Understanding Humic Product Applications in Midwest Corn and Soybean and Where Improvements Could be Expected and Why

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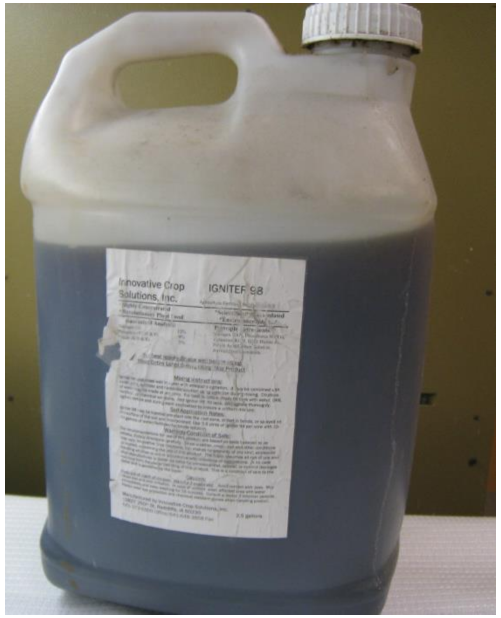
What are humic products?



Extracts of immature coals (leonardite, oxidized lignite), peats, composts.

Super-finely ground solid

Application rates of 0.4-4 gallon/ acre. Cost as low as $10/ acre.

Some can be mixed into other agrochemical applications

Literature reviews of humic product efficacy

Field studies

Strongest crop benefits in face of abiotic stresses

Calvo et al. (2014, Plant and Soil). Excellent review of all biostimulants

Canellas et al. (2015, Sciencia Horticulturae). Mix of field and greenhouse studies. Horticultural crops

Olk et al. (2017, Journal of Soils and Sediments). Knowledge gaps limiting use of humic products.

Greenhouse and Growth Chamber studies

Chen and Aviad (1990). "Humic Substances in soil and crop sciences: Selected readings."

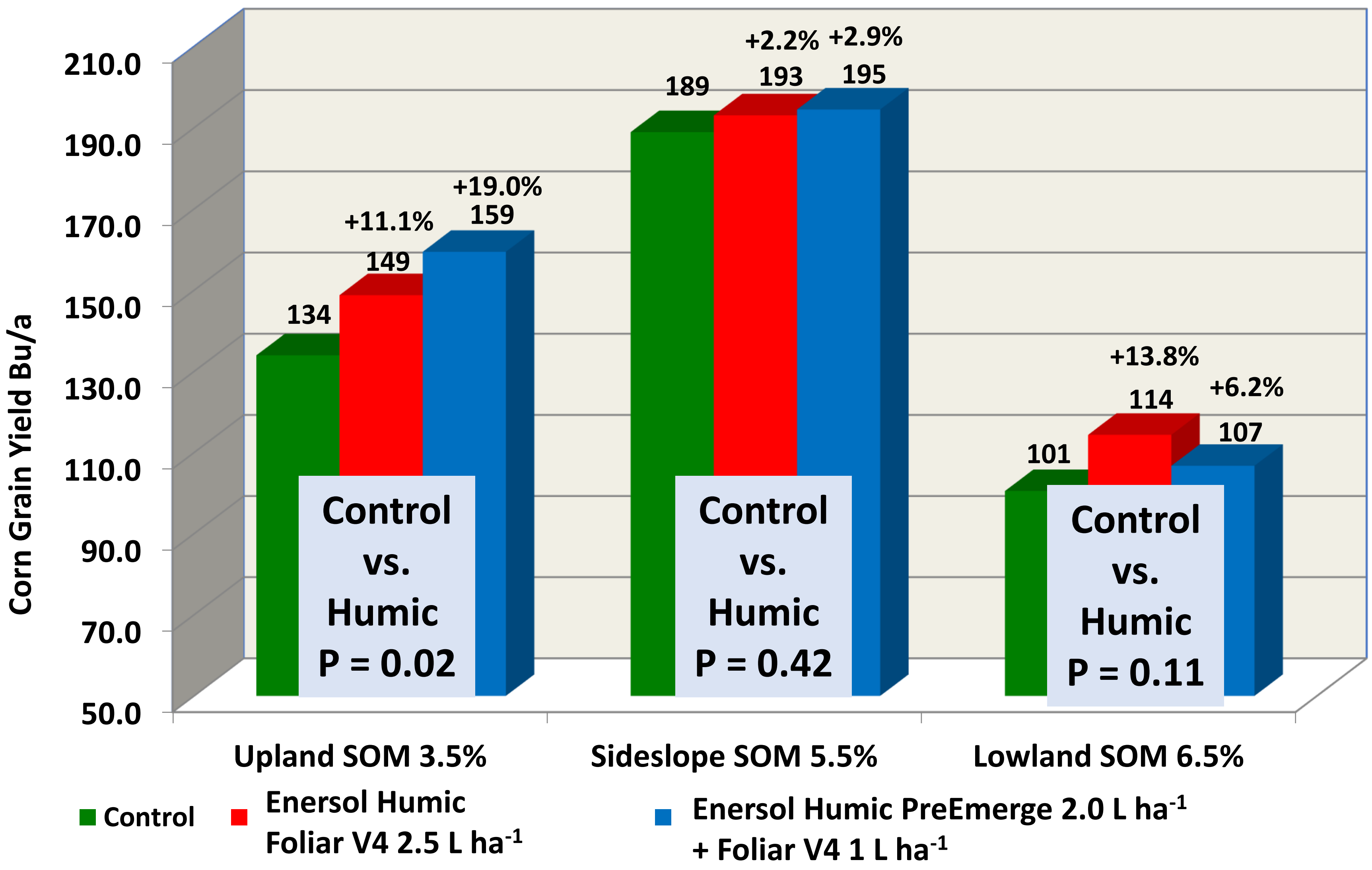
Rose et al. (2014). Advances in Agronomy.

Rainfed agriculture in Iowa: Strongest humic product responses occur with environmental stress (drought).

Landscape position	Upland	Side-slope	Lowland
Soil organic matter (%)	3.5	5.5	6.5
Soil type	Clarion	Nicollet	Webster

