Multi-year study on field application of sugarcane bagasse biochar

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Presentation Layout

- Sugarcane production
- Problem Statement
- Biochar manufacture
- Field Set-up and Harvest
- Biochar Characterization
- Biochar Field Harvest Results
- Conclusions
- Future Work

Sugarcane Trivia

- Sugarcane *(Saccharum)* is a tall perennial grass.
- Native to both warm temperate, sub tropical and tropical regions, grown in more than 90 countries.
- Cultivars are complex hybrids and one of most efficient photo-synthesizers in plant kingdom.
- Fibrous stalks grow 2 to 4 m tall and accumulate sucrose.
- Sugarcane is world's largest crop by production quantity with 64 million acres and annual production of 1.83 billion tons, generating 280 MMT biomass residues.
- Brazil, India, China, Thailand, Pakistan & Mexico, U.S. is 10th with 1.6% of total.
- Cane accounts for 80% of sugar produced.

Louisiana Sugarcane Production

- 11 operating sugar factories
- 420,000 acres of sugarcane, world's northernmost sugarcane crop, covering 22 Louisiana parishes
- 13 M tons sugarcane processed; 1.4 M tons raw sugar produced (1/2 LA Superdome)
- Major part of LA economy: $2 billion industry, 17,000 employees
- High fiber energy cane




Pictures courtesy of the American sugarcane League

Meanwhile, in the last 40 years…

LOUISIANA SUGARCANE INDUSTRY PRODUCTION DATA 1974 TO 2015

Crop Year	ACREAGE		SUGAR PRODUCTION			CANE PRODUCTION		YIELD	MOLASSES	INDUSTRY	
	Total Planted	Harvested For Sugar	Sugar Raw Value	Sugar Per Acre	Per Gross Ton	Gross Cane Ground	Gross Cane Per Acre	Recover Per Gross Ton	80 Brix	Number of Farms	Number of Mills
	acres	acres	short tons	pounds	pounds	tons	tons	%	gallons	#	#
1974	322,455	307,722	593,922	3,860	157	7,566,270	24.6	7.85	41,956,517	1,180	37
1975	330,861	308,000	643,652	4,180	157	7,273,509	23.6	8.85	40,361,988	1,214	36
1976	328,011	291,000	644,800	4,432	177	8,599,287	29.6	7.50	47,060,076	1,178	34
1977	323,633	304,000	668,175	4,392	150	8,327,441	27.4	8.02	43,501,022	1,103	33
1978	288,847	268,000	550,352	4,107	160	6,112,517	22.8	9.00	31,413,562	977	28
2009	421,000	391,000	1,449,575	7,415	208	13,967,304	35.7	10.38	71,419,876	510	11
2010	420,000	390,000	1,401,145	7,184	231	12,111,932	31.1	11.56	68,051,613	510	11
2011	408,000	381,000	1,405,313	7,387	236	11,916,887	31.3	11.80	69,522,277	490	11
2012	427,000	397,000	1,706,687	8,629	232	14,722,225	37.2	11.59	79,220,681	475	11
2013	440,000	409,000	1,589,367	7,771	227	14,035,540	34.3	11.32	73,641,752	475	11
2014	413,000	380,000	1,509,768	7,963	237	12,760,857	33.6	11.83	70,292,829	451	11
2015	410,000	382,000	1,417,633	7,413	222	12,756,470	33.4	11.10	64,189,200	450	11

92 %

69 %

36 %

From ASCL 2016, USDA/NASS & LA Cooperative Extension Service

The leftovers…



- Major by-products of crystalline sucrose manufacture from cane:
  - sugarcane molasses and bagasse (factory); 4 M tons; 20% surplus (0.8 M t)
  - sugarcane extraneous leafy material (field); ~ 6 dry t/acre, 2.5 M t Louisiana
- Minor by-products of crystalline sucrose manufacture from cane:
  - fly ash, filter cake, lime and calcium carbonate residues
- Bagasse: most important by-product by volume (50% MC), primary source of fuel – steam & electricity generation to operate sugarcane factories
- Commercially-viable value-added products:
  - animal feed, mulch, fuel, biochar, particle board, 2nd gen. biofuels






Pictures taken from: afdc.energy.gov; bioenergyconsult.com; tower.co.za; energy.agwired.com

From Trash to Treasure - Why residues?

