100 YEARS OF THE CULLARS ROTATION (c. 1911)

Charles C. Mitchell
Dennis Delaney
Auburn University, AL
Kipling S. Balkcom
USDA-ARS, Auburn, AL

Abstract

Alabama's "Cullars Rotation" experiment (circa 1911) was placed on the National Register of Historical Places as the oldest, continuous, soil fertility experiment in the South in 2003. Along with its nearby predecessor on the National Register, "The Old Rotation" (circa 1896), these experiments contain the oldest, cotton research plots in the world. Both are located on the campus of Auburn University in east-central Alabama. Treatments on the Cullars Rotation demonstrate dramatically the long-term effects of fertilization and the lack of specific nutrients on non-irrigated crop yields over a 100-year period. The Cullars Rotation is one of the few sites where controlled nutrient deficiencies can be observed on 5 different crops during the course of a year (cotton, crimson clover, corn, wheat, and soybean). The experiment preserves a site for monitoring nutrient accumulation and loss and soil quality changes and their effects on long-term sustainability of an intensive crop rotation system.

The Cullars Rotation on the Alvis Field

The Cullars Rotation was named for J.A. Cullars who owned and farmed this land in the late 19th and early 20th centuries along with his brother-in-law, John P. Alvis. Early records suggest that Mr. Cullars and Mr. Alvis allowed Professor George F. Atkinson of the Agricultural and Mechanical College of Alabama (now Auburn University) and others to conduct numerous early cotton fertility experiments on this property. Professor Atkinson's research on this site led to the discovery that "cotton rust" was caused by a deficiency of potassium (Atkinson, 1891, 1892).

An appropriation by the Alabama Legislature in 1911 enabled the Alabama Agricultural Experiment Station to conduct on-farm research throughout the state. Williams and Funchess (1923) summarized 226 experiments on farmers' fields throughout Alabama. Williams (1929) added to the data available from these tests. An extensive cotton, corn, and legume fertility test begun in 1911 on the Auburn farm of Mr. Cullars and Mr. Alvis is the only one of these experiments that has been continued. Unlike the nearby Old Rotation experiment which was begun by Professor J.F. Duggar, records do not credit any single researcher with designing the Cullars Rotation experiment. Names of professors and researchers that have been associated with the Cullars Rotation, chronologically, include J.F.Duggar, E.F. Cauthen, J.T. Williamson, M.J. Funchess, D.G. Sturkie, E.M. Evans, L.E. Ensminger, J.T. Touchton, C.C. Mitchell, and D.P. Delaney. The site of the Cullars Rotation became known as the Alvis Field.

In 1938, the "Alvis Field" was sold to Alabama Polytechnic Institute (now Auburn University) by Bessie Alvis Emerick and Lillian Alvis Miller, daughters and heirs of Mr. John P. Alvis. In 2000, construction of the Jule Collins Smith Museum of Art occupied most of the Alvis Field but the Cullars Rotation with a 40-foot border is preserved for on-going research and demonstration on sustainable crop production for soils of the southern U.S.

Agronomics and Experimental Design

The Cullars Rotation was designed primarily to study the long-term effect of phosphorus, potassium, lime and other nutrients on a 3-year rotation which included cotton, corn, small grain and summer legumes (cowpeas, crotalaria or soybean). Today, the experiment is a three-year rotation of (1) cotton followed by crimson clover, (2) corn harvested for grain followed by winter wheat, and (3) soybean double cropped after wheat is harvested for grain. It is located on a Marvyn loamy sand (fine-loamy, siliceous, thermic Typic Kanhapludults), a soil associated with Alabama's Coastal Plain physiographic region.

Experimental Design

Original design was 11 soil treatments replicated 3 times, one replicate for each of the 3 crops in the 3-yr rotation, in an ordered block design (Fig. 1). In 1914, an additional 3 treatments (designated A, B, and C) were added to include the effect of winter legumes in the rotation. Plot size is 20 x 99 feet with a 2-foot border between each plot and 20 feet between each tier (block). Plots were originally 110 feet long but were shortened in the 1950s so mechanical equipment could maneuver between tiers.

