Fertilization of Cotton on Black Belt Soils

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Background

Clayey, smectitic soils of the Blackland Prairie of Central Alabama and Mississippi were once the heart of the North American cotton belt in the 19th Century. Although cotton is not as widely grown as it once was, farmers who do grow cotton on these soils are seeing more problems with potassium (K) deficiencies in spite of the fact that these soils often test "high" or "very high" in K (Delaney et al., 2002). Some claim to get a yield response to K rates higher than those routinely recommended by the Auburn University Soil Testing Laboratory (Mitchell and Huluka, 2012).

Potassium deficiency in a commercial cotton field on a Black Belt soil in West Alabama.

Soil test calibration for cotton on these soils is weak. Most of Alabama's calibration came from greenhouse and field research with clover and sorghum-sudangrass in the early 1970s (Street, 1972) and from the Mississippi State University soil testing program where the Mississippi/Lancaster extract was developed (J.D. Lancaster, 1970, unpublished data). The Auburn University Soil Testing Laboratory uses this extract for clayey soils of the Alabama Blackland Prairie region (Hanlon and Savoy, 2009) because it is more effective at removing available P in calcareous soils than the Mehlich-1 procedure typically used on acid soils.

The Alabama Agricultural Experiment Station has maintained long-term soil fertility experiments called the "Rates of N-P-K test" at 7 locations around Alabama since 1954 (Cope, 1984). These experiments have been important in developing soil test calibration for the southeastern U.S. However, for some reason, this test was never established in the Blackland Prairie or "Black Belt" of Alabama. Soil test calibration and fertilizer recommendations for Black Belt soils have been poorly supported by research. On-farm research has not improved the situation because sites on farmers' fields are usually heavily fertilized and will not respond to direct applications of P and/or K. From 2002 to 2004, on-farm tests were conducted in this region with cotton using N, P, and K variables in an attempt to obtain some field calibration data (Mitchell et al., 2003). However, the logistics of managing on-farm tests resulted in limited, reliable data.

Objectives

The objectives of this research were (1) to determine optimum N rates for cotton, (2) provide soil test calibration for P and K on a typical Black Belt soil, and (3) establish a site similar to the NPK tests at other locations where on-going soil fertility research could be conducted.

Methods

In 2005, a comprehensive soil fertility experiment with cotton was established on the Black Belt Research and Extension Center west of Selma, Alabama. The previous year, 2004, the site was cropped to sorghum-sudangrass hay in an attempt to remove as much K as possible. No crop removal data were taken because of a severe outbreak of fall armyworms which limited dry matter yields. The soil at the site is an acid Vaiden clay (very-fine, smectitic, thermic Aquic Dystruderts) that initially tested low in P using the Mississippi-Lancaster procedure (16 mg P kg^{-1}), very high in K (180 mg K kg^{-1}) and high in Mg (60 mg Mg kg^{-1}) (Table 1).   .

Table 1. Initial, mean plow-layer soil test value (n=4) from site taken in 2004.					
Extract used	Soil pH_w	P	K	Mg	Ca
		--------------------------mg/kg and rating------------------------			
Mehlich-1	6.0	4 Very Low	88 High	35 High	2330 (not rated)
Miss/Lancaster	6.0	16 Low	180 V. High	60 High	10,000+

Treatments consist of 6 N rates, 4 P rates, 5 K rates and a no-lime treatment and an unfertilized treatment replicated 4 times in a randomized block design (Table 2). Plots are 15 feet wide (5, 36-inch row) and 25 feet long. Each tier is separated by a 5-foot alley. Because of disappointing yields in 2005 when cotton was planted no-till into a rye cover crop and excessive rainfall, the decision was made to switch to a ridge tillage system with no cover crop for 2006 through 2010. All the P and K and ½ of total N were applied within 1 week of planting in late April. Complement of N was applied in mid June during squaring. Lint yields were estimated by hand-picking 20 feet from the two middle rows in each plot. Relative yields are yields compared to the mean yield of treatment no. 5, the control treatment, which receives 90-100-100 pounds N-P_2O_5-K_2O per acre each year (Table 2). None of the plots received lime during the period 2004-2010 because of a soil pH>5.6.