- Plentiful, cheap and renewable resource
- Contain “intrinsic properties”
- Liability to growers and processors

- Adding value by locally converting sugarcane bagasse and leaf trash into biochars via thermo-chemical pyrolysis and bring back to fertilize the soil.
- Possibly realize profits for growers, factories and refineries while helping to protect the environment and public health.

USDA

Biochar Production

sugarcane bagasse

sugarcane trash

Mill

< #10 mesh

milled feedstock

N_2

650°C; 1 hr

Pyrolysis

syn-gas

bio oil

Screen/sieve

Biochar

Field Study

- Feedstock: sugarcane leaf residue & bagasse, fly ash.
- Soil: Cancienne silt loam under continuous sugarcane production (> 40 yr), 101 km SW New Orleans.
- Field: In 2013, single seed cane applications in-furrow before soil covering. Fertilizer N (112 kg.ha-1), K (67 kg ha-1) applied each Spring. Pest management according to BMPs.
- Treatments: BG or TR biochar at either 800 or 1,600 kg.ha^{-1}; FA at either 630 or 1,260 kg.ha^{-1}; control: no treatment; 4 reps.
- Harvest: millable stalks counted each year (2014-17). Ten stalks cut per plot, weighed, crushed. Juice extracted, analyzed for % Brix and % sucrose. Yields calculated using stalk counts (ha^{-1}), fresh weight (kg.stalk^{-1}), and TRS (kg sucrose.t^{-1} cane).