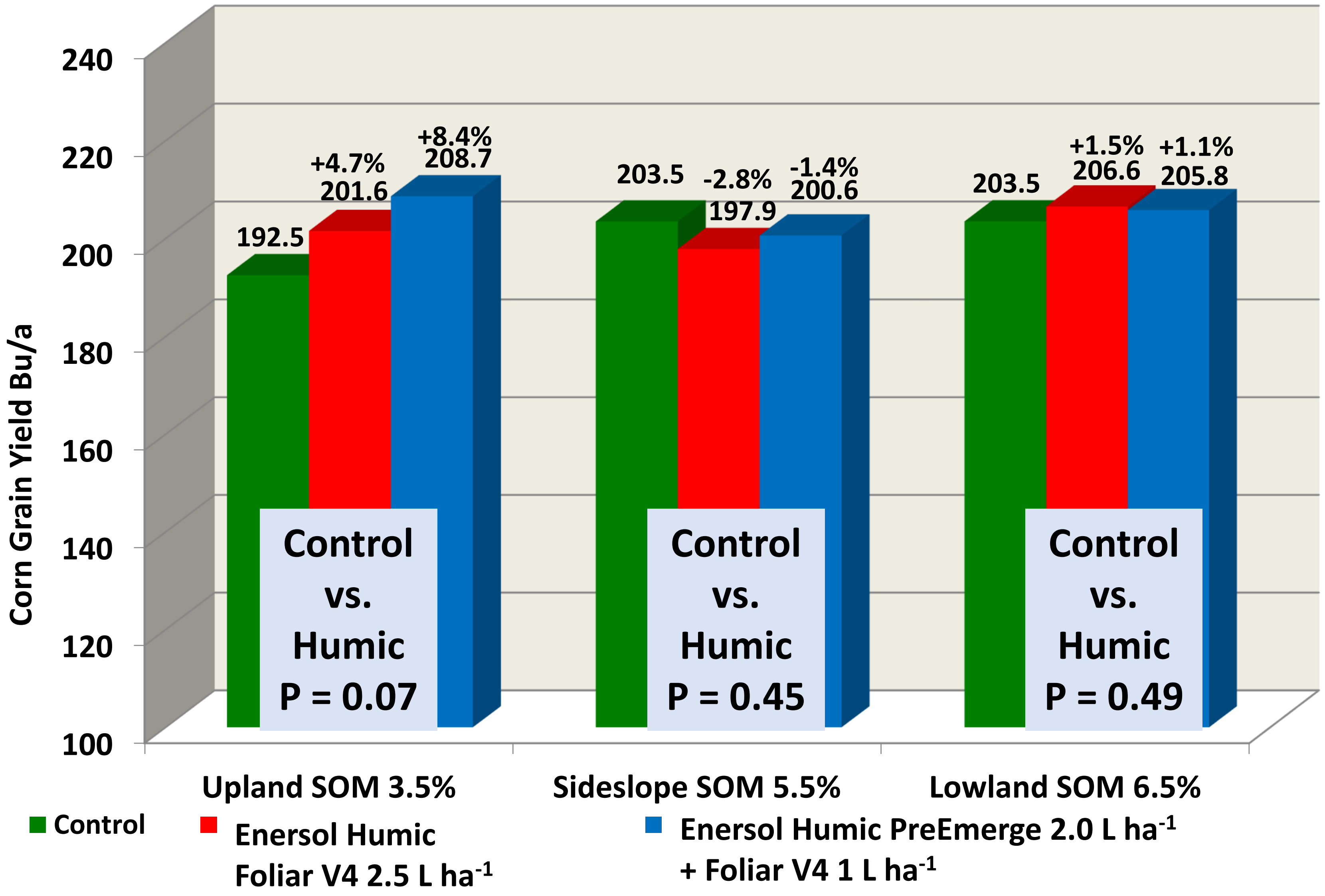
Corn Grain Yield (Combine Monitor) by Soil Type
2012 Finch Field, Ames, IA, 4 Reps

Severe Drought Year



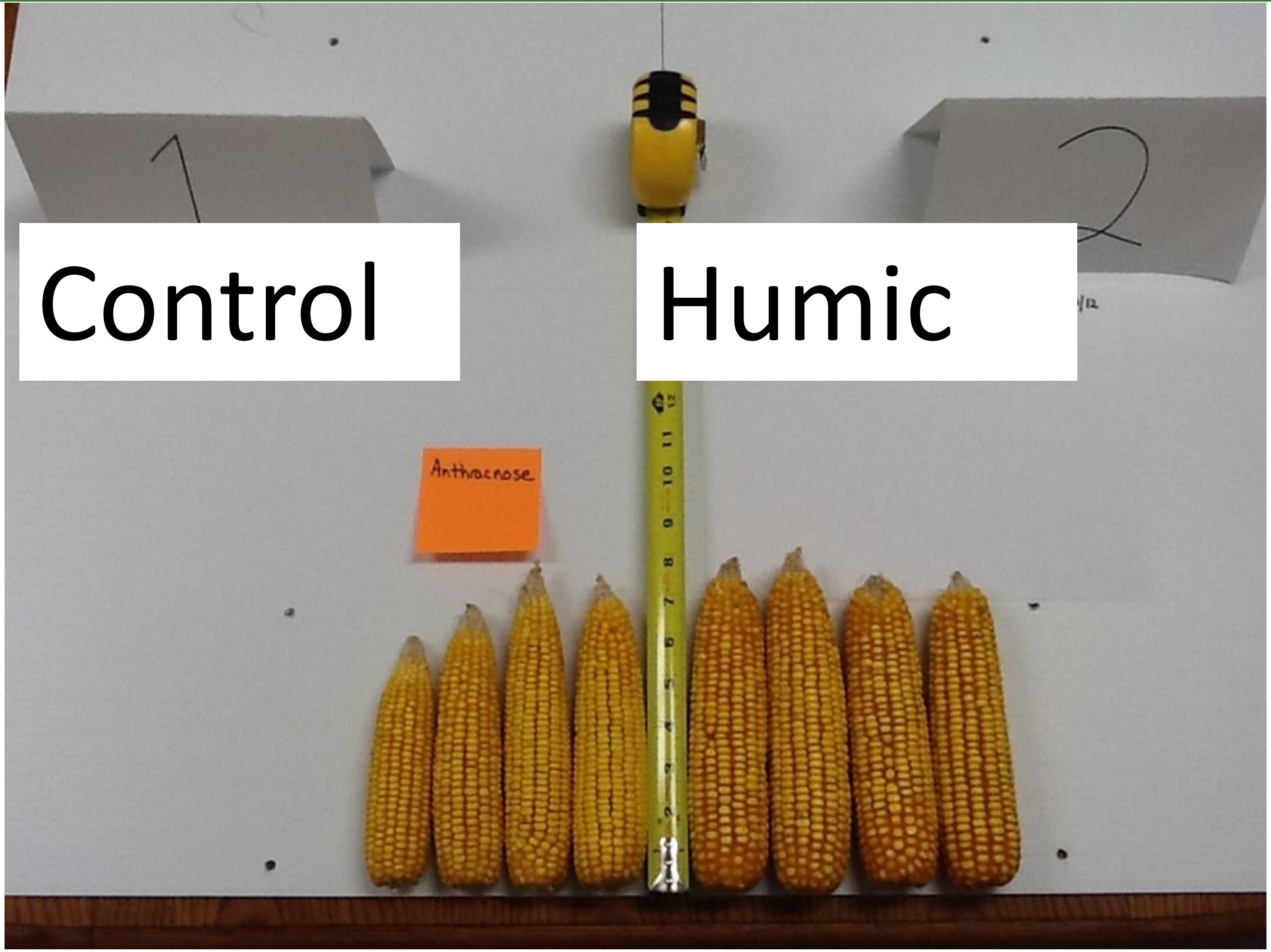
Corn Grain Yield (Combine Monitor) by Soil Type
2014 Finch Field, Ames, IA, 4 Reps

