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Is Mississippi Irrigation Water Accumulating Salts in Soil and Potentially Limiting Soybean Growth?, 66-2022

FINAL REPORT

Michael J. Mulvaney, mjm1166@msstate.edu, (850)382-5221
Vaughn Reed, vr401@msstate.edu, (662)325-2311
Drew Gholsen, drew.gholson@msstate.edu, (662)686-3215
Corey Bryant, cjb777@msstate.edu, (870)723-0543

Rationale/Justification for Research

Detailed attention is paid to irrigation water quality in parts of the country where salts are known to accumulate in soils, such as the southwestern US. In the mid-south, however, salt accumulation in soils has not been considered problematic, even though water quality analyses indicate that bicarbonate in water often exceeds 400 ppm, along with ‘severe’ concentrations of both sodium and chloride. These anecdotal reports are corroborated by water quality survey data published by Nandula et al. (2018). Bicarbonate, sodium, chloride, and other salts may accumulate during dry periods in MS soils due to repeated wetting and drying of soils in the rhizosphere when irrigation water with high salt concentrations is used. When leaching rainfall events occur, these salts may wash out of the rhizosphere, such that salt accumulation may not be evident, although plant damage may have already occurred. However, in poorly drained soils such as exist in much of Mississippi, leaching of salts may not occur and result in salt accumulation, especially after prolonged periods of irrigation. Entering preliminary MS water quality data into the Irrigation Water Analysis Results and Interpretation tool (NMSU, 2022) showed “severe limitations” due to sodium and bicarbonate levels, and “increasing problems” with irrigation water pH and total dissolved solids. However, these results must be interpreted alongside calcium, magnesium, total dissolved solids (TDS), and electrical conductivity (EC), data we do not have. Soybean is considered moderately salt-tolerant, with yield reductions expected when soil salinity >5 dS/m (Phang, et al., 2008; Papiernik et al., 2005) (response depends on the tolerance of individual varieties) but no soil salinity data from Mississippi soils are available. We propose to conduct a survey of water and soil across Mississippi along a chronosequence to determine if salt accumulation is a potentially yield-limiting factor for soybean production.

Objectives

Objective 1: Survey on-farm irrigation water quality to assess the quantity and types of salts applied to soils in irrigation water.

Objective 2: Quantify salt concentrations in Mississippi soils.

Report of Progress/Activity

Objective 1:

Seventy-four irrigation water samples were collected from around Mississippi (Figure 1) and sent for laboratory analysis. The samples collected were limited to this number because sample collection was done close to when growers had terminated irrigation. Sixty-two of these samples were sourced from an aquifer (well), while five were rainwater (Table 1). Almost all water samples (98.4% of well water sources and 40% of rainwater/surface water sources) contained >100 mg/L bicarbonate (HCO_3). None of the samples from either source had pH, EC, Na, Cl, TDS, and SAR values higher than the acceptable threshold limit. Note that “threshold limits” are somewhat arbitrary and based on recommendations from salt-affected areas of the US. Furthermore, the results of one parameter affect the toxicity of another parameter. For example, the problematic threshold of irrigation water EC depends on the sodium adsorption ratio (SAR) of the soil. Therefore, it is important to interpret irrigation water salinity in the context of soil properties. Given the

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preliminary nature of this study, we chose high thresholds with the reasoning that we didn't want to cause concern where none need exist.

Preliminary results suggest irrigation water quality was not generally problematic for crop growth. However, caution should be exercised when applying irrigation water from the sampled area to sodium-sensitive crops, as the SAR values ranged from 1 to 9. Also, Total Dissolved Solids (TDS) ranged from 69.76 to 1643.4 mg/L, which may result in some usage restrictions where it might be necessary to apply sufficient water to move accumulated salts (due to evaporation) below the root zone.

Sixty-one (98.4%) and two (40.0%) of the aquifer and rainfed samples, respectively, had higher HCO_3 than the threshold limit (100 mg/L). High concentrations (greater than 100 mg/L) of bicarbonate can be detrimental to crop growth and are usually associated with high pH water (Ayers and Westcot, 1985). The pH of water samples were, however, considered acceptable. Summary results are presented in Table 2.

