Energy Sorghums: Types and Production

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Potential US C4 Bioenergy Grass Feedstocks

Crop	Growth	Propagation	History	Biomass	Notes
Switchgrass	Perennial	Seed	None	Lignocellulose	Problems w/ seed prod. & stand est.
Sugarcane	Perennial	Cutting	Sugar	Sugar, Lignocellulose	cold sus. limits range
Miscanthus	Perennial	Rhizomes	None	Lignocellulose	Propagation limited
Sorghum	Annual	Seed	Grain, Forage	Sugar, Starch Lignocellulose	Drought tolerance

Miscanthus
← Sorghum
Sugarcane →

Switchgrass

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Sorghum as a biomass crop……..

- C4 photosynthesis
- Wide Adaptation
- High Yield Potential with regrowth potential
- Water Use Efficiency
- Drought Tolerance
- Pest Resistance
- Good Crop Rotation
- Non competitive with food, feed systems

- Existing Agricultural Infrastructure
- Non-invasive
- Winter Standing
- Excellent Genetic Platform
- Composition
  - Starch, sugar, cellulose available
- Perennial Crop

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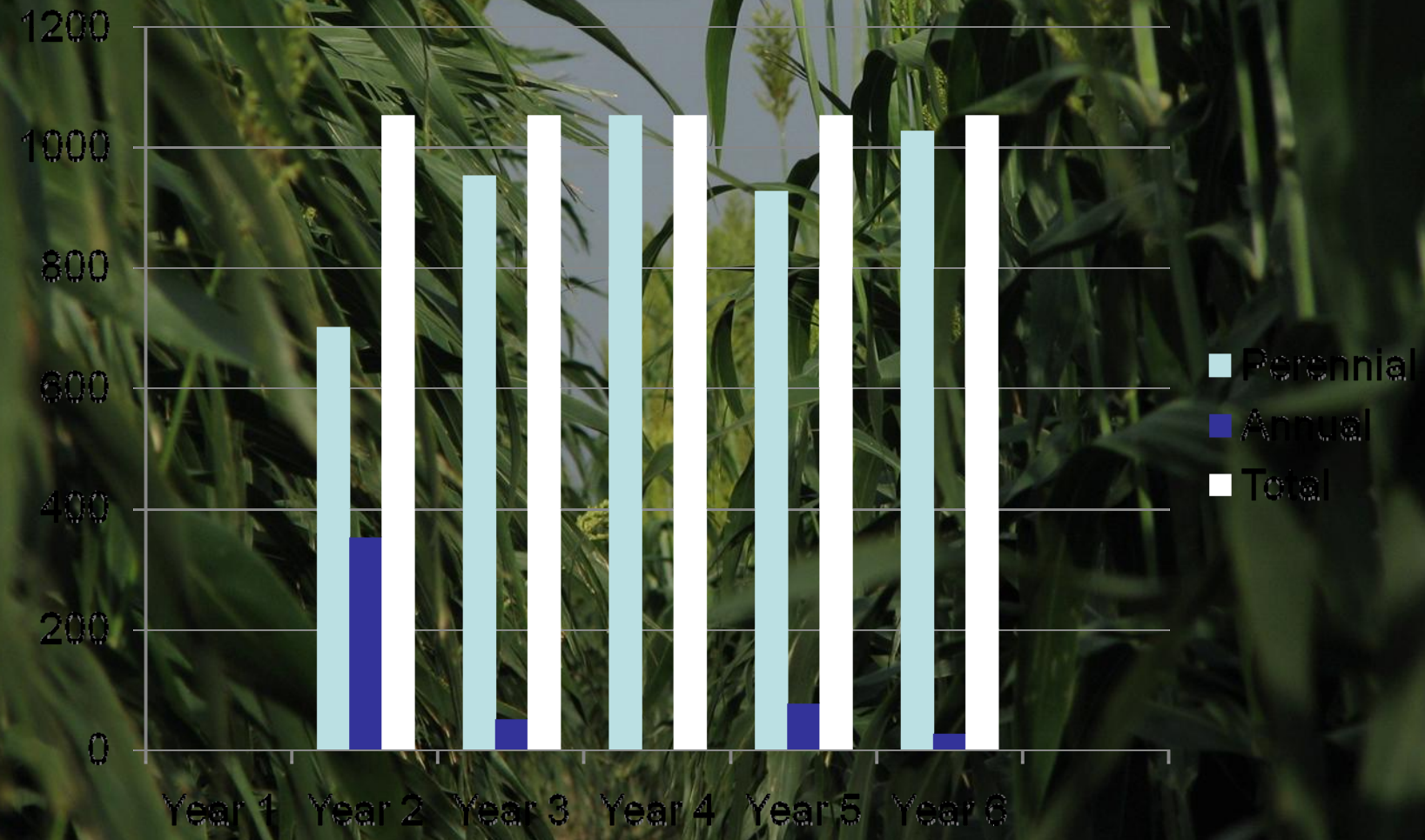
Even in a perennial system, an annual is needed……



Source: Mendel Biotech, Inc.