Results

Excessive rainfall and anaerobic soil conditions dramatically reduced yields in 2005. Extreme drought plagued the test in 2006 and 2007 (Fig. 1, 2)). Yields in 2008 were the highest of the 6-yr study averaging 1150 pounds lint/acre in spite of severe leaf spot diseases (Alternaria, Cercospora, and Stemphylium) which actually defoliated some plots, especially the low K treatments. This problem has become a serious limitation to cotton production on Black Belt Prairie soils in Alabama but it is also unpredictable (Delaney et al., 2002). Leaf spot also occurred in 2009 but did not hurt yields as much as 2008 because it occurred later in the season. Leaf spot diseases do not appear to be a serious problem on other soils of the state. Cotton in 2009 was harvested late (November 13) due to an extremely wet fall season. If the 2006 through 2009 crops had been machine harvested, very little of the lint would have been saved because of hard locks and weak bolls. Extreme heat and a late-season drought may have reduced yields in 2010. Severe 2,4-D damage was noted in mid-summer (June10 through early July) in 2010 when a nearby landowner aerially sprayed a clearcut timber tract. Surprisingly, the cotton recovered and made a modest yield.

Lint Quality

Selected treatments were tested each year for lint quality. No treatment differences were observed in 2007 but there were significant difference in 2008, 2009, and 2010 (Table 2). The "No K" treatment had significantly lower overall fiber quality (Table 3).

Yields

Because of the higher yields and significant differences in treatments on yield in 2007 through 2010, these data probably are more relevant to producers (Table 2, Fig. 2).

N rates. Optimum total N rates over the 6 years of the experiment appear to be around 60 pounds N per acre. Although there was a more dramatic response to N rates in 2005, yields were low because excessive rainfall resulted in severe denitrification losses on these poorly drained soils. The current standard annual N rate is 90 lb. N per acre (Mitchell and Huluka, 2012).

P_2O_5 rates. One would have anticipated more dramatic responses to rates of P than we found in these tests because of the low soil test P rating. Except for the low-yielding, wet year of 2005, and the drought year of 2007, the "no P" treatment has produced relative yields between 96 and 120 percent of the control treatment which gets 100 pounds P_2O_5 per acre per year. There was never a significant yield response to added P. This calls into question the current "low" rating for this soil test value for cotton.. The definition of a "low" soil test rating indicates that the soil will produce less than 75% of its potential without fertilization of that nutrient. Farmers in this region often place extra resources on P fertilization because of the generally "low" P rating of many of these soils. These data suggest that they may not need to put as much effort into P fertilization because cotton does not respond to added P at these soil test levels. As previously noted, current soil test P calibration was based on clover yields and not cotton production on these soils (Street, 1972).

K_2O rates. In spite of the fact that this soil initially tested "very high" in K, there were significant increases in yield with higher rates of K_2O up to 100 pounds per acre each year except 2006. These results provide credibility to growers' claims that additional K seems to increase yields even though the soils are rated "high" or "very high" for K and none is recommended from the Auburn University Soil Testing Laboratory. The most dramatic yield response to added K occurred in 2008 when we had the highest yields of the 6-yr study but also had the most severe defoliation due to foliar diseases. There may be justification to change soil test K ratings for these soils and increase K recommendations for cotton.

Soil Test K. Periodically during the study, plow-layer soil samples were collected from selected treatments. Both Mehlich-1 (M1) and Mississippi/Lancaster (ML) extract were used to run extractable P, K, Mg and Ca. Samples collected in June, 2009, after 4 years of treatment, were used to correlate soil test K with cotton lint yields in 2009. There was no correlation between K extracted by the ML extract and cotton lint yields and only a weak correlation with the M1 extract (Fig. 4) in spite of the fact that there were significant responses to K applications. A 2002 Extension Timely Information Sheet on cotton leaf drop problems suggested that all cotton on Blackland Prairie soils should receive 120 lb. K_2O per acre regardless of soil test K (Delaney et al., 2002).

Annual applications of P and K are expected to increase soil test values while cropping should have a minimal effect on these values based on previous research (Mitchell, 2010). Fig. 5 and 6 demonstrate that both M1 and ML were both effective in measuring a buildup in soil K from previous applications. Simple calculations estimate that it took an average of 5 pounds K (6 lb. K_2O) to increase M1 K by 1 pound per acre. Because the ML extracts slightly more K, the same estimate is 4.5 pounds K (5.4 lb. K_2O) to increase the ML extractable K by 1 pound per acre.