Objective 2:

Eighty-one soil samples were collected from around the MS soybean growing region (Figure 1) and sent for laboratory analysis. Seventy-six of these soil samples were from sites where the source of irrigation water is an aquifer (well), while five were from rainwater sites. The soil samples' chemical properties (pH, EC, Na, Cl, HCO_3 , TDS, and SAR) were generally low. However, two samples from the aquifer water-irrigated fields had EC values above 1000 μS . Fourteen samples, twelve from aquifer water irrigated fields and two from those irrigated with rainwater had their HCO_3 above 100 mg/L. Generally, the soils are acceptable compared to the water samples in objective 1. This may have resulted from the fact that soils were sampled in the fall/winter (off-season after harvest), such that HCO_3 accumulation during the on-season might have leached prior to soil sampling. Therefore, in-season chronosequential sampling is suggested to capture the actual amount of salt accumulation in soil from irrigation water.

Since MSU does not have expertise in irrigation water and soil salinity, we consulted with two experts from the Southwestern US, where salinity is a regular issue. The first was Dr. Hailin Zhang, Director of the Soil, Water and Forage Analytical Laboratory at Oklahoma State University. The second was Dr. Todd Skaggs, Research Leader at the Agricultural Water Efficiency and Salinity Research Unit in Riverside, CA. In summary, both agreed on the interpretation of our data. In summary, we believe that all parameters of soil and water quality look acceptable, with the important exception of irrigation water bicarbonate levels. After consultation with these experts, we believe it is prudent to conduct controlled environment (greenhouse) studies to determine if high bicarbonate levels present in MS irrigation water are actually harmful to crop growth. Two approaches, neither perfect, are suggested to address this question, and both would likely require a student to work on the issue:

1. Dilute MS irrigation water at different dilutions in a controlled environment. The problem with this approach is that all parameters will be diluted, and we cannot say that it was bicarbonate that was the issue. However, all parameters other than bicarbonate are acceptable, so it could be inferred that bicarbonate was responsible for any response.

2. Acidify MS irrigation water at different levels in a controlled environment. The problem with this approach is that acid will contain other elements, thus confounding the study. However, this approach only changes 2 (or 3) parameters: bicarbonate (and thereby pH) and the acid anion, which theoretically could be counterbalanced in water solution. This approach is more complicated, requiring titrations and other wet chemistry.

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Forthcoming End Products

1. Results will be developed into an Extension publication so that the data are not lost and may be utilized by other researchers as well as growers interested in water and soil quality at the county level.
2. Having conducted a soil and water survey across the soybean-producing region of Mississippi, the consensus is that future research is warranted to determine if the extraordinarily high irrigation water bicarbonate levels limit soybean growth. Should we proceed with this line of research, additional funding would be required.