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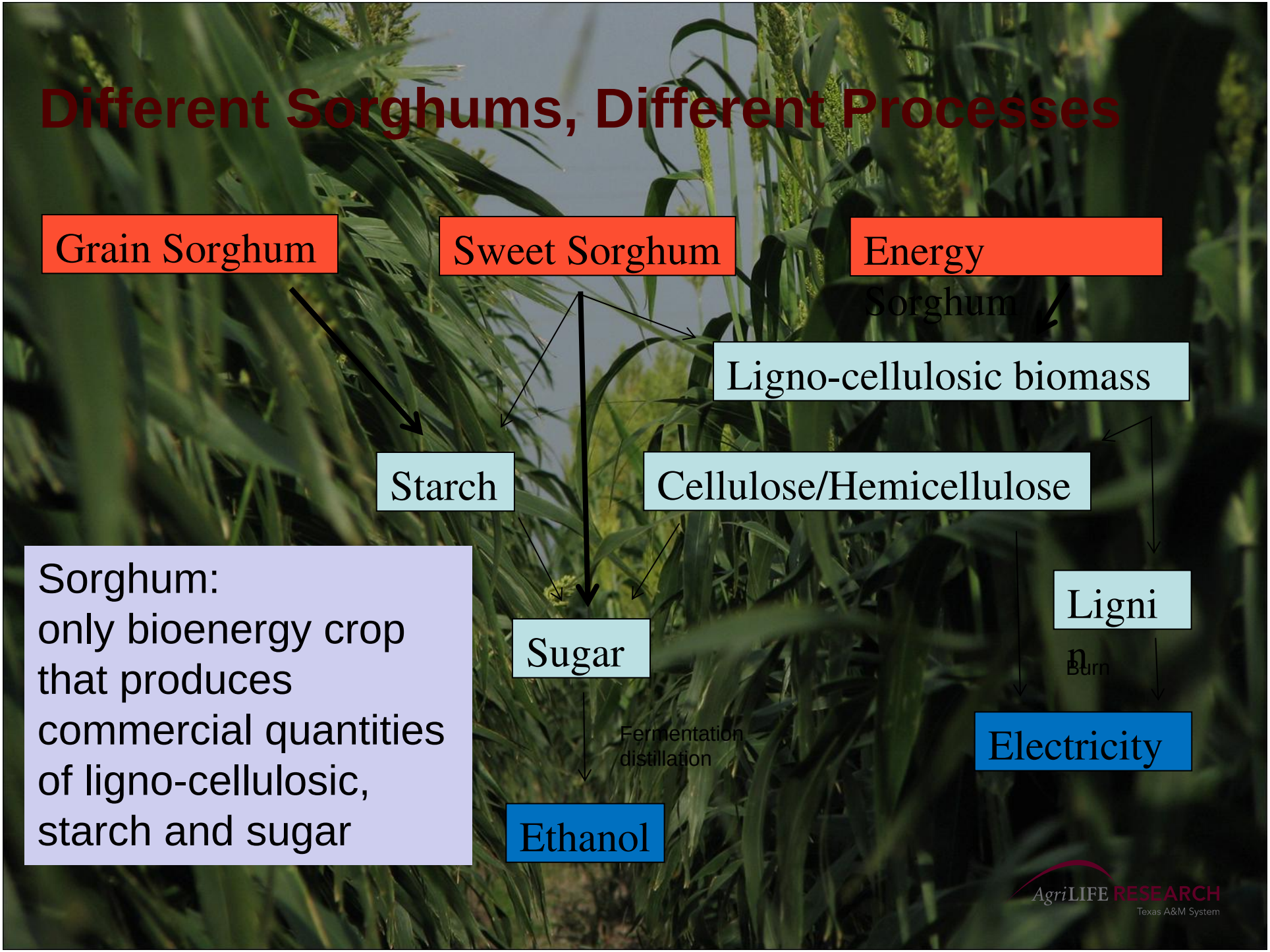
Different Sorghums – Different Uses, Carbohydrate Profiles and Total Yield