Conclusions

In spite of extreme weather conditions at this site and some man-made problems, e.g., phenoxy herbicide drift in 2010, we have observed some consistent trends in cotton response to N, P, and K after 6 years of fertilization and cropping. Only 4 of 6 years (2007, 2008, 2009, and 2010) have produced reasonably good lint yields (~1.5 to 2 bales per acre). Surprisingly, yield responses to increasing N rates above 60 pounds per acre have not been evident. Significant differences in 2007 through 2010 due to treatments suggest a need for modification of soil test ratings for both P and K on these soils. Phosphorus may be currently rated too low and potassium may be rated too high for cotton on these soils. While the relationship between M1 extractable K and cotton lint yields was weak, it was linear and did not plateau as we would have expected. One possible solution is to apply at least 120 lb. K_2O per acre to all cotton planted on Blackland Prairie soils.. For both the M1 and ML extracts, it took about 5 pounds K (6 pounds K_2O) to increase soil test K by 1 pound per acre. Since these are the only established soil fertility variable plots on the Black Belt R&E Center, we hope that they will be maintained indefinitely as is the "Rates of NPK" experiment at 7 other Alabama locations to provide more conclusive evidence for changes in soil test calibration for similar soils.

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Acknowledgement

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Table 2. Fertilizer treatments and mean cotton lint yields on a Vaiden clay in West Alabama, 2005-2010.

Treatment number	Description	Annual rate of nutrients applied			Cotton Lint Yields					
		N	P_2O_5	K_2O	2005	2006	2007	2008	2009	2010
		---------------------------pounds per acre------------------------------								
N variables										
1	No N	0	100	100	177	311	870	960	812	329
2	Low N	30	100	100	214	380	1040	1070	760	466
3	Moderate N	60	100	100	265	403	990	1220	855	934
5	Control	90	100	100	388	393	1076	1350	830	802
4	High N	120	100	100	237	400	1037	1340	858	848
6	No S/VH N	150	100	100	320	387	1040	1360	877	858
P variables										
7	No P	90	0	100	280	378	910	1310	995	793
8	Very low P	90	20	100	205	394	940	1350	974	676
9	Low soil P	90	40	100	274	375	1091	1260	892	829
10	Moderate P	90	60	100	233	388	1027	1470	951	867
5	Control	90	100	100	388	393	1076	1340	830	802
K variables										
11	No K	90	100	0	157	353	585	600	470	717
12	Very low K	90	100	20	170	324	784	770	444	637
13	Low K	90	100	40	253	295	803	1030	815	878
14	Moderate K	90	100	60	341	335	922	1030	747	809
15	High K	90	100	80	319	349	806	1150	1005	918
5	Control	90	100	100	388	393	1076	1340	830	802
Other variables										
16	No lime	90	100	100	196	413	1027	1350	852	864
17	Nothing	0	0	0	160	300	649	670	475	541
	L.S.D $_{P<0.1}$				135	ns	220	210	179	153
	Mean yield				260	370	930	1150	800	760

Table 3. Fiber quality as affected by selected treatments in 2007-2010.					
Treatment	Lint %*	Micronaire*	Length*	Strenth*	Uniformity*
2007					
No N (#1)	43	4.23	1.01	26.6	81.9
No K (#11)	43	3.60	1.02	25.9	81.6
High K (80 lb. K2O/acre, #15)	42	4.23	1.00	26.8	82.0
2008					
No N (#1)	49.5 a	4.05 a	1.04	27.8 ab	81.9 ab
High N (120 lb. N/acre, #4)	46.5 bc	4.22 a	1.07	28.8 a	83.0 a
No P (#7)	47.2 b	4.18 a	1.05	27.8 ab	81.0 b
No K (#11)	45.2 c	3.15 b	1.06	26.8 b	80.5 b
High K (80 lb. K_2O/acre, #15)	46.0 bc	3.78 ab	1.06	28.8 a	82.0 ab
2009					
No N (#1)	47 a	4.65 a	1.07 c	26.9 ab	82.0 a
High N (120 lb. N/acre, #4)	43 c	4.05 b	1.14 a	28.5 ab	83.3 a
No P (#7)	45 b	4.50 a	1.10 bc	28.6 a	82.4 a
No K (#11)	43 c	3.47 c	1.10 bc	26.6 b	80.7 b
High K (80 lb. K_2O/acre, #15)	43 c	4.32 ab	1.12 ab	27.9 ab	82.7 a
2010					
No N (#1)	0.47 a	4.58 a	1.01	25.0 b	80.4
High N (120 lb. N/acre, #4)	0.46 b	4.88 a	1.04	27.6 a	81.8
No P (#7)	0.46 b	4.87 a	1.04	26.5 ab	81.4
No K (#11)	0.46 ab	4.90 a	1.04	27.2 a	81.4
High K (80 lb. K2O/acre, #15)	0.45 b	4.12 b	1.02	25.9 ab	81.3
.*Values followed by the same letter are not significantly different at $P<0.05$.					