Ideal Growing Conditions



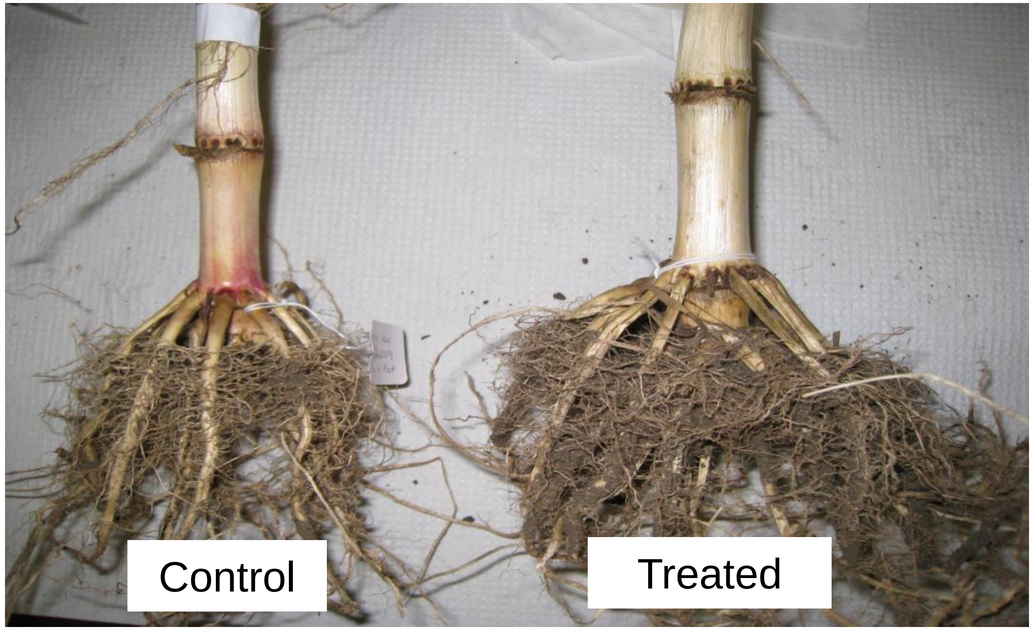
Drought stress, 2012 Finch field, Ames, IA

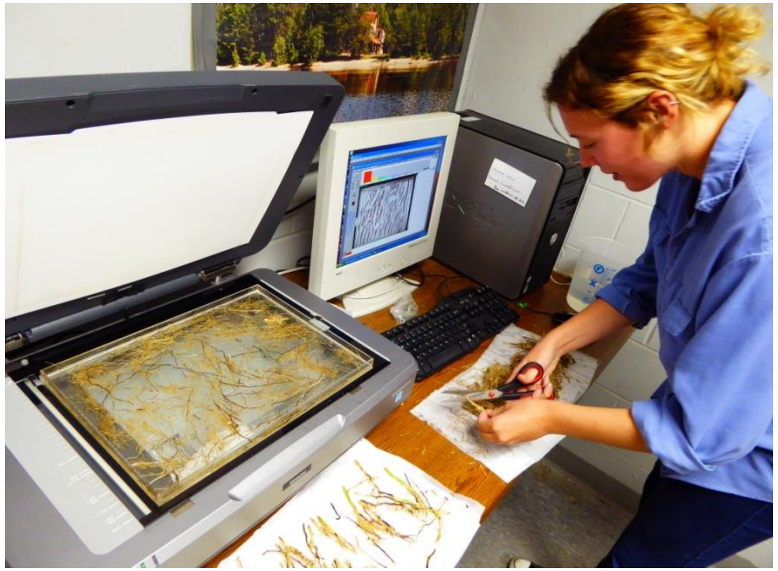
Corn Cob Length
The yield component causing grain yield responses



Primary benefit of humic product to grain yield: helping smaller corn plants compete with their bigger neighbors. This is a form of stress alleviation

Corn Root Measures (2013-2015)





Total corn root length (cm) for three plants in a 45 dm^3 soil volume at the R2 growth stage following AMCOL product at single or split application in two years.

Year	Weather		Upland soils				Lowland soils	
2013	Wet, then drought		Control	V4#	Pre + V4		Control	V4
		Total root length	21,920	28,927 (+32%)	32,831 (+50%)		ND	ND
		P level (LSD)		0.061	0.012			
2014	Near ideal	Total root length	16,718	21,186 (+27%)	18,105 (+8%)		19,083	23,225 (+22%)
		P level (LSD)		0.16	0.67			0.13

Application rates: 2.5 L ha^{-1} at V4, and 1+2 L ha^{-1} for split application at pre-emergence and V4, respectively.

MINERALS TECHNOLOGIES

Roots are the primary source of stable soil carbon

(Balesdent and Balabane, 1996; Gale and Cambardella 2000; Rasse et al., 2005; Menichetti et al., 2015)

Initial results: Benefits for soil properties:

In subsurface (5-12 inches): 10% less penetrometer resistance, increased water holding capacity

Subsoil (below 12 inches): 10% less penetrometer resistance

Wind Stress and Corn Biochemistry

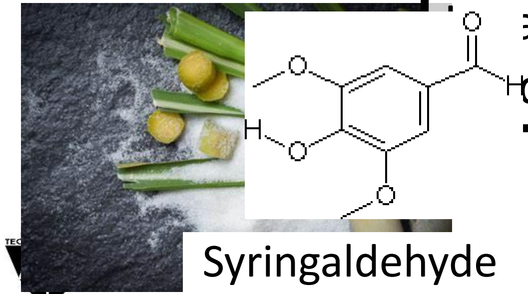
Humic Product Treated

Untreated 16 Border Rows

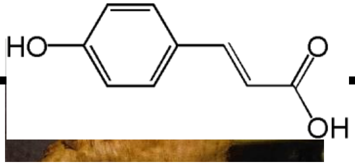
Corn plant biochemical responses to a humic product in two farmer's fields, by year.

Year	Weather	Lignin-phenols (11)		Non-glucose Carbohydrates (4)	
		Stover	Roots	Stover	Roots
2013	Wet , then Drought	0	+9 to +28% P=0.09 and 0.24	0	0
2014	Wet , then Ideal	-6% and -11% P=0.10 and 0.32	0	0	+10 to +38% P=0.02 and 0.005

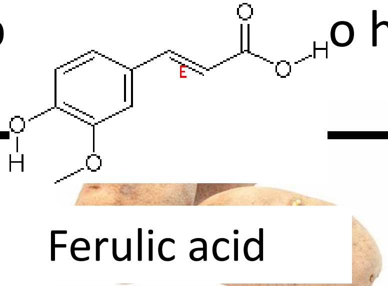
arbohydrate production the default p … o humic … ducts?