- Grain
- Forage
- Sweet
- Energy

Different Sorghums, Different Processes



Sorghum:
only bioenergy crop that produces commercial quantities of ligno-cellulosic, starch and sugar

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Sweet Sorghum Production Logistics

- Production Systems
  - use existing infrastructure
- Planting: sorghum based
- Harvest: cane based
- Process: cane based
- Seed of Sweet Sorghums
  - Cultivars
  - Hybrids
    - Forage
    - True Sweet

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Brix Values of Forage Sorghum Hybrids – Amarillo

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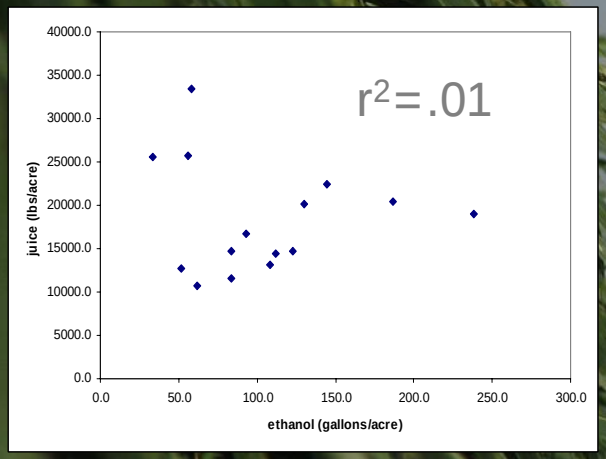
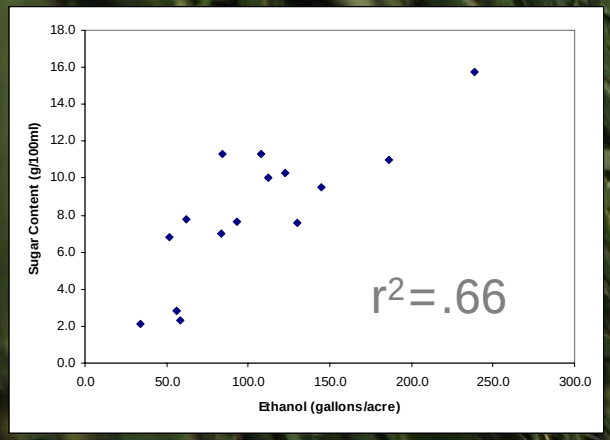
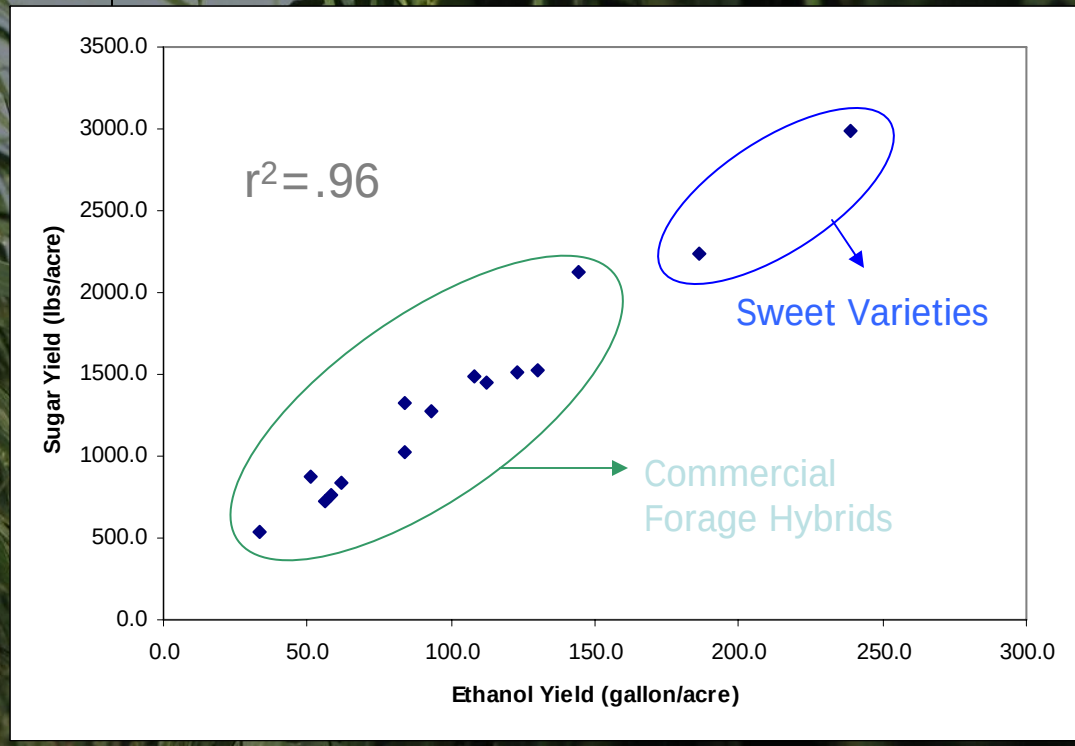
Sugar Yield: Brix and Juice