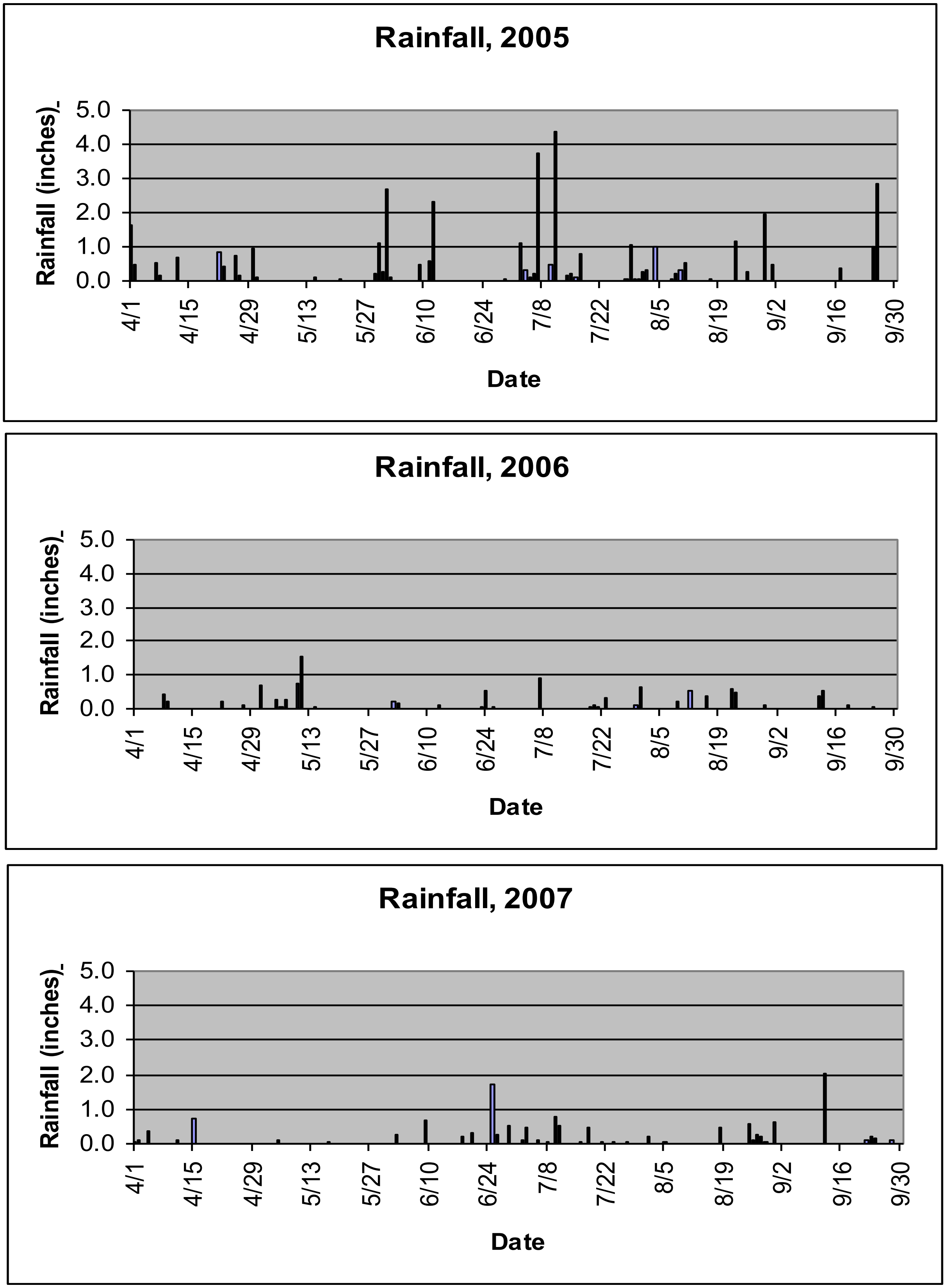

Fig. 1. Precipitation at Black Belt R&E Center, 2005-2007.