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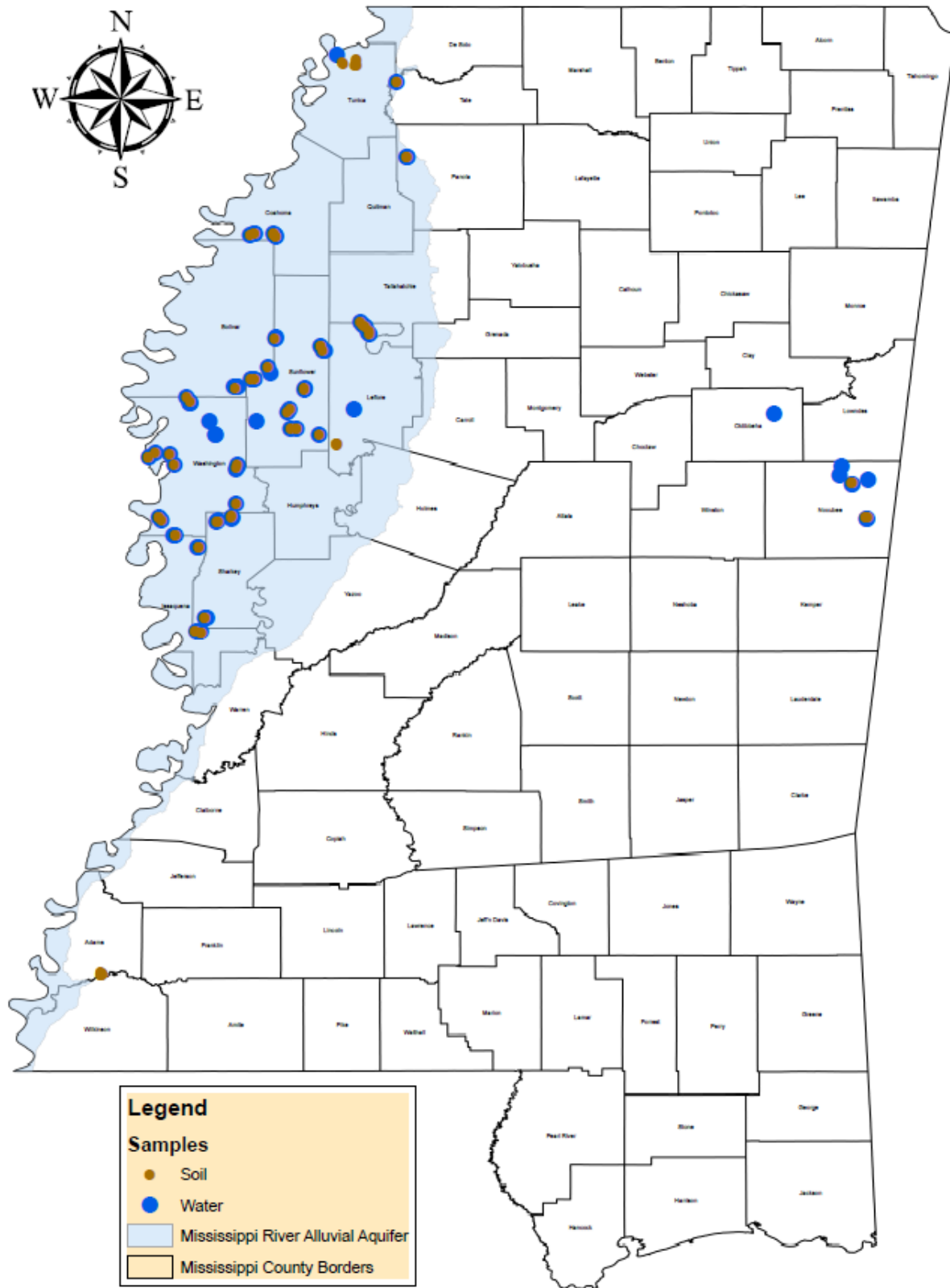


Figure 1. Water and soil sampling locations during 2022.

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Table 1. Summary of irrigation water quality parameters that could cause deleterious effects on crop growth. Threshold values are somewhat arbitrary but are generally the highest values of concern in salt-affected areas of the US.

Parameter	Threshold	No. Exceeding threshold		% Exceeding threshold	
		Aquifer (n=62)	Rainwater (n=5)	Aquifer (%)	Rainwater (%)
pH	8.5	0	0	0	0
EC	1500 μ S/m	0	0	0	0
Na	350 mg/L	0	0	0	0
Cl	351 mg/L	0	0	0	0
HCO ₃	100 mg/L	61	2	98.4	40
TDS	2000 mg/L	0	0	0	0
SAR	10	0	0	0	0

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Table 2. Summary statistics for analysis of water samples collected from soybean growing region in MS. Highlighted values exceed acceptable threshold values shown in Table 1.