Sugar Yield = Juice (lbs/acre) * Sugar Concentration (g/100ml)







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Sweet Sorghum Hybrids

- Varieties
  - Low Seed Yield
  - Difficult to Harvest
- Need Hybrids
- Seed Parent Development
  - High Brix
  - Short Height
  - Med to High Juice Volume
  - Good Seed Production
  - Daylength Insensitive

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Sweet Sorghum Yields vary….

- Genotype
- Environment
- Harvest Time
- Biomass (t/acre)
  - 40, (0 to 70) FW
  - 10, (0 to 17.5) DW
- Grain Yield
  - 1, (.5 to 2)
- Fermentable Sugars
  - 15-20% brix
  - 65-75% purity (FS)
  - Mostly sucrose, some glucose and fructose
  - Small amounts of starch
- Sugar Yield (ton/acre)
  - 1.5, (0 to 3)
- Ratoon Crop (%1st crop)
  - 70, (30-125)

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Other Issues in Sweet Sorghum

- Sugar is not Stable Post Harvest
- Just-in-Time Harvest
  - Yield
  - Quality
  - Choice of Hybrid
- Crop produces Grain
  - Management of starch in processing
- Year round production is not likely in US
  - Sub Tropical
  - Tropical
- Logical to combine with sugarcane production

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Energy Sorghum

- Photoperiod Sensitive:
  - Reproductive growth when daylengths < 12'15'' (or lower)
- Benefits:
  - Long Canopy Duration
  - Enhanced Drought Tolerance
  - Higher Biomass Accumulation