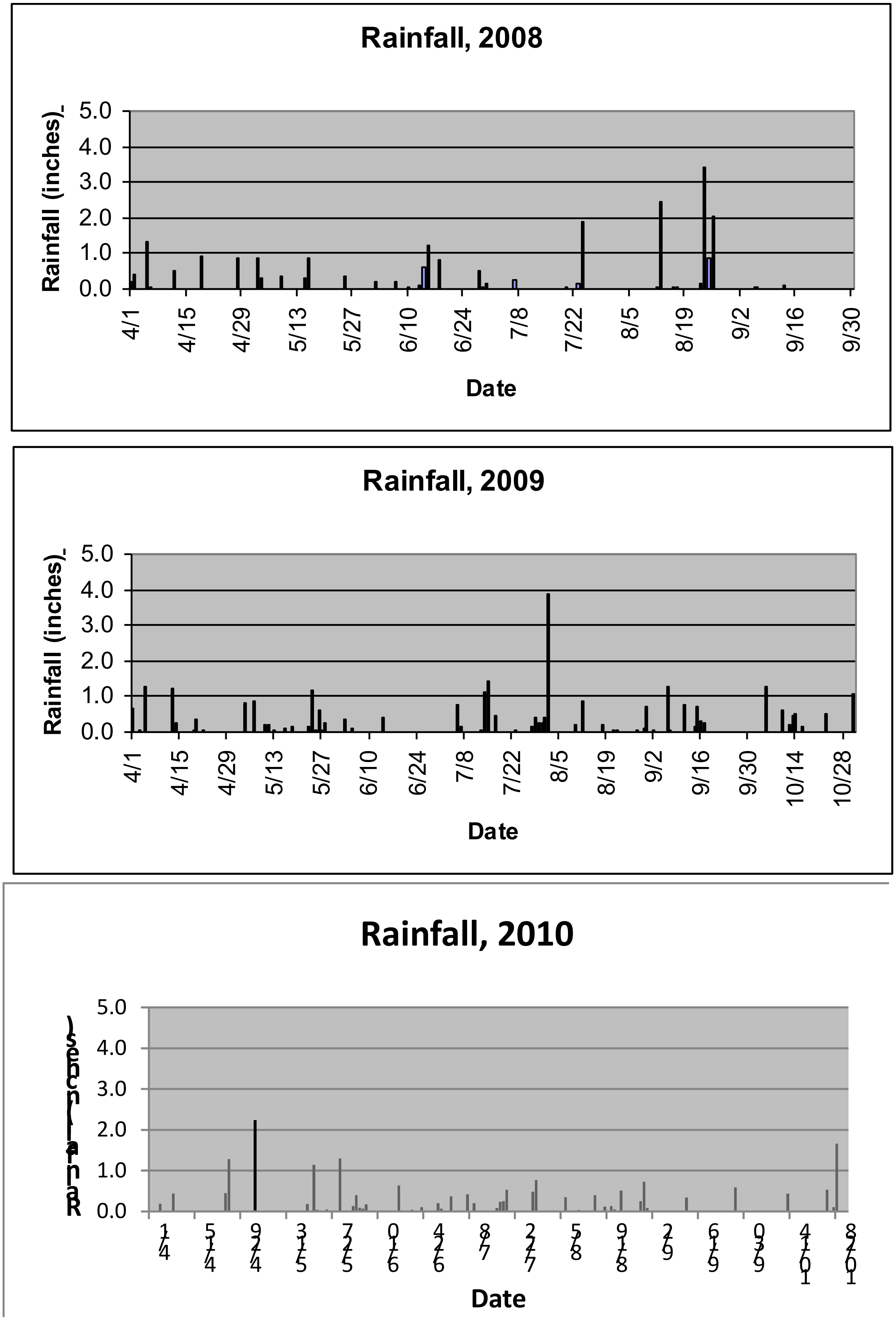

Fig. 2. Precipitation at Black Belt R&E Center, 2008-2010.