Syringaldehyde



p-Coumaric acid



Ferulic acid

2022 Boyd 32 Field – N Rate X Humic Split-Plot Design
8 Row Plots with 30-inch Row Spacing

Now, let's look at nitrogen stress

Treatments

Main Treatments (Nitrogen Fertilizer Rates):

T1 = 0 kg N/ha (0 lb N/a)

T2 = 70 kg N/ha (62 lb N/a)

T3 = 140 kg N/ha (125 lb N/a)

T4 = 210 kg N/ha (187 lb N/a)

T5 = 280 kg N/ha (250 lb N/a)

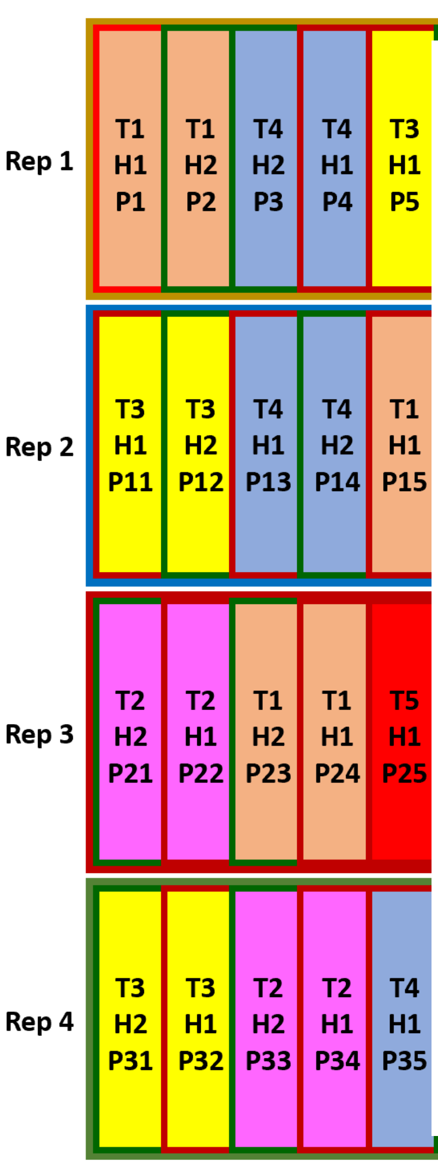
Apply UAN sidedress in interrows centers at earliest possible after emergence

Split Treatments (Humic Product):

H1 = Without (Control)

H2 = With (Humic Treated)
Enersol 32 oz/a broadcast foliar-applied at ~V4

2022 Boyd 32 Field – N Rate X Humic Split-Plot Design



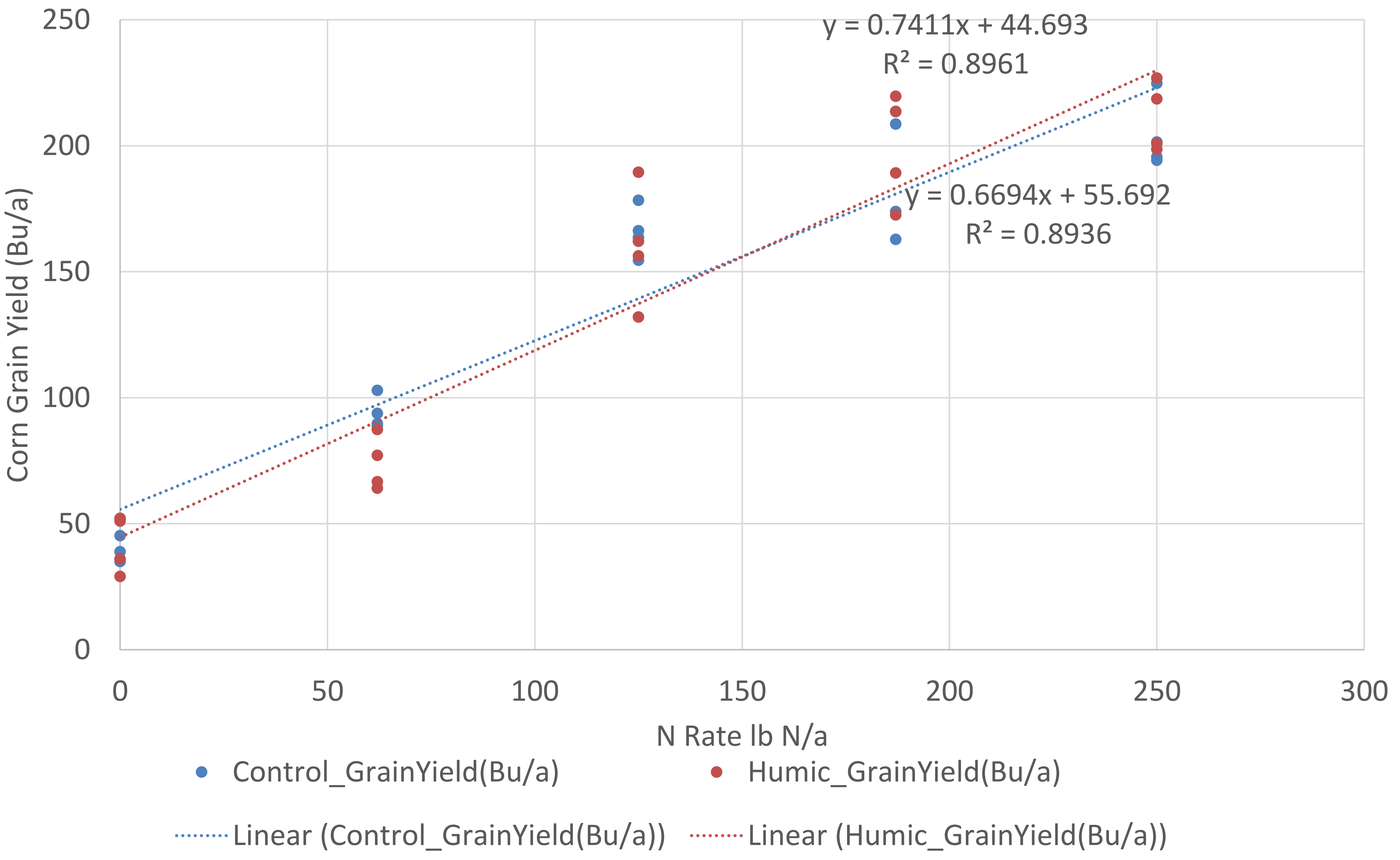
Combine grain yield response to a humic product 2021 (and 2020) field trial, Ames, IA (bushel/ acre)

N rate (lb $acre^{-1}$)	Control	Humic product	Difference	P level
0	42.8	42.1	-0.7	0.920
62	93.8	73.9	-19.9	0.015
125	165.7	160.0	-5.7	0.429
187	189.8	198.7	+8.9	Mainplot trmt: P=0.098 for 187 N and 250 N.
250	204.0	211.3	+7.3	
		2020		
0	34.6	34.4	-0.2	0.968
62	75.2	64.2	-11.0	0.125
125	138.6	149.2	+10.6	0.138
187	170.3	178.6	+8.3	0.238
250	169.0	165.9	-3.1	0.649