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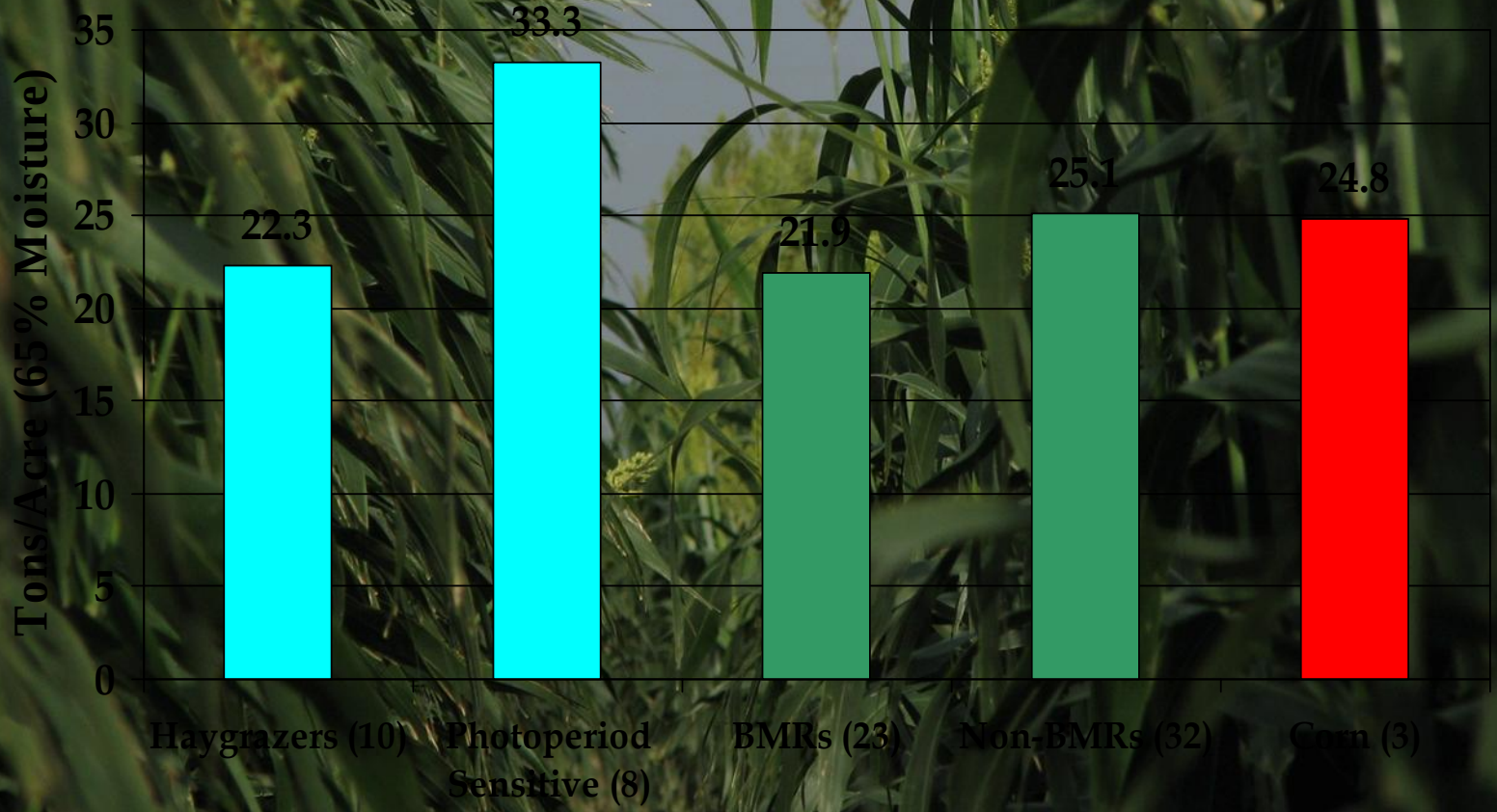
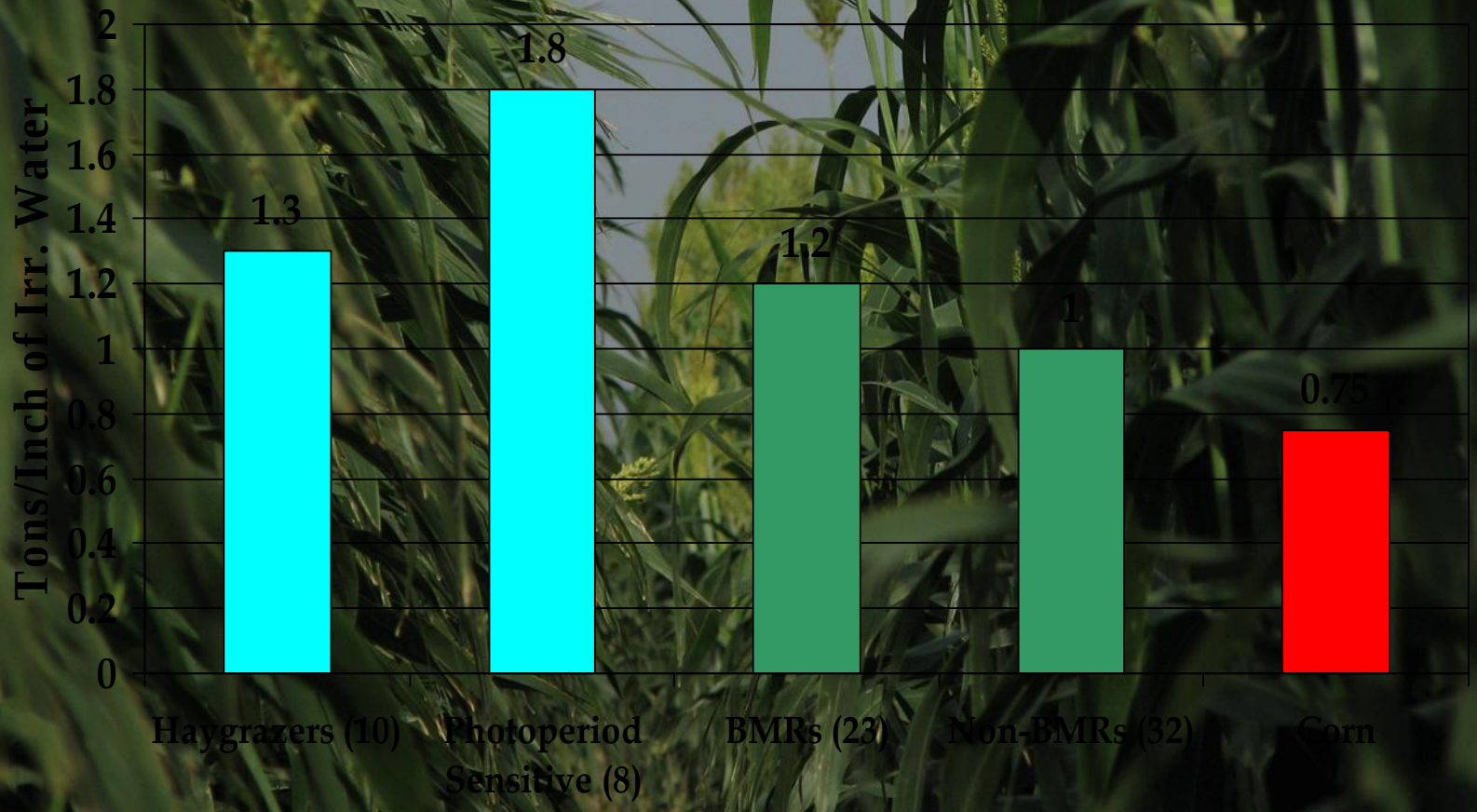
Biomass Yield Potential
Amarillo, Texas (2003-2005)