County	Sample points	Alkalinity			B (mg/L)			Ca (mg/L)			Cl (mg/L)			Cu (mg/L)			EC (dS/m)			EPP (mEq/L)			HCO3 (mg/L)		
		Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
Bolivar	5	298.38	354.03	320.17	0.03	0.06	0.044	76.3	112.6	88.28	6.4	20.2	15.48	0.01	0.01	0.01	0.007	0.0094	0.0074	3.89	4.03	3.98	364.0	431.9	390.62
Coahoma	7	236.18	345.17	278.37	0.02	0.05	0.036	54.2	87.1	67.40	3.2	7.6	5.47	0.01	0.01	0.01	0.005	0.0066	0.0054	3.87	4.02	3.95	288.1	421.1	339.61
Tallahatchie	1	216.68	216.68	216.68	0.04	0.04	0.040	58.3	58.3	58.30	9.3	9.3	9.30	0.01	0.01	0.01	0.005	0.0051	0.0051	4.12	4.12	4.12	264.3	264.3	264.30
Leflore	5	221.67	289.11	249.92	0.02	0.04	0.028	53.2	74.1	63.73	3.9	8.2	6.05	0.01	0.01	0.01	0.005	0.006	0.0052	3.77	4.13	3.99	270.4	352.7	304.88
Sunflower	15	160.93	312.84	250.27	0.02	0.05	0.035	44.7	78.8	62.12	2.9	19.7	9.14	0.01	0.01	0.01	0.003	0.0065	0.0053	3.67	4.42	4.00	196.3	381.7	305.32
Washington	18	197.07	445.32	312.71	0.03	0.15	0.073	64.4	95.2	77.62	3.2	18.0	6.92	0.01	0.01	0.01	0.005	0.0083	0.0066	3.61	4.14	3.82	240.4	543.3	380.61
Sharkey	7	244.09	366.67	306.68	0.05	0.12	0.071	53.0	99.7	70.33	4.8	10.7	6.56	0.01	0.02	0.01	0.005	0.0076	0.0063	3.63	4.05	3.86	297.8	447.3	369.30
Issaquena	4	247.7	358.45	317.24	0.05	0.11	0.085	58.3	73.9	64.98	3.5	5.8	4.48	0.01	0.01	0.01	0.005	0.0066	0.006	3.63	4.03	3.90	302.2	437.3	387.03
Panola	2	185.22	187.22	186.22	0.02	0.02	0.020	55.2	55.7	55.45	5.9	7.3	6.60	0.01	0.01	0.01	0.004	0.0041	0.0041	3.66	3.84	3.75	226.0	228.4	227.20
Noxubee	7	34.34	116.38	78.72	0.01	0.05	0.026	3.1	59.1	25.76	2.2	42.3	14.00	0.01	0.01	0.01	0.002	0.004	0.0027	4.07	5.59	4.65	41.9	142.0	96.04

County	Sample points	Fe (mg/L)			Mn (mg/L)			Na (mg/L)			PAR (mEq/L)			pH			SAR (mEq/L)			SO4 (mg/L)			TDS (mg/L)		
		Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
Bolivar	5	0.17	0.31	0.23	0.13	0.34	0.23	17.0	44.1	26.10	0	0.1	0.05	7.7	8.0	7.8	0.38	0.91	0.59	33.9	113	55.90	548	765	613.85
Coahoma	7	0.32	0.76	0.51	0.1	0.44	0.24	10.3	15.0	11.81	0	0.1	0.05	7.8	8.0	7.9	0.28	0.38	0.31	0.4	34.7	8.10	382	564	461.79
Tallahatchie	1	0.84	0.84	0.84	0.31	0.31	0.31	17.8	17.8	17.80	0.1	0.1	0.07	7.9	7.9	7.9	0.50	0.50	0.50	45.9	45.9	45.90	422	422	422.36
Leflore	5	0.42	0.61	0.49	0.14	0.58	0.29	9.2	20.4	12.70	0	0.1	0.05	7.8	8.0	7.9	0.27	0.52	0.34	3.4	52.6	20.80	375	504	435.43
Sunflower	15	0.08	0.7	0.43	0.05	0.35	0.18	7.3	36.7	16.89	0	0.1	0.05	7.6	8.0	7.8	0.25	1.01	0.45	3.4	86.8	23.98	269	546	446.12
Washington	18	0.06	0.68	0.25	0.07	0.68	0.29	9.4	42.3	19.42	0	0.1	0.04	7.5	8.4	7.9	0.23	0.96	0.46	0.5	98.5	34.49	428	708	556.39
Sharkey	7	0.05	0.49	0.30	0.02	0.35	0.18	16.6	36.6	22.94	0	0.1	0.04	7.7	8.4	8.0	0.39	0.88	0.57	1.0	57.9	23.07	422	637	531.03
Issaquena	4	0.16	0.63	0.48	0.03	0.23	0.14	15.6	25.4	19.40	0	0.1	0.05	7.9	8.1	8.0	0.40	0.62	0.48	1.2	18.7	6.90	428	574	520.24
Panola	2	0.34	0.83	0.59	0.29	0.42	0.36	11.2	13.0	12.10	0	0	0.03	7.8	8.0	7.9	0.36	0.41	0.39	6.0	10.9	8.45	323	324	323.62
Noxubee	7	0.01	0.31	0.08	0.01	0.01	0.01	5.5	62.2	23.83	0.1	0.2	0.12	7.1	7.9	7.6	0.19	1.99	8.11	1.0	54.6	17.24	96.6	261	185.49