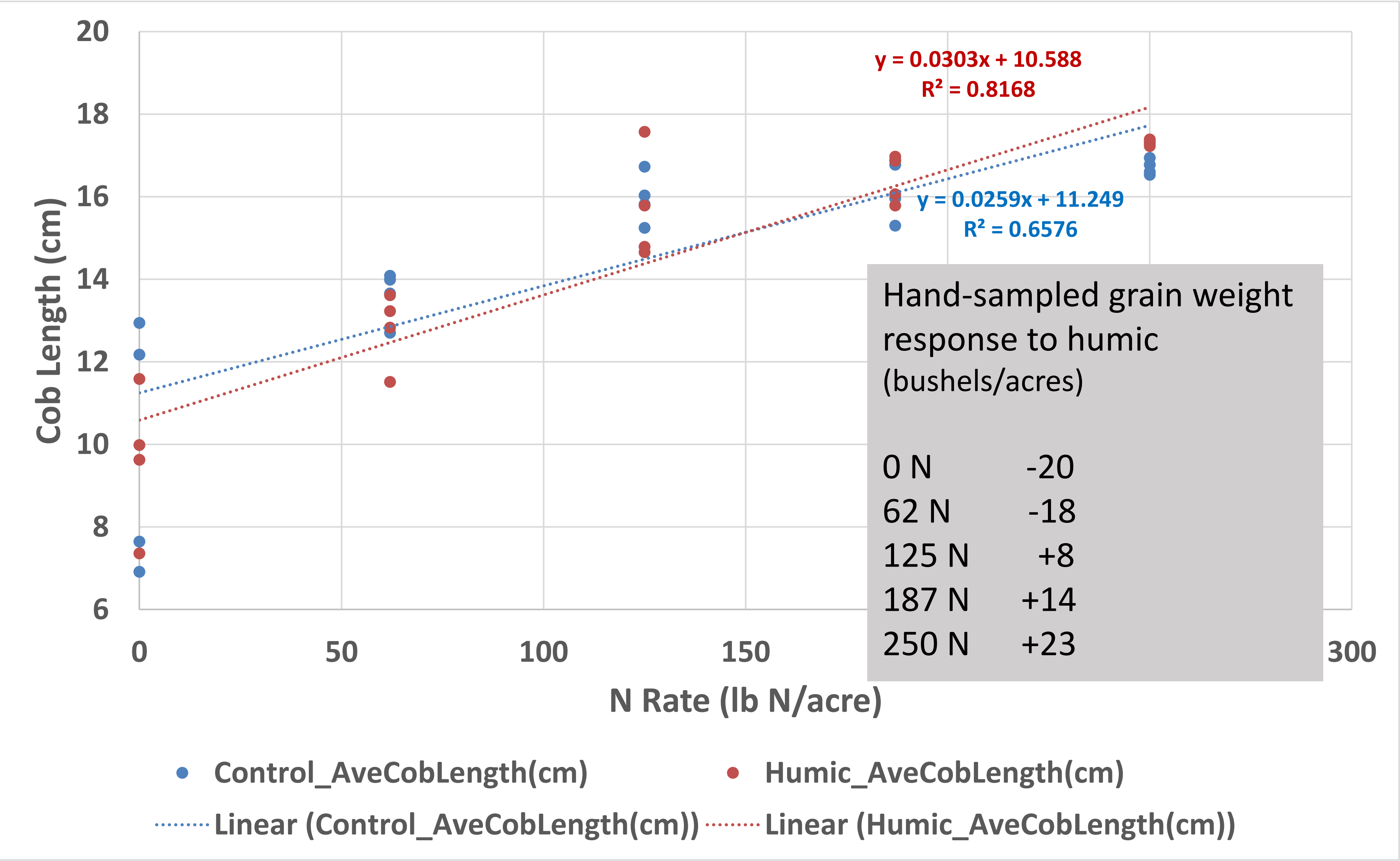
Combine grain yield response to a humic product 2022 (and 2021) field trial, Ames, IA (bushel/ acre)

N rate (lb $acre^{-1}$)	Control	Humic product	Difference	P level
0	42.8	42.1	-0.7	0.920
62	93.8	73.9	-19.9	0.015
125	165.7	160.0	-5.7	0.429
187	189.8	198.7	+8.9	0.225
250	204.0	211.3	+7.3	0.323
		2022		
0	69.0	64.3	-4.7	0.704
62	114.3	107.7	-6.6	0.431
125	168.7	164.8	-3.9	0.641
187	171.4	179.7	+8.3	0.328
250	186.7	191.6	+8.9	0.294

2021 Combine grain yield
Humic vs Control across five N fertilizer rates



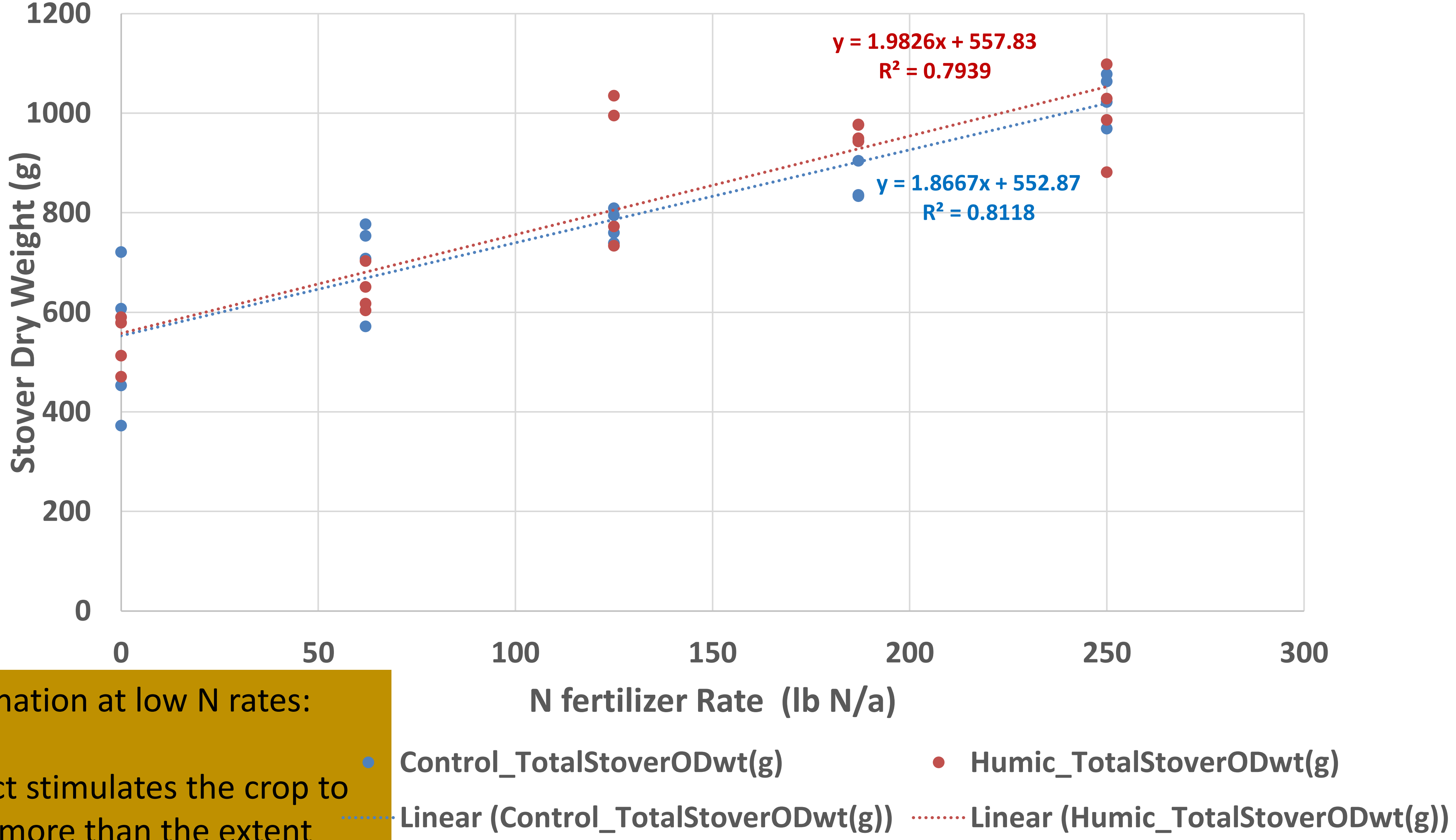
2021 Cob length for hand-samples (7 plants/plot)
Humic vs Control across five N rates