Tillage and other cultural practices

Prior to 1997, all crops were conventionally tilled with moldboard plowing, disking, and regular cultivation. All green manure crops (winter legumes, cowpeas, and crotalaria) and crop residues were turned under using a moldboard plow. Since 1997, all crops have been grown with minimum tillage and transgenic cultivars. Cotton and corn are planted directly into previous crop residue in narrow rows (30-inch rows) after paratilling or in-row subsoiling. Soybeans are drilled into wheat residue in June using a no-till drill. *Since 1996, few insecticides have been applied for insect control.* This has been possible because of the boll weevil eradication program in East Alabama and the advent of Bollgard® technology. All crops are machine harvested although cotton and corn yield estimates are made by hand-harvesting portions of each plot.

Fertilization

In the early years of the Cullars Rotation, sources of plant nutrients were blood meal (12-1-1) and cottonseed meal (6-1-1) for N, superphosphate (0-18-0) and rock phosphate for phosphorus, and kainit (0-0-12) for potassium. In recent decades, phosphorus as concentrated superphosphate (0-45-0), potassium as muriate of potash (0-0-60), sulfur as gypsum (18% S), and a micronutrient mix containing B, Zn, Mn, Cu, and Mo are applied to appropriate plots in split applications in the spring prior to planting cotton and in the fall just prior to planting small grain. Nitrogen as ammonium nitrate (34-0-0) is applied to appropriate plots just prior to planting cotton and corn with the remaining N applied as a sidedress application to these crops. The small grain is topdressed with 60 pounds N per acre in late February. Fertility treatments and recent soil test results are presented in Table 1.

The Yield Record

Few research areas exist in the U.S. where one can see such dramatic deficiencies of plant nutrients on one site. Particularly dramatic are the plots where no soil amendment has been applied since 1911 (treatment C), the “no K” plots (treatment 6), the “no lime” plots (treatment 8), and the “no P” plots (treatment 2) (Fig. 2-5). Deficiencies sometimes appear on the other treatments but are less dramatic. In general, cotton is most sensitive to low soil K in this experiment while corn, soybean, and small grain are most sensitive to low soil P (Table 2). Cotton and soybean seem to be more sensitive to the acid soil (pH = 4.7 in 2004) in the no lime treatment than other crops in the rotation. Since 1955, all plots except treatment 8 (no lime) and treatment C (nothing) receive an application of ground, dolomitic limestone whenever the surface soil pH drops below 5.8. Although B fertilization of cotton and reseeding clover and Zn fertilization of corn are routinely recommended by Auburn University’s Soil Testing Laboratory (Adams et al., 1994), no crop demonstrated a significant response to micronutrient fertilization in the period 1995-2004. Mean yields of cotton, corn, soybean, and small grain from 2001 through 2010 seem to reflect long-term trends (Table 2).

Long-term trends as demonstrated by the 5-yr running average yields in Fig. 2-5 show periods of yield increases and dramatic decreases. Because this is a non-irrigated experiment, short-term droughts and other weather-related disasters during the growing season can have dramatic effects on yields. Year-to-year yield variability is high as reflected by the coefficient of variation in the 10-year average yields in Table 2. However, the downward yield trend in the late 1970s and early 1980s reflect management problems when the main research farm moved and no one was left to take care of the day-to-day management of these plots. Nevertheless, the relative yields of the different fertility treatments remained about the same.

Coincidentally, record crop yields have been recorded on the Cullars Rotation since 1996 when we switched to genetically modified varieties, and in 1997 when we switched to conservation tillage:

- 1996: 1580 pounds cotton lint per acre (3+ bales) on plot 7
- 1996: 75.1 bushels soybean per acre on plot 10
- 1999: 161 bushels corn per acre on plot A
- 1999: 63.5 bushels wheat per acre on plot 9
- 2000: 64.7 bushels wheat per acre on plot 5
- 2001: 70.0 bushels wheat per acre on plot 11
- 2004: 1930 pounds cotton lint per acre (almost 4 bales) on plot 1

These yields are attributed to (1) favorable growing seasons, (2) adoption of deep tillage to disrupt traffic pans, (3) conservation tillage which allows better moisture infiltration, higher water holding capacity, and cooler soils, (4) higher plant populations , (5) timely planting, (6) better weed control especially through the new genetically modified varieties, and (7) less insect problems as a result of the boll weevil eradication program and the new Bollgard® cotton varieties.