Biochar Set-up

Biochar Application and Sugarcane Planting

Biochar Application and Sugarcane Planting

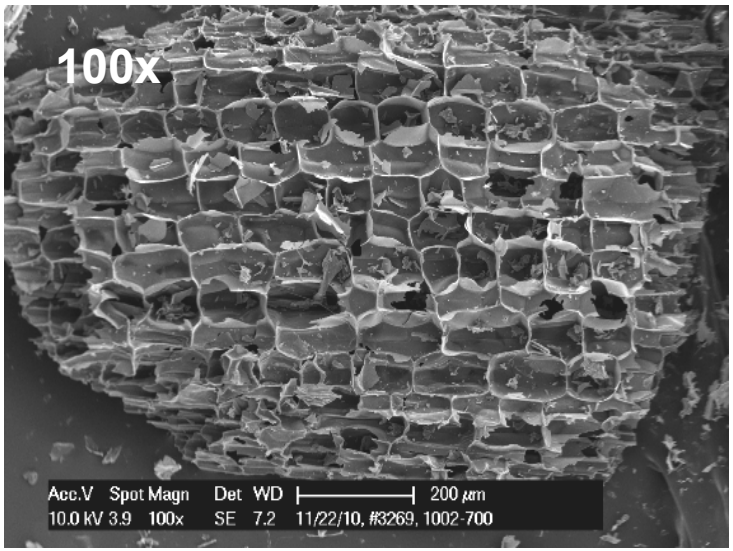
Row Cover and Sugar Cane Growth Check

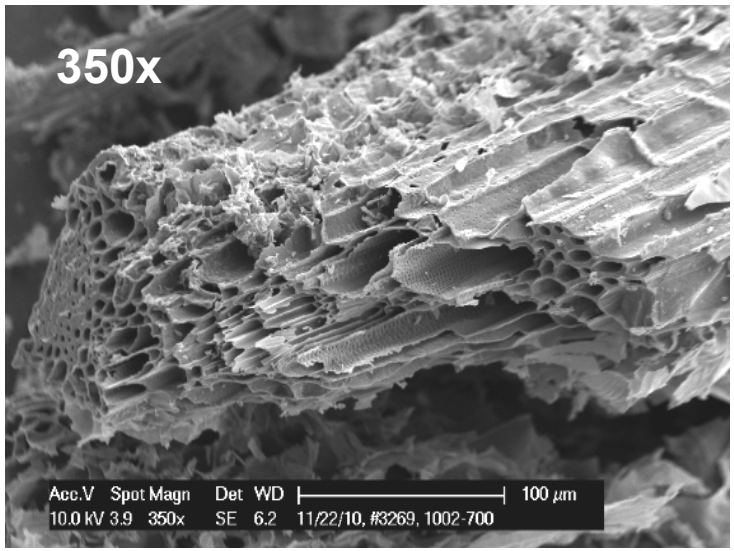
Sugar Cane Harvest

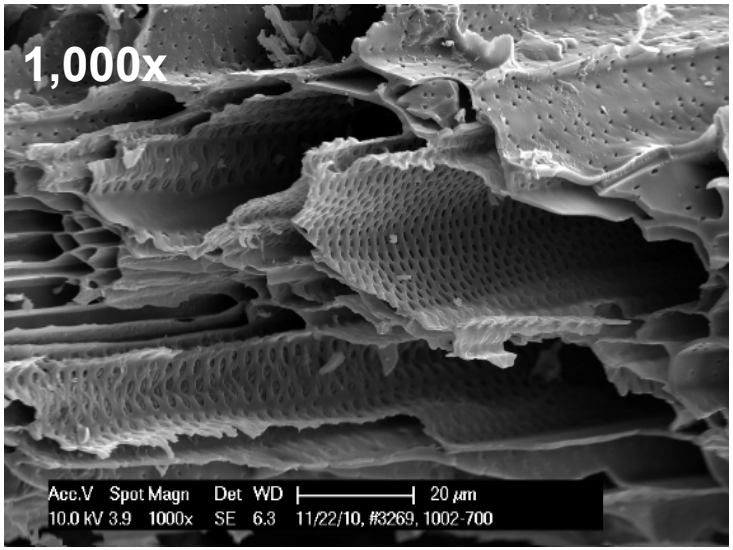
Sugar Cane Preparation

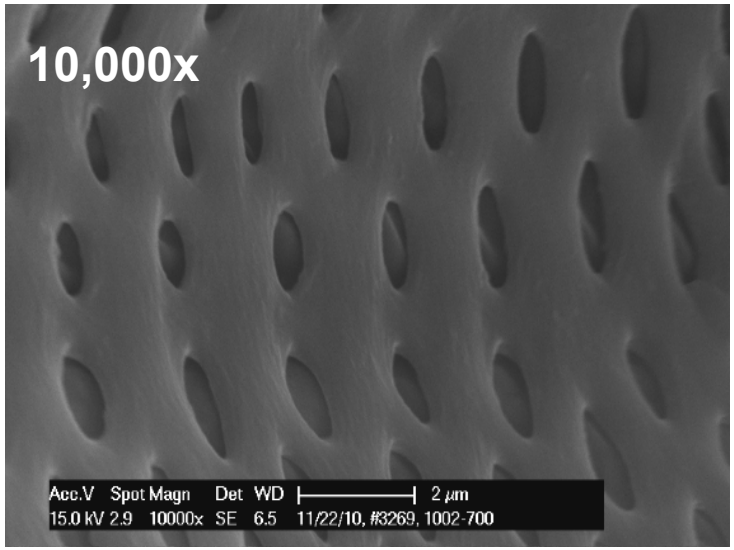
Sugar Cane Juice Extraction

SEM Micrographs - Biochar from Trash Residue

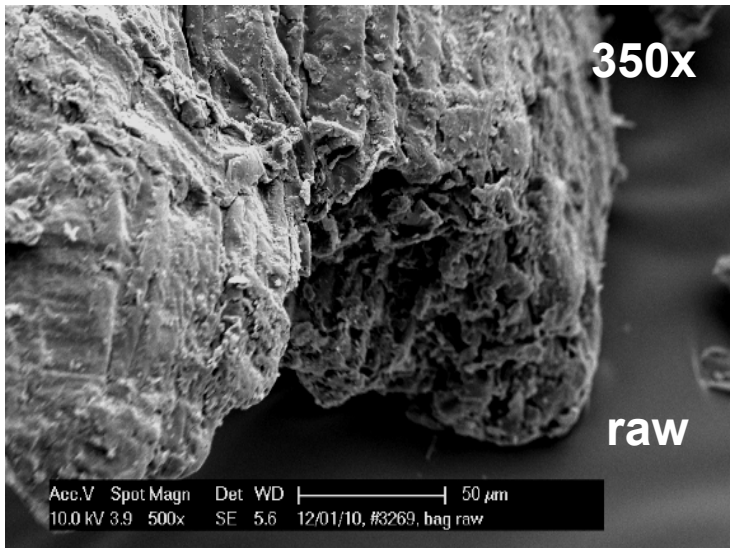


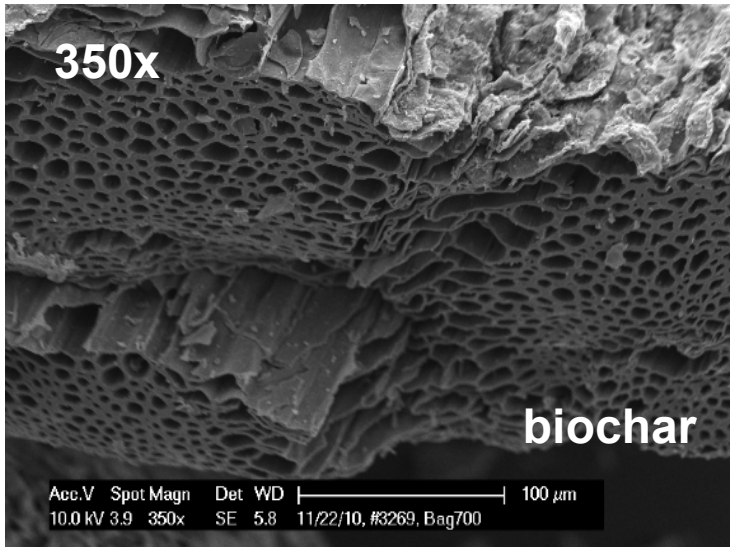


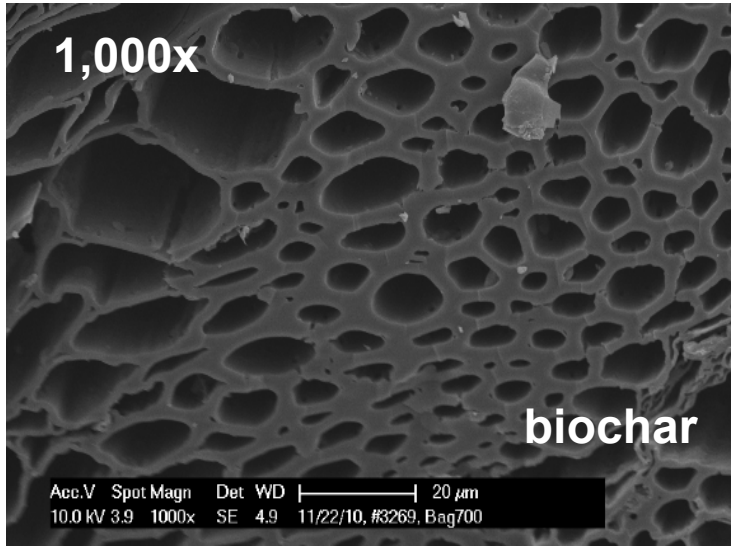




SEM Micrographs - Biochar from Bagasse







Biochar Physico-Chemical Properties

	Yield %	Surf. Area m^2/g	pH	Density g/cm^3	C %	O %
Leaf Trash	-	-	-	-	45.8	22.5
BC	40.9±1.7	22.5±11.5	9.65±0.03	0.095	45.9	0.6
Bagasse	-	-	9.65±0.03	-	43.7	37.7
BC	35.4±1.1	148±11	7.94±0.01	0.228	59.4	3.3
Fly Ash	-	Negl.	10.5±0.08	0.415	-	-
Soil			**6.7**	**1.25**		

Proximate Analysis

Sample		C_{vol} %	C_{fixed} %	Ash %	HHV BTU/lb
Leaf Trash	raw	74.7	19.3	6.0	7922
	biochar	10.8	59.8	29.4	9713
Bagasse	raw	75.0	15.6	9.4	7367
	biochar	10.1	63.8	26.1	10291
Fly Ash		5.43	4.31	90.3	716

Carbonization ⇨ growth of aromatic structures & polymerization reactions ⇨ carbon enrichment & development of porosity as VM is removed

Biochar Composition - Select Elements ($mg.g^{-1}$)

