Value-Added Bioproducts: Biorefining Perennial Grass Biofuel Feedstocks

Yifeng Xu[1], Jamie L. Foster[2], James P. Muir[3] and Russell W. Jessup[1].
370 Olsen Blvd 2474 TAMU, Texas A&M University, College Station, TX[1];
Dept. of Soil and Crop Sciences, Texas A&M AgriLife Research, Beeville, TX[2];
Texas A&M AgriLife Research, Stephenville, TX[3].

Introduction

Biofuels produced from non-food based lignocellulosic feedstocks have potential to replace a significant percentage of fossil fuel consumption due to high biomass yield potential and suitability for cultivation on marginal lands. However, commercialization of lignocellulosic biofuels is still hampered by technology issues and decreasing oil prices. Integrated biorefinery approaches, where value-added chemicals are produced in conjunction with biofuels, offer significant potential towards overcoming this economic disadvantage.

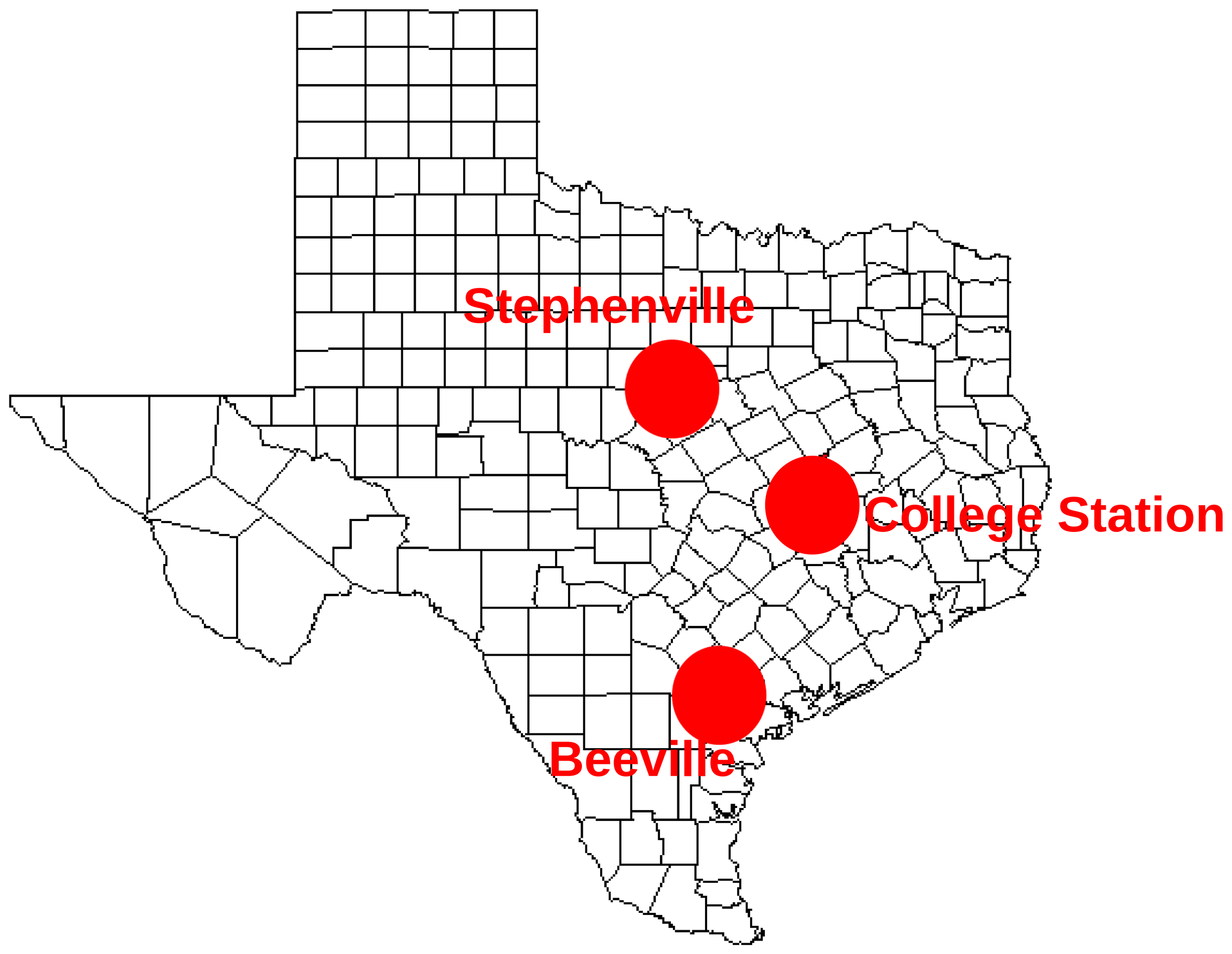
Objectives

- Characterize biomass yields and chemical composition, including hemicellulose, cellulose, acid detergent lignin, crude protein, succinic acid and biosilica concentration in diverse feedstocks.
- Characterize chemical composition including hemicellulose, cellulose, acid detergent lignin, crude protein and succinic acid concentration under drought stressed and non-drought stressed conditions in diverse feedstocks.

Materials and Methods

- Twelve plant entries include Pearl Millet-Napiergrass (PMN) hybrid, Napiergrass, Annual sorghum, Pearl millet, Perennial sorghum, Switchgrass, Sunn hemp, Giant miscanthus and Energy cane.
- Replicated plots (n=3) were planted in a completely randomized design in College Station, Beeville, and Stephenville, TX.
- Neutral detergent fiber (NDF), acid detergent fiber (ADF), acid detergent lignin (ADL) was determined successively by using an Ankom 200 Fiber Analyzer (Ankom Technologies, Macedon, NY). Nitrogen (N) was determined using an elemental analyzer (Vario Macro, Elementar, Germany) and crude protein (CP) was calculated as 6.25·N.
- Measurement of succinate or succinic acid was conducted using the Succinate (Succinic Acid) Colorimetric Assay kit (Biovision, Milpitas, California, USA).
- Silica was tested using a portable X-ray fluorescence spectrometer (DELTA Premium, OLYMPUS, Tokyo, Japan). Pellets of both Si calibration standard and dried and ground plant samples were made.