Electrical Conductivity (EC); magnesium, total dissolved solids (TDS); Sodium Adsorption Ratio (SAR); Potassium absorption ration (PAR); Exchangeable potassium percent (EPP)

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Table 3. Summary statistics for analysis of soil samples collected from soybean growing region in MS

County	Sample points	Alkalinity			B (mg/L)			Ca (mg/L)			Cl (mg/L)			Cu (mg/L)			EPP (mEq/L)			HCO3 (mg/L)			Mn (mg/L)		
		Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
Bolivar	3	54.21	147.44	108.68	0.01	0.02	0.01	16.9	49.7	33.37	7.8	25.0	15.93	0.02	0.09	0.05	3.65	5.0	4.3	66.1	179.9	132.6	0.01	0.02	0.01
Coahoma	8	5.79	44.09	23.71	0.02	0.06	0.04	5.7	19.9	14.16	2.6	12.8	6.69	0.01	0.03	0.02	3.47	5.0	4.0	7.1	53.8	28.9	0.01	0.07	0.02
Tallahatchie	1	62.26	62.26	62.26	0.05	0.05	0.05	21.0	21.0	21.00	7.7	7.7	7.70	0.06	0.06	0.06	4.36	4.4	4.4	76.0	76	76.0	0.02	0.02	0.02
Leflore	7	3.86	122.61	40.37	0.01	0.13	0.07	7.4	142.2	52.23	2.4	51.1	19.14	0.01	0.06	0.04	3.77	6.3	5.0	4.7	149.6	49.2	0.01	0.05	0.03
Sunflower	14	14.31	101.84	48.67	0.01	0.06	0.03	11.2	85.3	35.46	4.1	81.6	15.96	0.01	0.06	0.04	3.47	7.1	4.5	17.5	124.2	59.4	0.01	0.07	0.03
Washington	14	18.09	144.38	63.07	0.02	0.12	0.05	13.5	145.4	42.16	3.2	148.9	28.22	0.02	0.15	0.06	3.72	9.6	4.9	22.1	176.1	76.9	0.01	0.08	0.03
Sharkey	6	18.80	99.59	48.19	0.01	0.25	0.09	16.5	110.4	64.48	23.7	192.0	85.25	0.03	0.12	0.06	4.19	6.8	5.2	22.9	121.5	58.8	0.01	0.11	0.04
Issaquena	6	7.90	36.41	19.97	0.02	0.07	0.04	10.0	50.1	26.08	6.6	47.4	15.60	0.01	0.04	0.02	3.87	4.9	4.4	9.6	44.4	24.4	0.01	0.12	0.04
Panola	2	7.95	8.13	8.04	0.08	0.31	0.20	27.0	33.1	30.05	3.4	6.2	4.80	0.03	0.21	0.12	8.84	9.0	8.9	9.7	9.9	9.8	0.22	0.77	0.50
Tate	2	6.53	6.87	6.70	0.04	0.05	0.05	8.3	9.9	9.10	5.0	8.5	6.75				3.84	4.3	4.1	8.0	8.4	8.2			
Tunica	8	9.62	121.19	62.92	0.06	0.30	0.14	11.7	285.5	82.65	3.6	44.1	15.23				3.85	7.7	5.2	11.7	147.9	76.8			