Source: B. Bean, T

Water Use Efficiency
Amarillo, Texas (2003-2005)



Source: B. Bean, TCE

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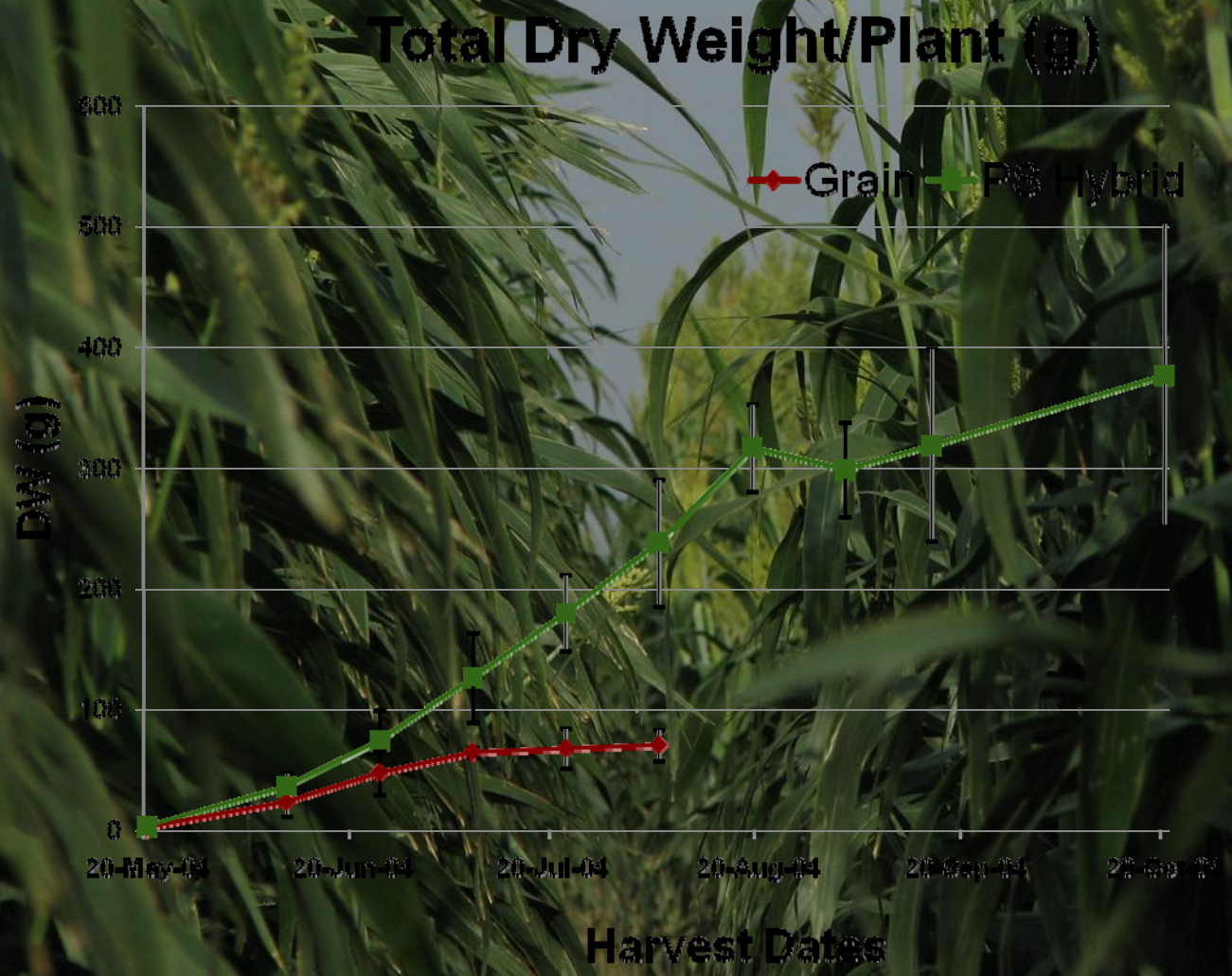
Energy Sorghum Growth Curves