Sample	P	Mn	Ca	K	Fe
Leaf Trash	0.90 ± 0.04	0.12 ± 0.01	4.31 ± 0.26	8.91 ± 0.46	2.59 ± 0.84
BC	2.53 ± 0.06	0.20 ± 0.00	11.9 ± 0.4	23.9 ± 0.7	2.25 ± 0.32
Bagasse	0.23 ± 0.00	0.06 ± 0.00	0.98 ± 0.21	1.79 ± 0.06	1.07 ± 0.00
BC	1.07 ± 0.02	0.26 ± 0.02	6.88 ± .22	8.65 ± 0.27	6.89 ± 0.63
Fly Ash	3.12 ± 0.09	0.03 ± 0.00	0.03 ± 0.00	19.4 ± 0.04	12.8 ± 1.22

Yield Results, All Treatments

Cane Yield (ton/ha)

Effect	Num DF	Den DF	F Value	Pr > F
trt	14	180	1.87	0.0325
year	3	180	8.59	<.0001
trt*year	42	180	0.47	0.9973

Obs	trt	Estimate	Error	Group
1	tra1	57.4	2.38	A
2	bag2	55.8	2.38	AB
3	tra2fa1	55.2	2.38	AB
4	bag1fa2	54.6	2.38	AB
5	bag2fa1	53.7	2.38	AB
6	bag2fa2	53.5	2.38	AB
7	bag1fa1	52.9	2.38	ABC
8	tra1fa1	51.9	2.38	ABCD
9	tra1fa2	51.4	2.38	ABCD
10	bag1	51.1	2.38	ABCD
11	tra2fa2	50.6	2.38	BCD
12	fa2	49.9	2.38	BCD
13	fa1	49.2	2.38	BCD
14	tra2	46.8	2.38	CD
15	control	45.6	2.38	D

TRS (Kg/ton)

Effect	Num DF	Den DF	F Value	Pr > F
trt	14	177	1.98	0.0219
year	3	177	95.49	<.0001
trt*year	42	177	0.76	0.8531

Obs	trt	Estimate	Error	Group
1	fa2	210.81	3.61	A
2	tra2	207.97	3.61	AB
3	fa1	206.07	3.61	ABC
4	bag2fa1	205.29	3.61	ABCD
5	bag1fa1	205.00	3.61	ABCD
6	tra2fa2	203.27	3.61	ABCDE
7	tra1fa1	202.35	3.61	ABCDE
8	tra1	201.62	3.61	ABCDE
9	bag1fa2	200.60	3.61	BCDE
10	tra1fa2	199.78	3.61	BCDE
11	bag1	198.37	3.61	BCDE
12	bag2fa2	197.43	3.61	CDE
13	tra2fa1	195.93	3.61	DE
14	bag2	195.88	3.61	DE
15	control	193.99	3.61	E

Sugar Yield Results (t/ac), Subgroups

- *control = control*
- *bagasse = bag1, bag2, bag1fa1, bag1fa2, bag2fa1, bag2fa2*
- *flyash = flyash1 and 2*
- *trash = same as bagasse*

Effect	Num DF	Den DF	F Value	Pr > F
trt	3	221	3.98	0.0087
year	3	221	0.30	0.8236
trt*year	9	221	1.30	0.2375

Obs	trt	Estimate	Error	Group
1	bagasse	10723	219.3	A
2	trash	10497	219.3	A
3	fly ash	10318	219.3	A
4	control	8787	219.3	B

- *Treatments: tra1, tra2, fa1, fa2, bag1, bag2, control*

Effect	Num DF	Den DF	F Value	Pr > F
trt	6	81	3.00	0.0106
year	3	81	0.44	0.7272
trt*year	18	81	1.12	0.3468

Obs	trt	Estimate	Error	Group
1	tra1	11572	713.28	A
2	bag2	10987	713.28	AB
3	fa2	10477	713.28	AB
4	fa1	10160	713.28	ABC
5	bag1	10128	713.28	ABC
6	tra2	9712	713.28	BC
7	control	8787	713.28	C

- *treatments tra1, bag1, fa1, vs control*

Effect	Num DF	Den DF	F Value	Pr > F
subtrt	3	45	7.16	0.0005
year	3	45	0.38	0.7667
year*subtrt	9	45	1.77	0.1001