Fig 1. Field trial locations



Source: Wikimedia Commons

Fig 2. Plant entries

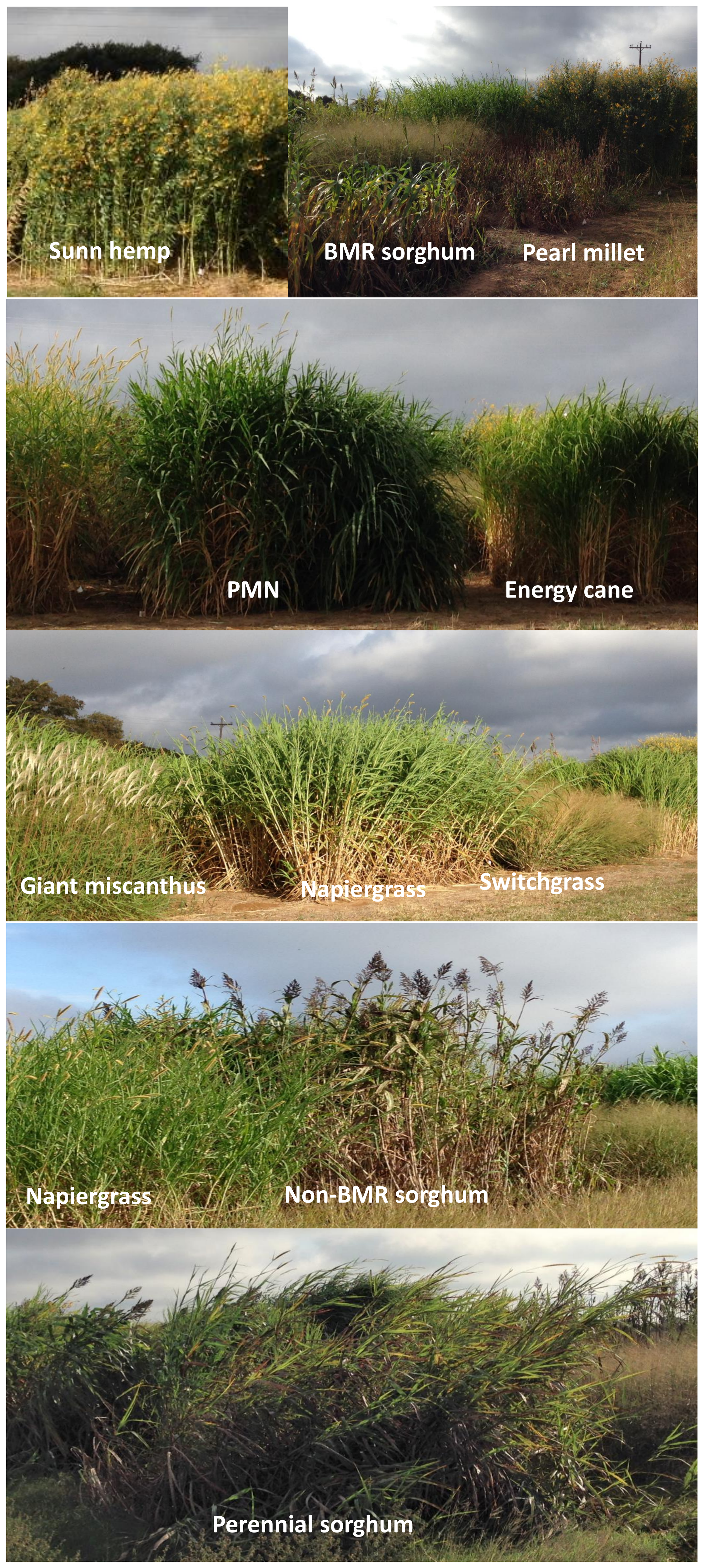
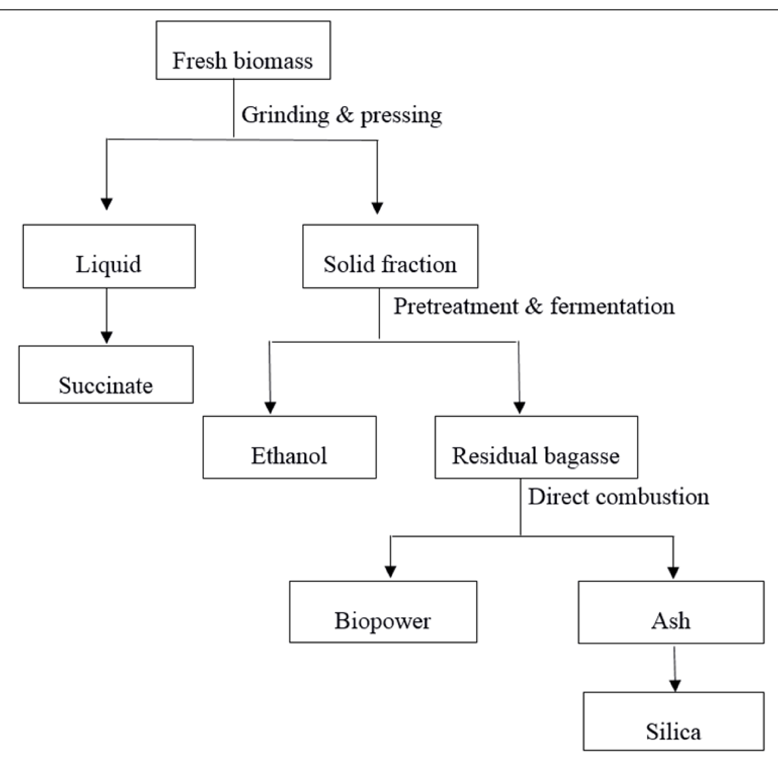


Fig 3. Pellet of dry plant sample and XRF spectrometer

Fig 4. Illustration of conceptual integrated biorefinery producing ethanol, biopower, succinate, and silica.



Results

- The silica yield of the third year PMN was the highest in College Station and Beeville (Table 1a). And in Stephenville, even in its first year, the PMN possessed the highest silica yield, with similar silica yield from one napiergrass accession and the energy cane.
- The third year PMN had the highest succinate yield (kg ha-1) at College Station and Beeville (Table 1b). At Stephenville, PEPU 09FL03 had the highest succinate yield, while the first year PMN and the energy cane was equivalent.
- For the potential integrated biorefinery production, the PMN had the highest overall ranking, followed by energy cane and napiergrass cultivars (Table 2).