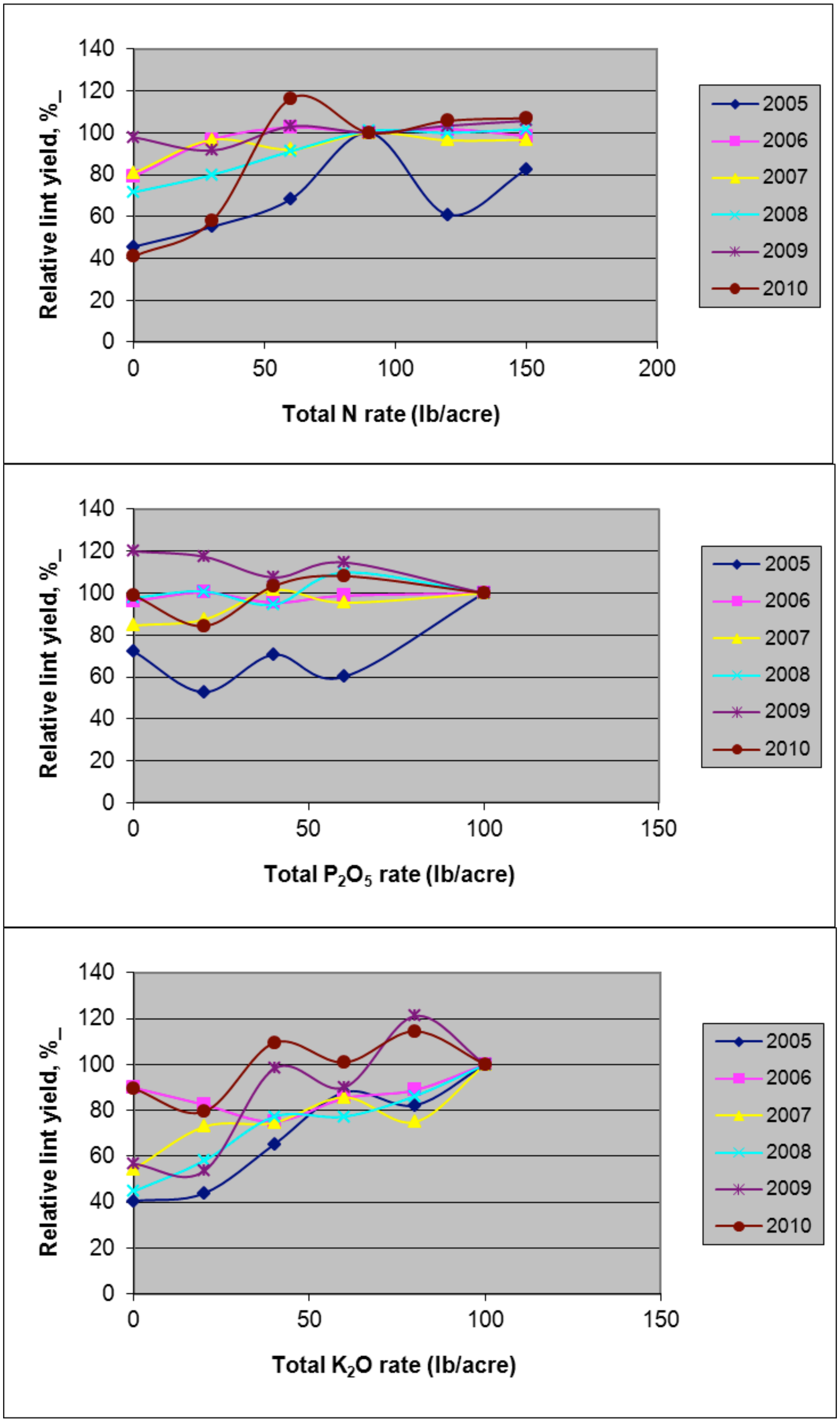

Fig. 3. Effect of rates of N, P_2O_5, and K_2O on relative cotton lint yields in 6 years on a Vaiden clay in West Alabama.

