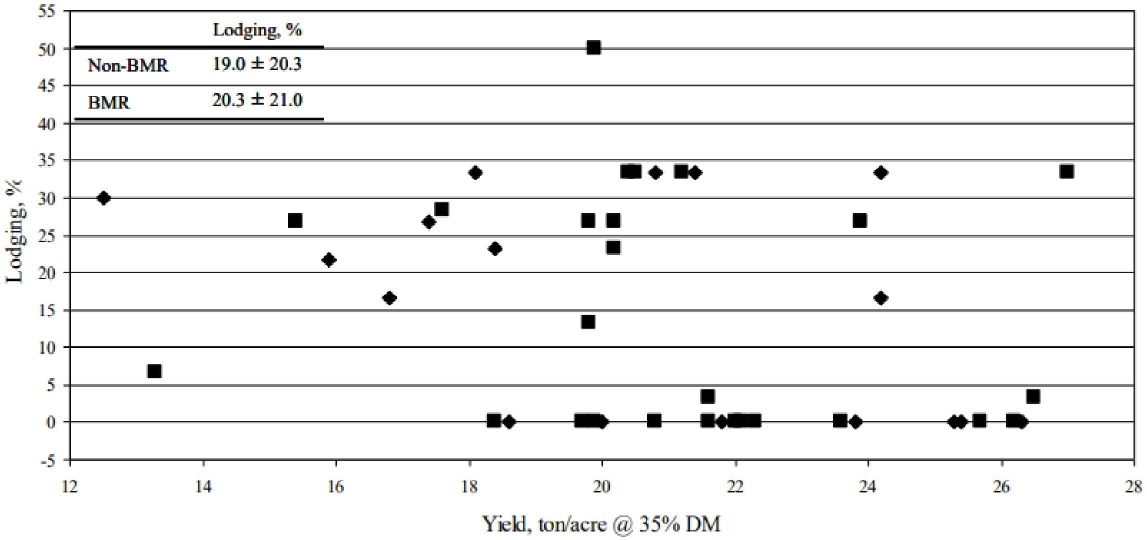


Figure 2. Relationship of yield and lodging of normal (♦) and BMR (■) forage sorghum varieties entered in the 2014 Texas Panhandle Sorghum Silage Trial (Bell et al., 2014).

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Nuevas Variedades de Sorgo "bmr" en Centro America

- Cattle production (beef and dairy) is important throughout Central America.
- Sorghum is the principal supplemental forage in the production of milk and meat.
- Most production is small farmer based with low inputs and minimal access to advanced technology. \
- Goal of Project
  - Introduce bmr into adapted cultivars to
    - Improve forage quality and palatability
    - Maintain adaptation to the región
    - Evaluate throughout Central America

Additional Traits

Dry (D) or Juicy (d) Stalk

- Dry 60-70%
- Juicy 70-80%

- Dry stalk common in
  - Silage
  - Sorghum sudangrass (baling)

Male Sterility

- sterile hybrids using different sterility inducing cytoplasm

- No grain development (without outside pollen)
  - Increases stalk sugar concentrations
  - Increases tillering
  - hay types but some promoting for silage.
- Increased risk of ergot infection

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Additional Traits

- Herbicide Resistance
  - ACCase
  - ALS
- Sorghum/Sugarcane Aphid
  - Importance to prevent Aphid Infestation
- Low/No Dhurrin
  - Eliminates the possibility of prussic acid poisoning
  - Newer trait and more testing needed to assess any potential negative effects

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Summary

- The rate of Silage Improvement is
  - Crop Specific
  - Resource Contingent
- New technology is applicable to Silage Improvement
  - fit within the program
  - Increases efficiency
- Adoption of Traits requires
  - Economic returns sufficient to justify effort
  - Adaptation and performance cannot lag

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Questions