Summary

The Cullars Rotation experiment continues to document long-term trends in non-irrigated crop yields and soil changes due to variable rates of P, K, S, micronutrients and lime. It provides a valuable and accessible teaching tool for monitoring crop nutrient deficiencies. It also is a source of uniform soil with variable fertility conditions for allied studies. No other such resource exists in the Coastal Plain of the southern United States. For these and other reasons, The Cullars Rotation was placed on the National Register of Historical Places in 2003.

Web site for Cullars Rotation: *http://www.ag.auburn.edu/agronomy/cullars.htm*

Acknowledgement

The Cullars Rotation is one of several long-term, soil fertility experiments maintained by the Auburn University Department of Agronomy and Soils and the Alabama Agricultural Experiment Station in cooperation with the USDA-ARS National Soil Dynamics Laboratory. This experiment has received periodic support through the commodity checkoff programs of the Alabama Wheat and Grain Crops Committee, the Alabama Soybean Committee and the Alabama Cotton Commission.

Literature Cited

Adams, J.F., C.C. Mitchell, and H.H. Bryant. 1994. Soil test fertilizer recommendations for Alabama Crops. Ala. Agric. Exp. Stn. Dep. Ser. No. 178. Auburn University, AL.

Atkinson, G.F. 1891. Black rust of cotton. Agric. Exp. Stn. Bul. No. 27. Agricultural and Mechanical College of Alabama, Auburn, AL

Atkinson, G.F. 1892. Some leaf blights of cotton. Agric. Exp. Stn. Bul. No.36. Agricultural and Mechanical College of Alabama, Auburn, AL

Williamson, J.T., and M.J. Funchess. 1923. Fertilizer experiments with cotton. Agric. Exp. Stn. Bul. 219. Alabama Polytechnic Institute. Auburn, AL.

Williams, J.T. 1929. Fertilizer experiments with cotton. Agric. Exp. Stn. Bul. No. 228. Alabama Polytechnic Instituate, Auburn, AL

Table 1. Treatments since 1985 and mean soil pH and Mehlich-1 extractable plant nutrients and rating from 0-6 inch soil samples taken November, 2004, on the Cullars Rotation. Particularly relevant values are shaded.

Plot	Treatments†						Soil pH	Soil-test rating and Mehlich-1 extractable nutrients‡			
	Description	N	P	K	S	Other		P	K	Mg	Ca
								----------------mg/kg-----------------			
A	No N/+legume	0	✓	✓	✓		6.1	VH 63	M 46	H 28	423
B	No N/no legume	0	✓	✓	✓	No legume	6.0	VH 57	M 44	H 23	330
C	No soil amendments	**0**	**0**	**0**	**0**		**5.2**	**L 5**	**L 21**	**L 6**	**73**
1	No winter legumes/ + N	✓	✓	✓	✓	No legume	6.2	H 46	M 52	H 33	371
2	No P	✓	0	✓	✓		6.2	**VL 3**	M 34	H 31	285
3	Standard fertilization	✓	✓	✓	✓		6.1	VH 51	M 42	H 37	395
4	4/3 K	✓	✓	✓	✓	Extra K	6.2	VH 81	M 47	H 38	525
5	Rock phosphate	✓	✓	✓	✓	Rock P	6.0	**EH 200**	M 47	H 30	732
6	No K	✓	✓	0	✓		6.3	EH 101	**VL 13**	H 43	541
7	2/3 K	✓	✓	✓	✓		6.2	VH56	M 37	H 34	826
8	No lime	✓	✓	✓	✓	No lime	4.7	VH 68	L 26	L 3	200
9	No S	✓	✓	✓	0		6.2	VH 90	M 50	H 46	1100
10	Standard fertilization + micronutrients	✓	✓	✓	✓	+ Zn,Cu, Mn, Fe, B & Mo	6.3	VH 85	M 66	H 36	953
11	1/3 K	✓	✓	✓	✓		6.1	VH 67	L 28	H 32	680
	$LSD_{.05}$						*0.3*	*11*	*16*	*8*	*376*