Obs	trt	Estimate	Error	Group
1	trash	11572	767.72	A
2	fly ash	10160	767.72	B
3	bagasse	10128	767.72	B
4	control	8787	767.72	C

- *treatments tra2, bag2, fa2, vs control*

Effect	Num DF	Den DF	F Value	Pr > F
subtrt	3	45	2.96	0.0421
year	3	45	0.10	0.9572
year*subtrt	9	45	1.14	0.3554

Obs	trt	Estimate	Error	Group
1	bagasse	10987	606.42	A
2	fly ash	10477	606.42	A
3	trash	9712	606.42	AB
4	control	8787	606.42	B

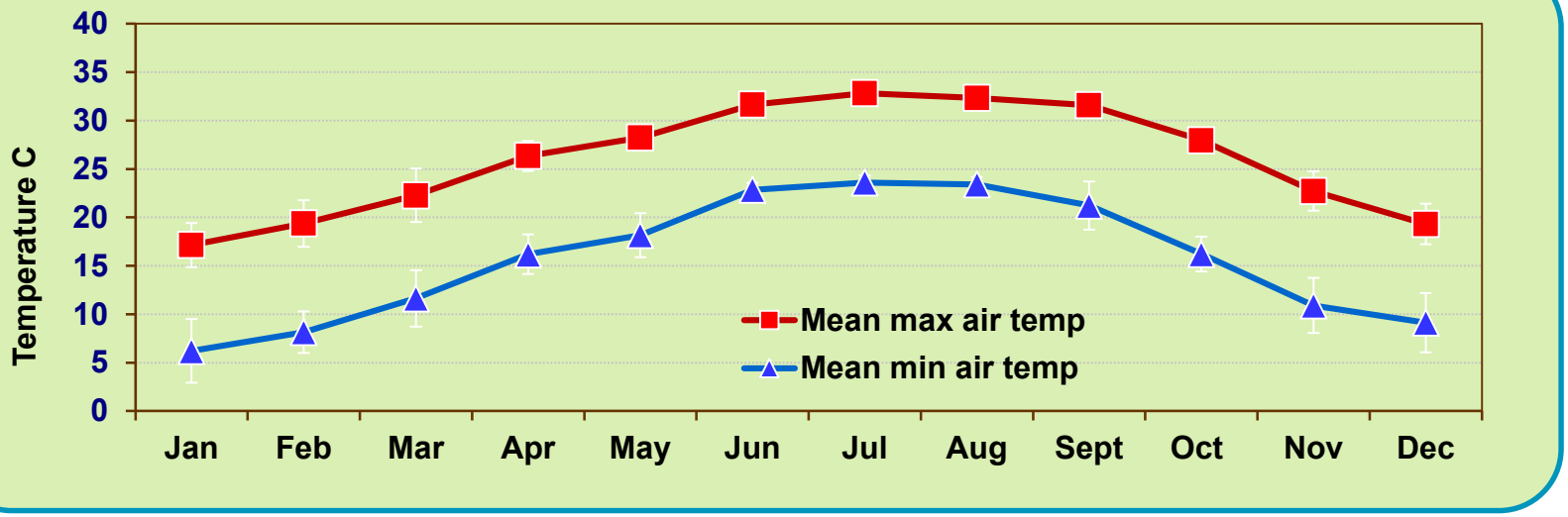
Overall Trends

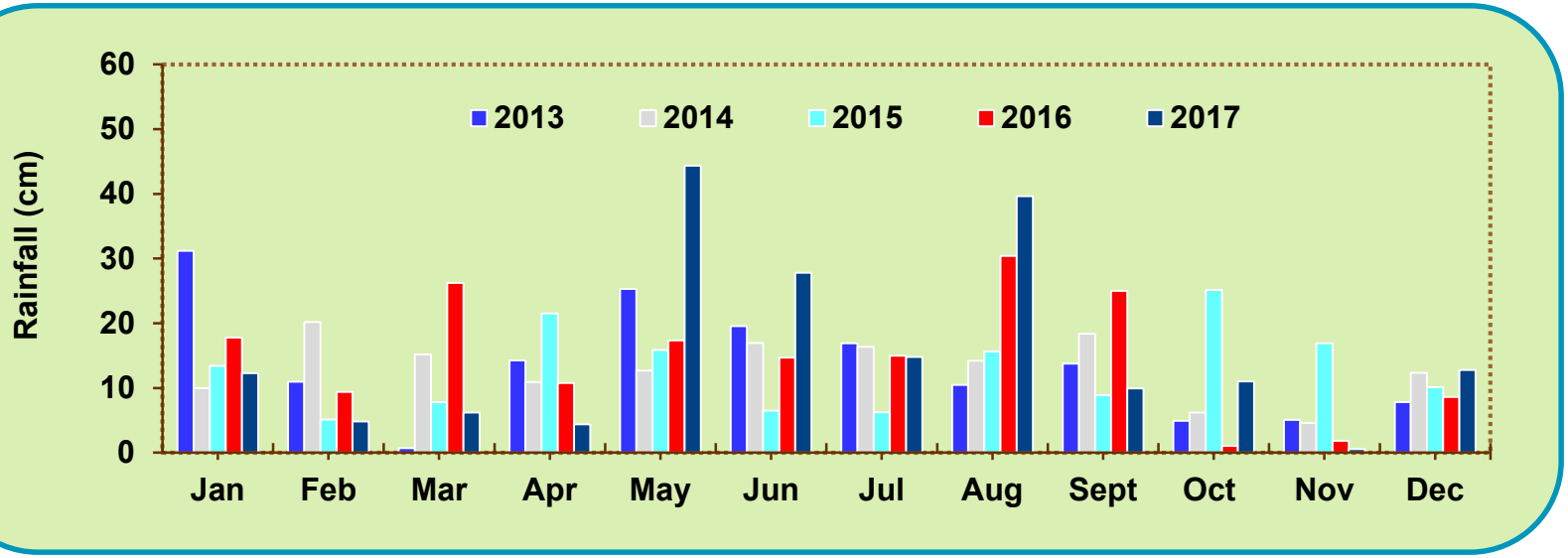
- ✓ *Data represent means of four crop years (2014-2017) of harvested sugar cane.*
- ✓ *TR = Trash biochar; BG = bagasse biochar; FA = fly ash*

Treatment	Millable stalks (ha^{-1})	Sugarcane yield (ton ha^{-1})	TRS (kg Mg^{-1})	Sucrose yield (kg ha^{-1})
Control	**87,500** BC*	**102.4** C	**97.0** C	**9,850** C
TR 1	**96,050** A	**128.7** A	**100.8** ABC	**12,970** A
TR 2	**82,940** C	**104.9** C	**104.0** A	**10,890** BC
BG 1	**88,650** ABC	**114.5** BC	**99.2** BC	**11,350** ABC
BG 2	**94,700** AB	**125.0** AB	**97.9** C	**12,320** AB
FA 1	**87,310** BC	**110.3** C	**103.0** AB	**11,390** ABC
FA 2	**89,100** ABC	**112.0** BC	**105.4** A	**11,740** AB

- ✓ *Sugarcane yield increased following biochar and fly ash additions at two rates to soil at planting.*
- ✓ *TRS and Sucrose yield also increased for all treatments as compared to control*

Weather Patterns





Conclusions

- Biochar contributes needed nutrients to the sugarcane and builds soil organic carbon.
- Biochar addition to soil can be seen as a sustainable means to sequester carbon by increasing the recalcitrant pool of soil carbon.
- Biochar additions increased soil pH and soil fertility by providing plant macronutrients such as Ca, K, Mn and P.
- Adding biochar to the soil consistently resulted in improvements in both total sugar as well as total cane yield when compared to the control.
- Field application of TR biochar to soil increased stalk count, cane, and sucrose yield by 8,550 stalks ha-1, 26.3 t ha-1, and 3,120 kg ha-1, respectively.
- Sucrose yield for BG-2 and FA-2 treated plots was 2,470 and 1,890 kg ha-1 greater, respectively, than control plots.

Research Benefits to the LA Sugar Industry

- Envision new income streams for sugarcane growers and processors:
  - Biochar + Energy = ⇧ Yields + ⇧ $ Profits

- Utilize a sustainable soil management approach, adding carbon to soil and reducing fertilizer costs
- Valuable information for assessments of the sugar industry role in alternative energy market.

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