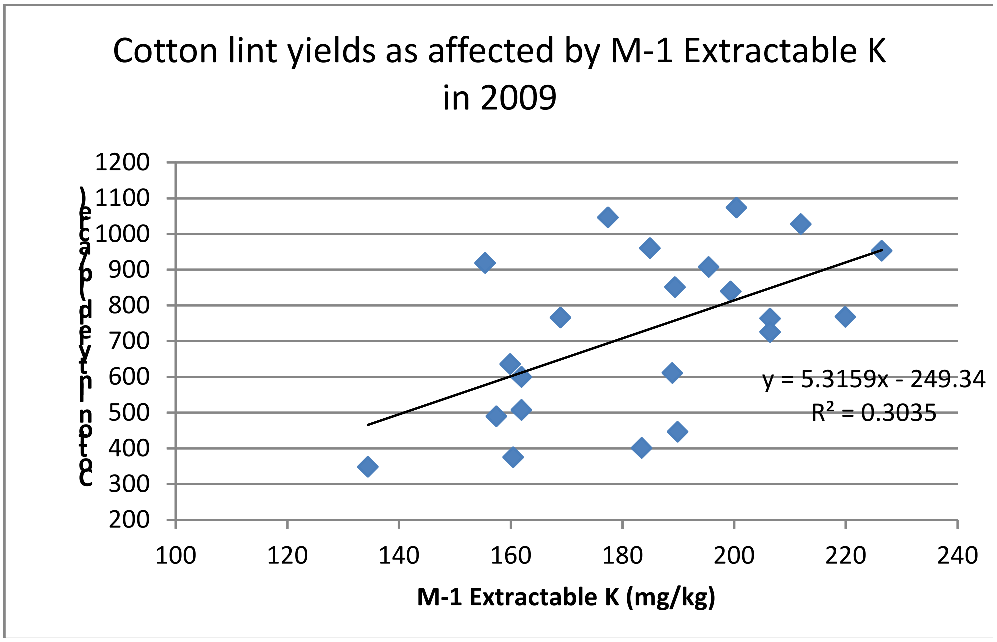

Fig. 4. Correlation between Mehlich-1 extractable soil K and cotton lint yields in 2009.

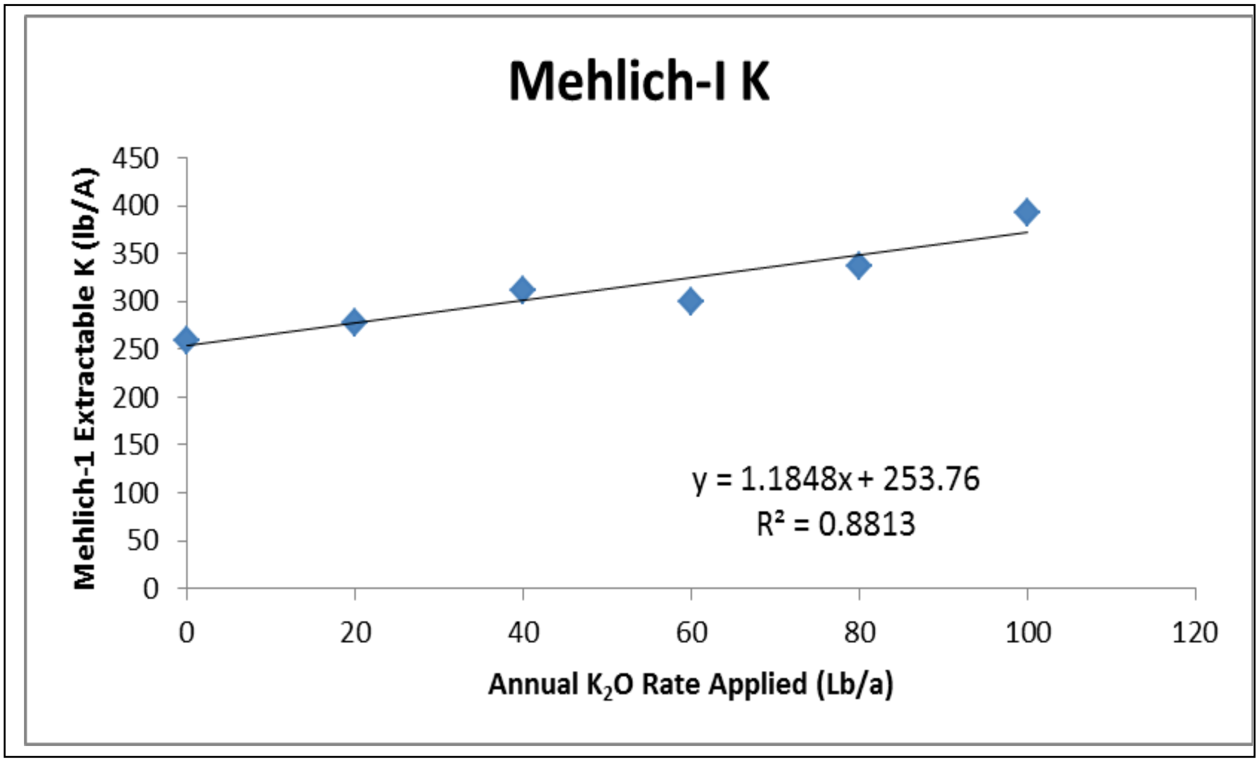

Fig. 5. Relationship between K applied and Mehlich-1 extractable K after 6 years. Samples taken 0-6 inches on 15 October 2010.