†Standard lime and fertilizer treatments:

- Limed to pH 5.8 to 6.5
- 90 lb. P_2O_5 per acre per 3-yr rotation
- 240 lb. K_2O per acre per 3-yr rotation
- 90 lb. N/acre on cotton
- 120 lb. N/acre on corn
- 60 lb. N/acre topdress on small grain
- 40 lb. sulfate-S/acre applied as gypsum to cotton and small grain

‡Rating based upon cotton on sandy soils (C.E.C. < 4.6 cmol/kg); VL=very low; L=low; M=medium, H=high (desirable range); VH=very high; EH=Extremely High (Adams et al., 1994).

Table 2. Mean crop yields on the Cullars Rotation, 2001-2010.

Plot	Treatment	Cotton lint	Corn grain	Soybean grain	Wheat grain	Clover dry matter
		lb/acre	bu/acre	bu/acre	bu/acre	lb/acre
A	No N/+legume	990	56	39.1	24.5	3080
B	No N/no legume	930	36	38.8	18.9	--
C	No soil amendments	20	0	0	0.4	0
1	No winter legumes/ + N	1190	94	41.1	46.3	--
2	No P	520	35	9.3	21.3	1620
3	No micronutrients	1220	98	41.0	47.3	3600
4	4/3 K	1020	89	39.7	44.6	3100
5	Rock phosphate	1080	94	41.6	47.7	2630
6	No K	0	36	21.9	39.6	1810
7	2/3 K	1030	101	40.0	51.3	3140
8	No lime, pH=4.9	220	32	2.7	9.0	870
9	No S	1030	90	41.4	45.9	2820
10	Complete fertilization + micronutrients	1150	102	42.8	50.3	3970
11	1/3 K	720	95	37.0	49.4	2840
	C.V.	*33.1*	*31.3*	*28.0*	*20.5*	*50.7*
	L.S.D. (P<0.05)	*233*	*19*	*7.7*	*6.4*	*1060*

Standard lime and fertilizer treatments:

- Limed to pH 5.8 to 6.5 (except plots “C” and 8)
- 200 lb. P_2O_5 per acre per 3-yr rotation (except plots “C” and 2)
- 270 lb. K_2O per acre per 3-yr rotation (except plots 4,6,7 and11)
- 90 lb. N/acre on cotton in split applications (except plots A, B, C)
- 120 lb. N/acre on corn in split applications (except plots A, B, C)
- 60 lb. N/acre topdress on small grain (except C)