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Energy Sorghum Logistics

- Lignocellulosic Biomass
- Multiple Types to minimize storage and extend season
  - Multi-cut
  - Single-cut
- Planting
  - Traditional Sorghum
- Harvest
  - Multiple Approaches
- Rainfed Production
- Storage and Processing
- Season Long Harvest
- Large Scale Testing
- New Hybrid Scale Up

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Energy Sorghum Observations

- Forage/Energy Sorghum PS Hybrids:
  - 8-10 dry T/acre
  - Animal palatability required
  - Multiple Harvest Crop
- Energy Sorghum:
  - Exp. Hybrids produce 8-14 dT/acre
  - Not selected for animal palatability
  - Single Harvest Crop
- Testing is Expanding this year….

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Composition Variation

Table 3. Descriptive statistics on the predicted bioenergy constituents for sweet and biomass studies

Constituent	SWHE† (*N*‡ = 489)			PSEX (*N* = 237)		
	Range	Mean (stdev)	# in top 5%	Range	Mean (stdev)	# in top 5%
Glucan	20.1 - 40.8	28.1 (4.2)	36	21.8 - 34.0	29.0 (2.4)	0
Xylan	7.7 - 18.3	13.7 (1.5)	0	15.3 - 21.0	17.0 (1.1)	36
Lignin	8.9 - 15.8	12.1 (1.3)	0	12.9 - 20.1	18.4 (0.9)	36
Solubles	21 - 43.2	31.5 (5.0)	36	16.8 - 37.7	23.4 (3.3)	0

SWHE, sweet heterosis study from College Station and Weslaco for 2007 and 2008;
PSEX, photoperiod-sensitive selections from College Station for 2008

‡Number of samples predicted

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Critical Research Needs

- Plant nutrition: specifically N
  - one ton of sorghum DM requires 20 lb N
- Genotype x Environment
- Harvesting technology
- Basic agronomics
- Water Management
  - Irrigated
  - Rainfed
- Cropping system sustainability

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Agronomy / Crop Production

- Seeding and harvest time:
  Goal: providing an continuous supply of feedstock
- Growth and quality curves over time
- Effect of planting date
- Effect of stockpiling feedstock in the field
- One harvest or two harvests?
- Continuous harvesting between mid-June and mid-November?