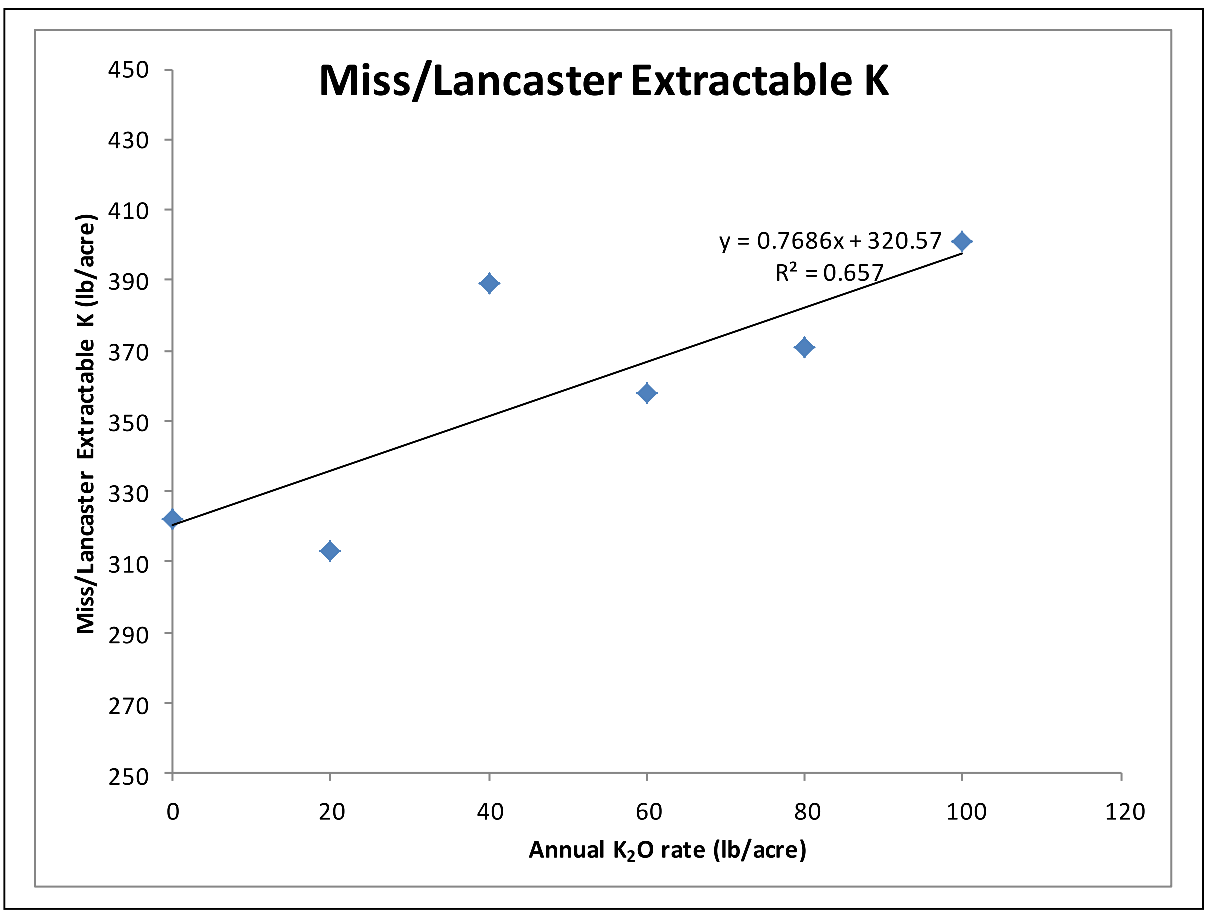

Fig. 6. Relationship between K applied and Mississippi/Lancaster extractable K after 5 years. Samples taken 0-6 inches on 15 June 2009.

The following photos may be used as needed to enhance bulletin.

Plots were hand fertilized with ½ N, P, and K at planting and the complement of N applied as a topdressing in June (above).

Area Extension agent Rudy Yates inspects severely defoliated cotton due to leaf spot disease on 6 September 2008..

Phenoxy herbicide damage to plots in July, 2010, from drift from a nearby forestry operation.

View of research site on August 14, 2009, with “No N” treatment in foreground.

Typical, early leaf-spot disease on cotton leaves in August, 2008. Problem was worst in the "no K" treatments as seen in this photo.