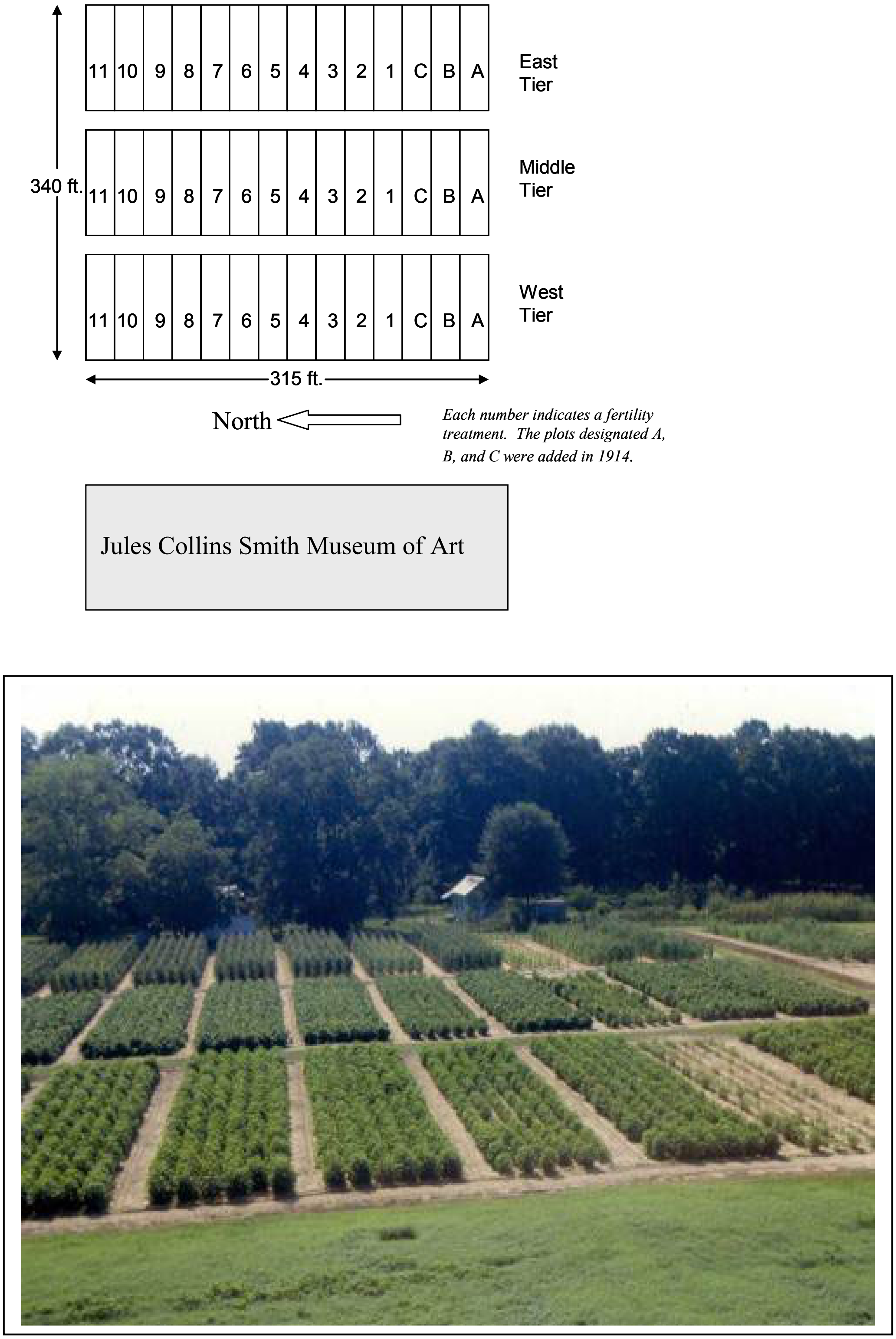


Figure 1. Schematic of Cullars Rotation (not drawn to scale) and view of experiment looking toward the east with plots A, B and C on the right as in the schematic.