Hand-sampled grain weight response to humic
(bushels/acres)

0 N	-20
62 N	-18
125 N	+8
187 N	+14
250 N	+23

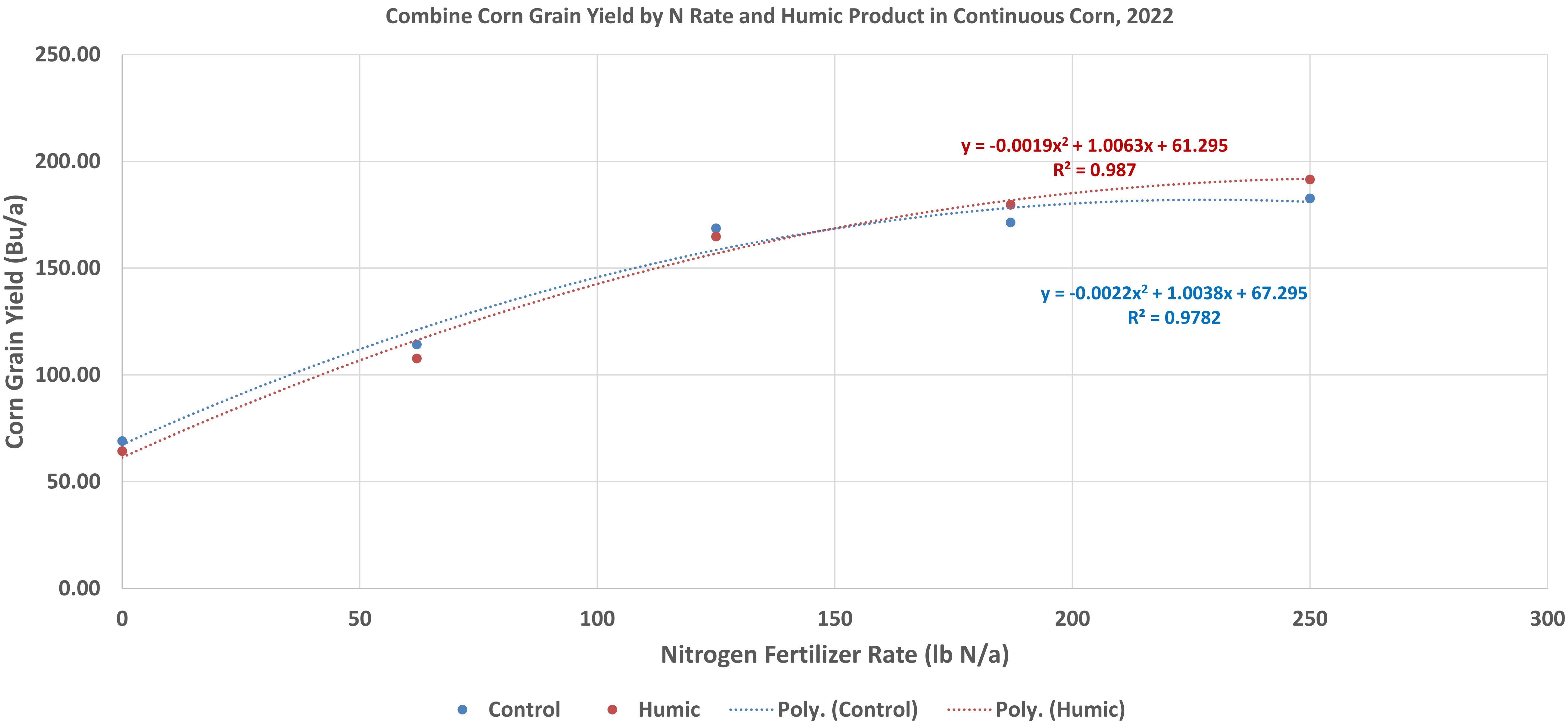
2021 Stover weight for hand-samples (7 plants/plot)
Humic vs Control across five N rates



Speculative explanation at low N rates:

The humic product stimulates the crop to grow excessively, more than the extent supported by the limited N supply.

2022 Combine grain yield
Humic vs Control across five N fertilizer rates



Soluble leaf sugar responses to a humic product 2022

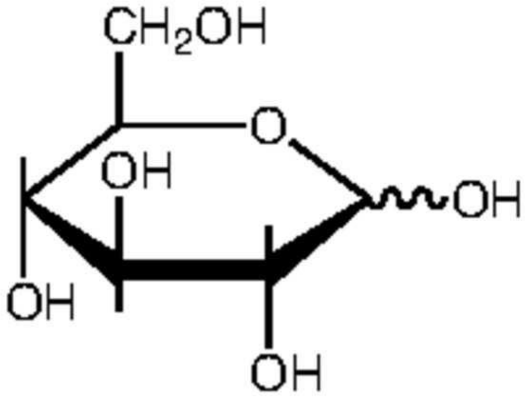
- Standard assay kits provided by Millipore-Sigma and Megazyme for glucose, sucrose, and fructose.
- Second youngest leaf sampled at V8, V14, and R2 growth stages.
- Distinguished leaf rib from rest of leaf.

Leaf rib concentrations of glucose and fructose at R2 corn stage, 2022 season, outside Ames, IA.

N rate	Humic		Glucose mean	St. error		Sucrose mean	St. error
0	N		6.30	1.59		3.82	0.44
0	Y		5.68	0.75		3.36	0.24
62	N		10.17	1.02		4.32	0.89
62	Y		6.36	0.49		8.04	0.17
125	N		8.48	0.19		5.76	0.33
125	Y		6.86	0.76		7.19	0.98
187	N		9.30	1.16		2.73	0.58
187	Y		7.28	0.26		2.18	0.63
250	N		9.68	1.50		0.43	0.27
250	Y		7.11	0.22		0.96	0.51

Leaf Non-rib concentrations of glucose and fructose at R2 corn stage, 2022 season, outside Ames, IA.

N rate	Humic		Glucose mean	St. error		Sucrose mean	St. error
0	N		0.520	0.125		3.153	0.550
0	Y		0.729	0.132		1.210	0.317
62	N		0.621	0.065		0.972	0.032
62	Y		0.568	0.055		0.941	0.045
125	N		1.376	0.338		0.677	0.049
125	Y		1,488	0.140		0.885	0.096
187	N		0.677	0.096		1.651	0.670
187	Y		1.143	0.222		3.116	0.198
250	N		0.526	0.110		0.772	0.053
250	Y		0.666	0.042		0.904	0.046



Glucose

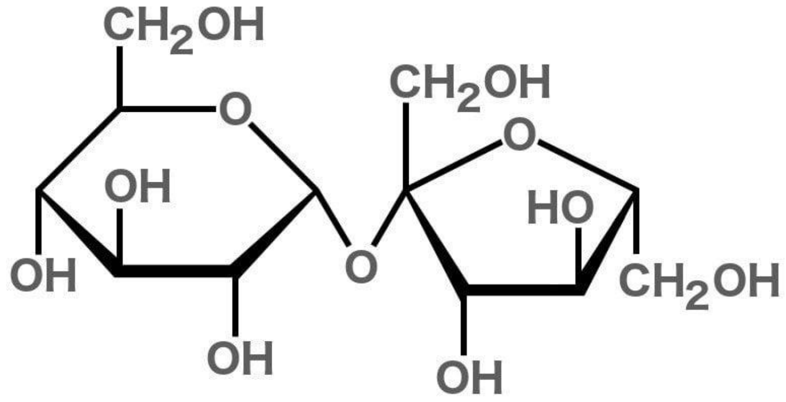
The most common monosaccharide in the world.