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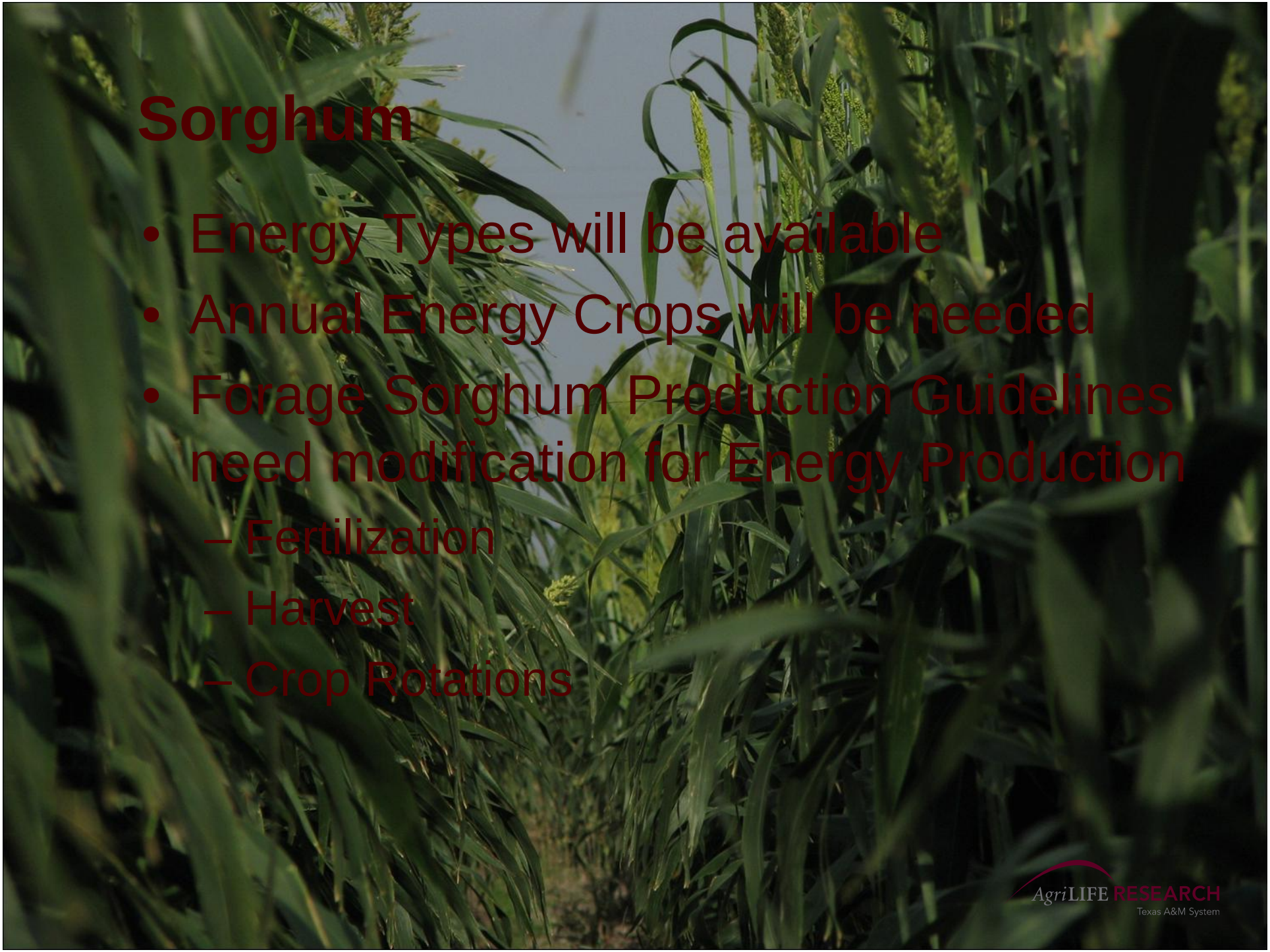
Stagger Planting in Sweet Sorghum

Umb	Della	M81	Della	M81	Umb	M81	Della	Umb	Della	Umb	M81
1304	1604	1904	2304	2604	2904	3304	3604	3904	4304	4604	4904
1303	1603	1903	2303	2603	2903	3303	3603	3903	4303	4603	4903
1302	1602	1902	2302	2602	2902	3302	3602	3902	4302	4602	4902
1301	1601	1901	2301	2601	2901	3301	3601	3901	4301	4601	4901
1204	1504	1804	2204	2504	2804	3204	3504	3804	4204	4504	4804
1203	1503	1803	2203	2503	2803	3203	3503	3803	4203	4503	4803
1202	1502	1802	2202	2502	2802	3202	3502	3802	4202	4502	4802
1201	1501	1801	2201	2501	2801	3201	3501	3801	4201	4501	4801
1104	1404	1704	2104	2404	2704	3104	3404	3704	4104	4404	4704
1103	1403	1703	2103	2403	2703	3103	3403	3703	4103	4403	4703
1102	1402	1702	2102	2402	2702	3102	3402	3702	4102	4402	4702
1101	1401	1701	2101	2401	2701	3101	3401	3701	4101	4401	4701
Umb	Della	M81	Della	M81	Umb	M81	Della	Umb	Della	Umb	M81
Plant Date											
April			May			June			July		
Predicted Harvest											
June	July	Sep	Aug	Sep	July	Sep	Sep	Aug	Oct	Sep	Oct



Sorghum

- Energy Types will be available
- Annual Energy Crops will be needed
- Forage Sorghum Production Guidelines need modification for Energy Production
  - Fertilization
  - Harvest
  - Crop Rotations

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