Table 1. Bioproduct yield at Stephenville, College Station and Beeville.

a. Silica yield (kg ha^{-1})

	Means		
Entry	Stephenville	College Station	Beeville
PMN 10TX13[Y]	1281 a[Z]	3249 a	2211 a
Merkeron[X]	631 abc	645 b	825 b
PEPU 09FL03[W]	1264 ab	311 b	639 b
PEPU 09FL01[W]	627 abc	247 b	494 b
BMR sorghum[V]	468 abc	238 b	412 b
SX-17[U]	577 abc	175 b	473 b
BMR pearl millet[T]	212 c	53 b	41 b
PSH 09TX15[S]	542 abc	200 b	559 b
Alamo switchgrass	350 bc	178 b	181 b
Tropical Isle Sunn Hemp	144 bc	90 b	-
Giant miscanthus (Mxg)	198 c	106 b	100 b
Energy cane[R]	1008 abc	518 b	613 b

b. Succinate yield (kg ha^{-1})

	Means		
Entry	Stephenville	College Station	Beeville
PMN 10TX13[Y]	236 a[Z]	370 a	556 a
Merkeron[X]	188 ab	77 b	145 b
PEPU 09FL03[W]	271 a	65 b	143 b
PEPU 09FL01[W]	153 ab	33 b	116 b
BMR sorghum[V]	74 ab	13 b	44 b
SX-17[U]	111 ab	17 b	99 b
BMR pearl millet[T]	53 ab	3 b	3 b
PSH 09TX15[S]	84 ab	13 b	89 b
Alamo switchgrass	87 ab	29 b	55 b
Tropical Isle Sunn Hemp	198 ab	81 b	-
Giant miscanthus (Mxg)	24 b	8 b	12 b
Energy cane[R]	248 a	50 b	86 b

Z Means within a column under each main factor followed by the same letter are not significantly different according to All Pairs, Turkey HSD. Y Pearl millet napiergrass hybrid PMN 10TX13. X Napiergrass cultivar Merkeron. W Napiergrass accession. V SDH2942 BMR sorghum. U Annual sorghum SX-17 cultivar. T Exceed BMR pearl millet. S Perennial sorghum hybrid PSH 09TX15. R Energy cane unknown accession.

Table 2. Summary ranking of potential across twelve candidate feedstocks.

	Biorefinery rank					
Entry	Cellulose[Z]	Hemicellulose	Lignin	Succinate	Si	Overall
PMN 10TX13[Y]	1	1	12	1	1	1
Merkeron[X]	3	3	9	4	3	3
PEPU 09FL03[W]	5	4	10	2	4	4
PEPU 09FL01[W]	6	6	8	6	6	5
BMR sorghum[V]	10	10	3	10	8	10
SX-17[U]	7	7	6	8	7	8
BMR pearl millet[T]	11	11	1	11	12	11
PSH 09TX15[S]	8	8	5	7	5	7
Alamo switchgrass	9	9	4	9	9	9
Tropical Isle Sunn Hemp	2	5	11	3	11	5
Giant miscanthus (Mxg)	12	12	2	12	10	12
Energy cane	4	2	7	5	2	2

[Z] All the traits were ranked based on their yield (kg ha^{-1}). The feedstock entry that had the highest yield was ranked first for cellulose, hemicellulose, succinate and silica yield. However, the feedstock entry that had the lowest yield was ranked first for lignin yield. The feedstock entry with the smallest total was ranked first overall. [Y] Pearl millet napiergrass hybrid PMN 10TX13. [X] Napiergrass cultivar Merkeron. [W] Napiergrass accession. [V] SDH2942 BMR sorghum. [U] Annual sorghum SX-17 cultivar. [T] Exceed BMR pearl millet. [S] Perennial sorghum hybrid PSH 09TX15. [R] Energy cane unknown accession.

Conclusions

- Noting the importance of cellulose and hemicellulose fractions towards ethanol conversion, PMN, napiergrass and energy cane had superior performance.
- For biosilica and succinate, the highest yields were also found in PMN, napiergrass and energy cane. Sunn hemp was superior for succinate production; however, its silica yield was low. Thus, PMN, napiergrass and energy cane appear to have the highest potential for utilization in the proposed biorefinery.
- With PMN being planted via seed and subsequently sterile in production fields, it provides a more economical feedstock with less invasiveness potential compared to napiergrass and energy cane.