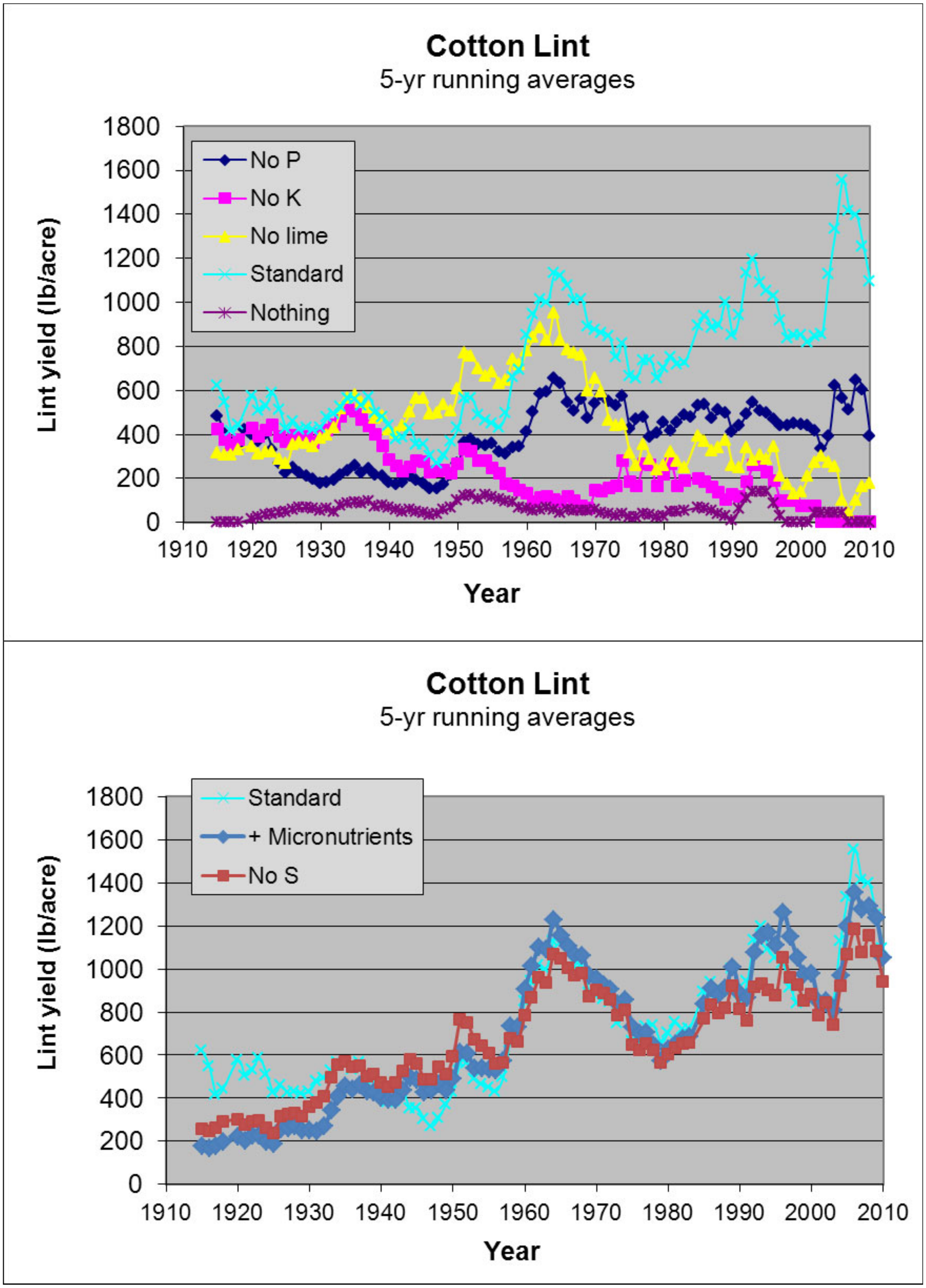
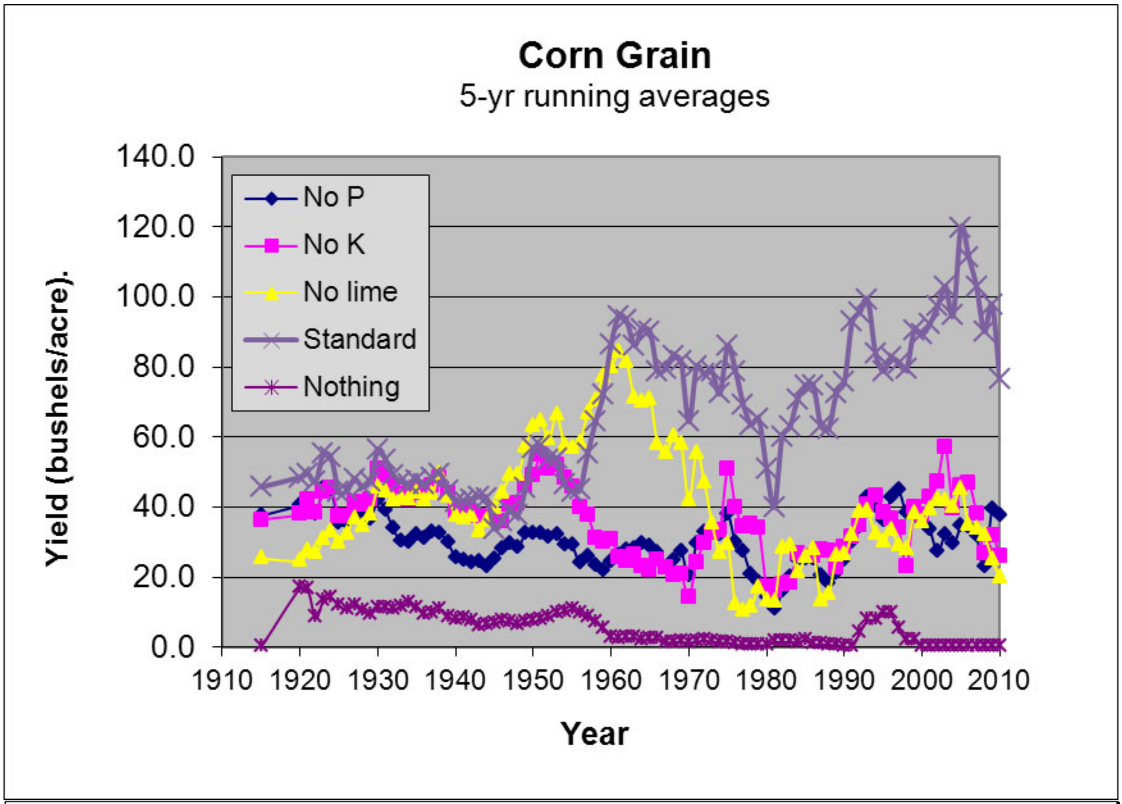