Created by photosynthesis.

Is the most important energy source in all organisms.

Can be converted by plants into cellulose and starch for long-term storage.

Catalyzes certain reactions in plants



Sucrose (Table sugar)

Primarily used in plants for short-term storage and transport of glucose (i.e., energy) from source to consumption sites

Less reactive than glucose.

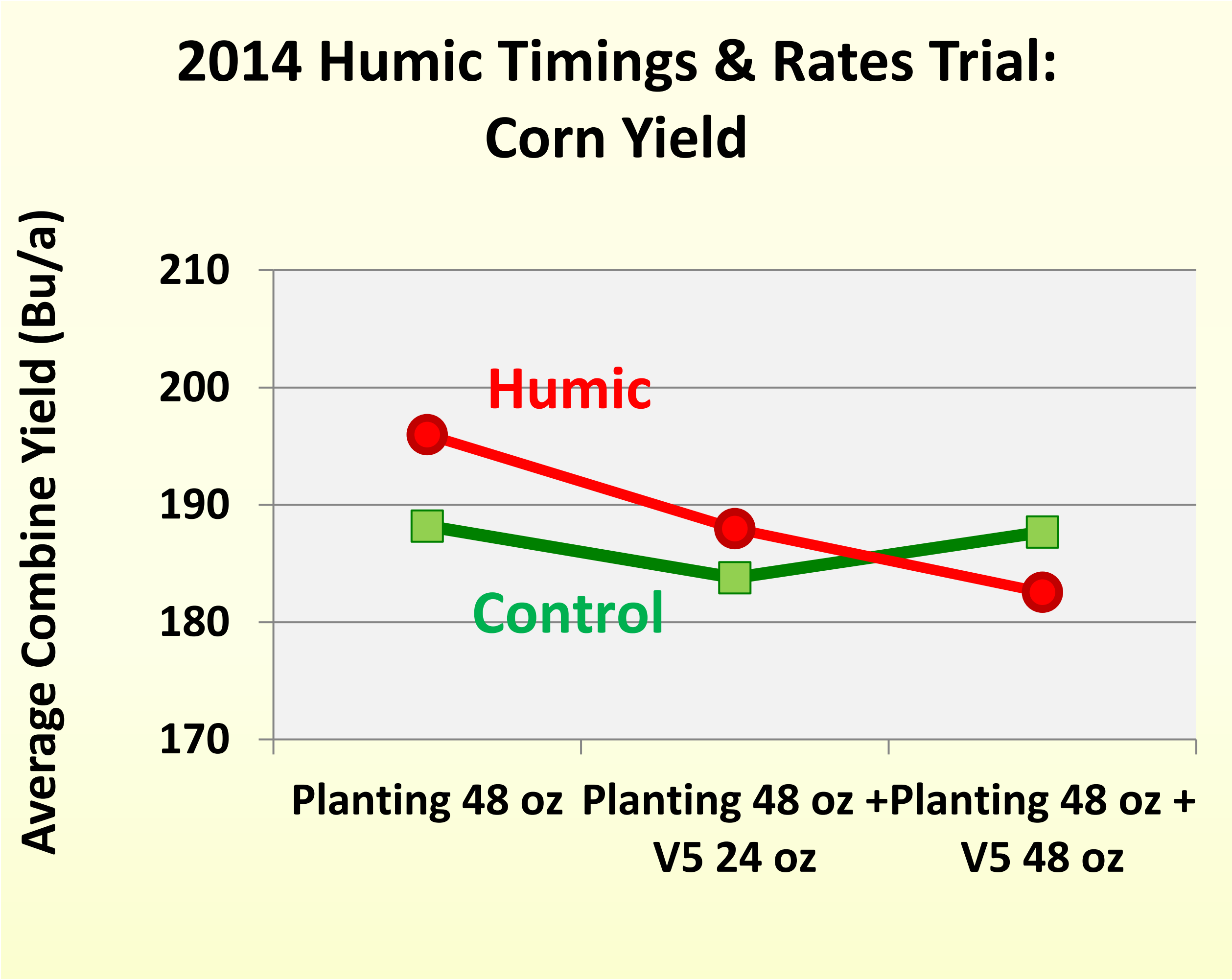
Catalyzes distinctly different reactions in plants than for glucose.

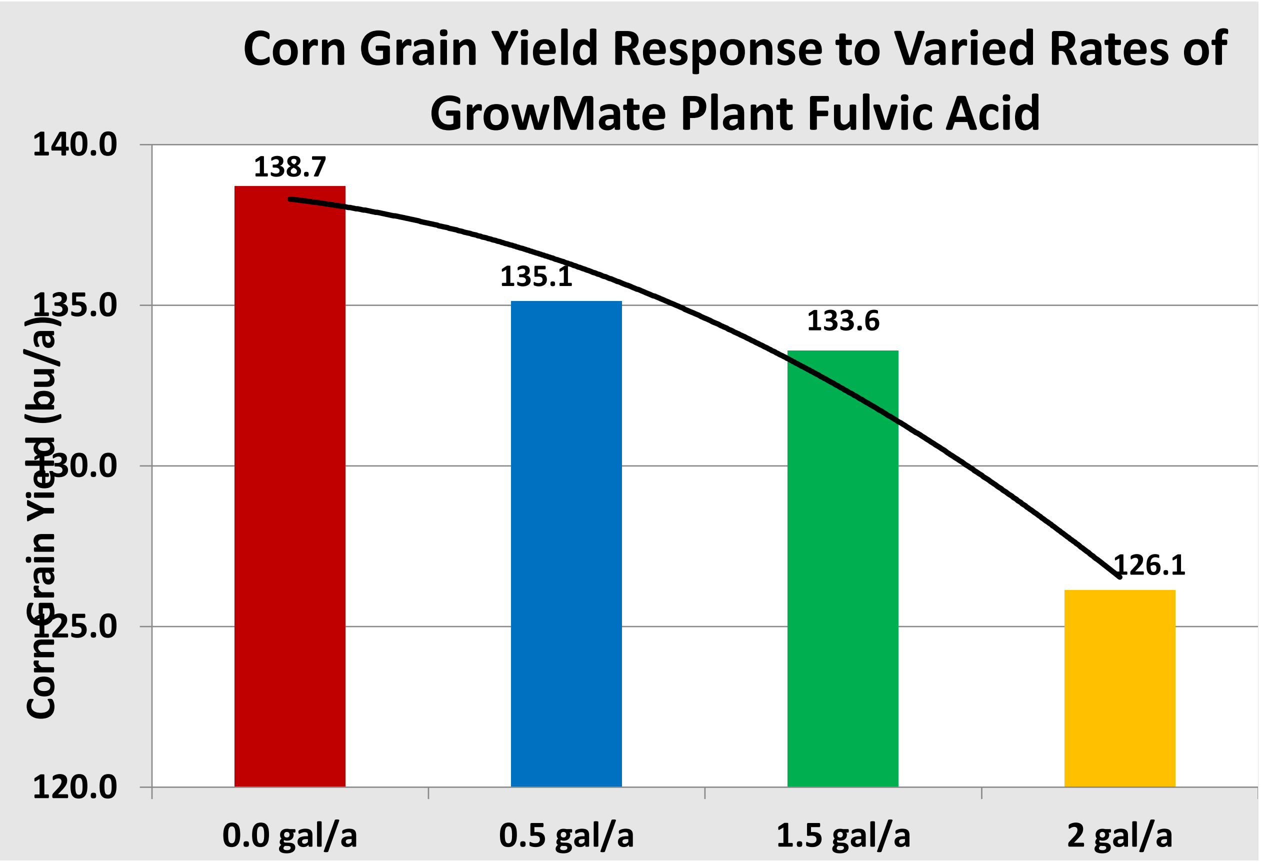
- In this field study on fertile Iowan soils, the humic product increased corn grain yield at the higher N fertilizer rates.
- Yet it did not increase nitrogen availability at the low N fertilizer rates.
- Might there be another mechanism(s) for humic product efficacy besides enhancing nutrient supply?
- Researchers say “Yes!” They look at stimulation of basic life processes.