Noxubee	4	18.29	145.69	83.80	0.05	0.09	0.07	33.4	66.5	48.33	4.6	10.8	6.50				3.69	4.4	4.1	22.3	174.9	101.5			
County	Sample points	Na (mg/L)			NO3_N			PAR (mEq/L)			pH			SAR (mEq/L)			SO4 (mg/L)			TDS (mg/L)			Zn (mg/L)		
		Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
Bolivar	3	13.0	38.8	22.6	0.8	0.8	0.8	0	0.16	0.09	7.6	8.0	7.7	0.5	1.2	0.9	25.8	72.7	43.97	151.1	385.3	263.3	0.01	0.02	0.02
Coahoma	8	4.1	9.2	7.7	0.2	9.1	2.4	0	0.16	0.06	6.2	7.4	7.0	0.2	0.6	0.5	4.2	49.6	21.01	58.5	129.2	99.3	0.01	0.04	0.02
Tallahatchie	1	9.2	9.2	9.2				0.1	0.09	0.09	7.5	7.5	7.5	0.5	0.5	0.5	16.4	16.4	16.40	137.6	137.6	137.6	0.02	0.02	0.02
Leflore	7	4.8	11.8	7.6	0.2	92.8	28.1	0	0.3	0.16	5.2	7.8	6.9	0.2	0.4	0.3	11.2	52.1	25.34	69.8	705.5	284.0	0.02	0.02	0.02
Sunflower	14	6.0	26.1	14.2	0.2	51.1	16.8	0	0.38	0.14	6.8	7.8	7.4	0.2	1.3	0.6	11.3	70.9	30.46	101.8	572.2	242.9	0.01	0.03	0.02
Washington	14	5.1	13.9	9.2	1.3	60.5	15.9	0	0.67	0.15	6.9	8.2	7.5	0.2	0.7	0.4	7.9	28.6	16.02	104.2	854.0	269.1	0.01	0.22	0.04
Sharkey	6	6.0	21.0	12.0	1.3	44.8	23.3	0.1	0.36	0.18	7.0	7.9	7.5	0.2	0.5	0.4	11.4	31.6	20.40	135.3	756.4	428.2	0.02	0.03	0.02
Issaquena	6	6.6	11.5	8.8	0.4	38.5	15.5	0	0.15	0.09	6.7	7.3	7.0	0.3	0.6	0.4	7.4	40.2	19.83	83.0	361.0	194.1	0.02	0.56	0.12
Panola	2	3.7	4.6	4.2	20.4	29.0	24.7	0.6	0.59	0.59	5.9	6.4	6.2	0.2	0.2	0.2	18.2	29.0	23.60	196.7	236.3	216.5	0.05	0.08	0.07
Tate	2	8.7	24.8	16.8	6.4	21.3	13.9	0	0.09	0.07	6.2	6.5	6.4	0.6	1.6	1.1	4.5	10.6	7.55	88.2	151.8	120.0			
Tunica	8	6.2	10.7	8.2	0.6	248.3	57.2	0	0.45	0.18	6.3	8.0	7.2	0.1	0.5	0.3	7.5	104.2	28.69	84.9	1643.4	482.5			
Noxubee	4	3.8	13.3	7.4	0.2	28.3	8.6	0	0.09	0.06	7.2	8.3	7.8	0.1	0.5	0.3	6.0	19.8	13.03	140.6	287.3	216.8			

Electrical Conductivity (EC); magnesium, total dissolved solids (TDS); Sodium Adsorption Ratio (SAR); Potassium absorption ration (PAR); Exchangeable potassium percent (EPP).