How much carbon are we adding via humic products?

Carbon source	Carbon input to soil ($kg\ ha^{-1}$)
Humic product (2 gallon/acre, 20% HA+FA)	2
Crop residues (5 tons ha^{-1})	2150
Soil organic carbon in Midwest (2% SOC, 6-inch plow layer, 1.2 g/cm^3 bulk density)	1,800,000

Toxic effects at excessive application rates





Corn and soybean yield responses to a humic product: nearly ideal precipitation patterns (2014-2015) vs. drought stress (2013, 2016-2017). Boyd 11 farm. Ames, IA

Year	Crop	Treatment	Timing	Grain Yield (bu/a)	% of Control	P > F[a] Compared to Control
2013	Soybean	Control	N/A	45.1	-----	-----
		Humic 34 oz/a	V4	48.5	+7.5	0.03
		Humic 41 oz/a	Pre-Emergence	47.9	+6.2	0.05
2014	Corn	Control	N/A	182.2	-----	-----
		Humic 34 oz/a	V4	179.4	-1.5	0.79
		Humic 27+14 oz/a	Pre-Emergence + V4	186.3	+2.2	0.69
2015	Soybean	Control	N/A	55.2	-----	-----
		Humic 64 oz/a	V4	56.9	+3.2	0.49
		Humic 128 oz/a	Pre-Emergence	57.3	+3.9	0.42
2016	Corn	Control	N/A	226.6	-----	-----
		Humic 32 oz/a	V4	233.7	+3.1	0.02
		Humic 64 oz/a	V4	236.1	+4.2	0.003
2017	Soybean	Control	N/A	54.4	-----	-----
		Humic 64 oz/a	V4	60.3	+10.8	<0.001
		Humic 128 oz/a	Pre-Emergence	61.5	+13.2	<0.001

Very different corn grain yield response under excessively wet conditions, 2018.

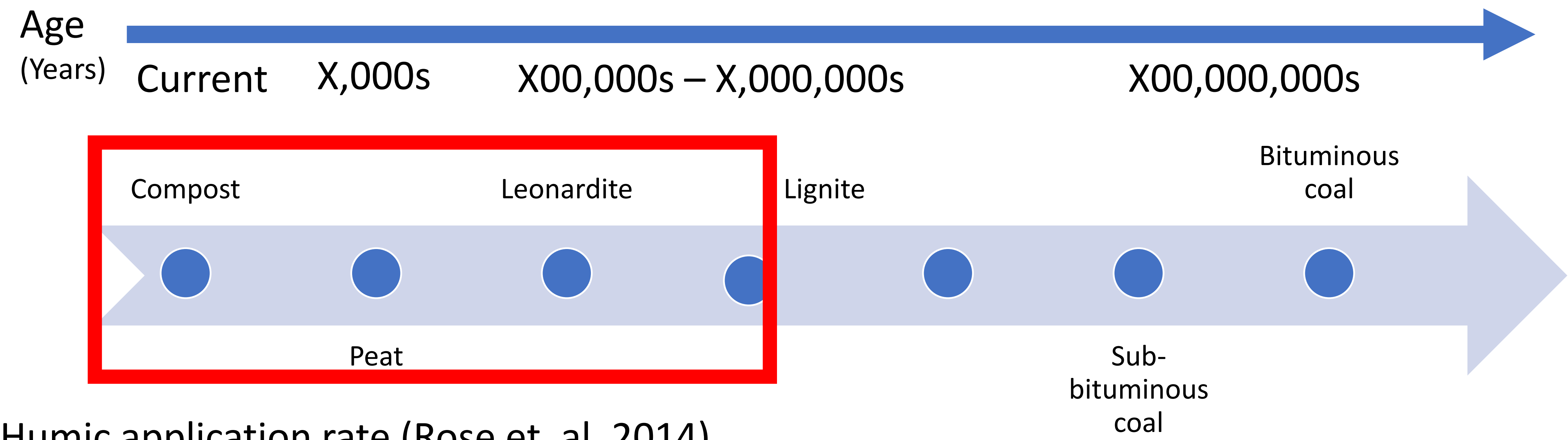
Factor	Trt Mean	Proc Mixed Pr>F	Proc Mixed LSD Pr>F	Proc Mixed Dunnett's Pr>F
Corn Combine Whole-Pass Grain Yield Bu/a @ 15.5% Market Moisture				
Trt 1 (Control)	182.4			
Trt 2 (32 oz/a Enersol)	183.0			
Trt 3 (64 oz/a Enersol)	169.8			
Main Trt Effect		0.1753		
Trt 1 vs. Trt 2			0.9317	0.9942
Trt 2 vs. Trt 3			0.1026	.
Trt 1 vs. Trt 3			**0.1161**	0.1933
Corn Combine Whole-Pass Grain Yield Mg/ha @ 15.5% Market Moisture				
Trt 1 (Control)	11.45			
Trt 2 (32 oz/a Enersol)	11.49			
Trt 3 (64 oz/a Enersol)	10.66			

Our thoughts (Per the Scientific Process)

- The active ingredient(s) is/are specific biochemical compounds that mimic life-promoting compounds. These active compounds are likely NOT true hormones.

- What might the nature and origin of these compounds be?

- A geologic view:



Humic application rate (Rose et. al, 2014)

1,000+ ppm

<200 ppm

Amino acids,
Carbohydrates

**Lignin,
Phenols**

Aromatic rings,
Fatty acids

Conclusions

- Field efficacy of humic products in Iowa was demonstrated (1) especially during environmental stresses, and (2) by positive grain yield responses of corn at medium to high N fertilizer rates, hence increased N use efficiency.

- At low N fertilizer rates, corn grain yield decreased with humic product use. This product did NOT make N more available to the crop.

- Multiple mechanisms might explain humic product field efficacy. Our data and previous results in Iowa are inconsistent with nutrient-based mechanisms. Instead, humic products might contain mimics of growth-promoting compounds, possibly of lignin origin.

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