Fig. 2. Long-term cotton yield trends on selected treatments on the Cullars Rotation, 1911-2010. Each point is a 5-yr running average.



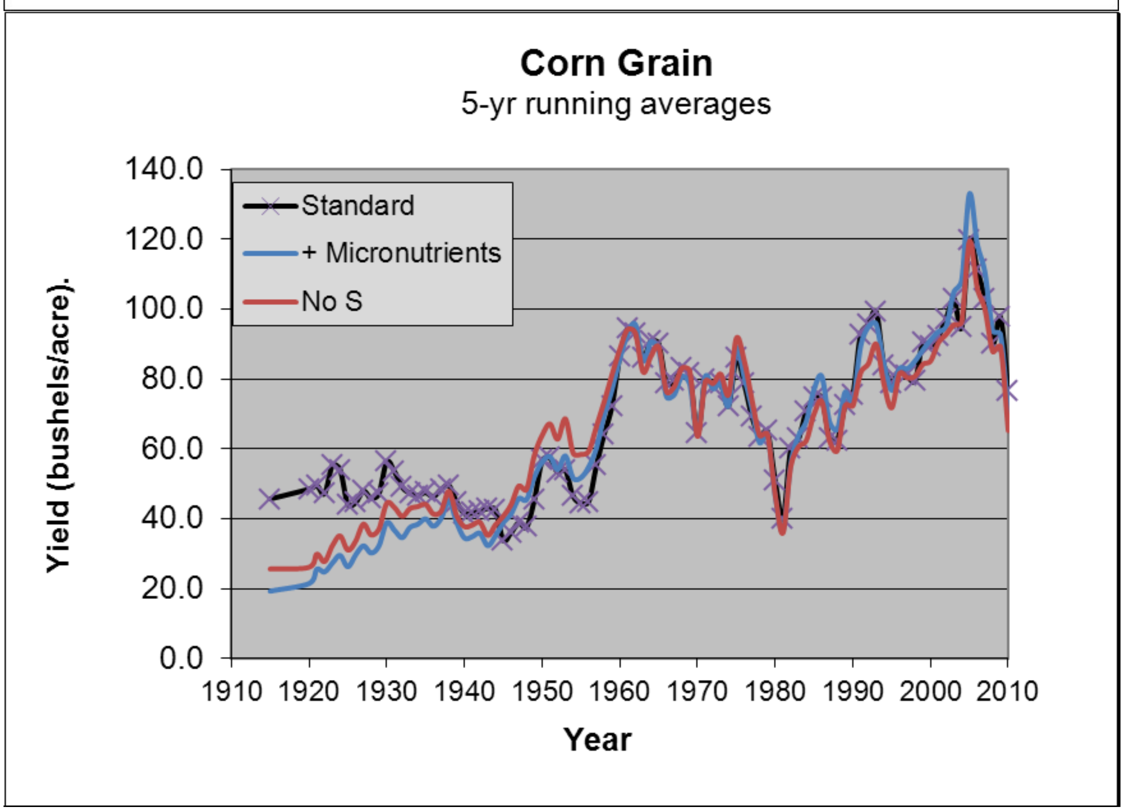


Fig. 3. Long-term corn yield trends on selected treatments on the Cullars Rotation, 1911-2010. Each point is a 5-yr running average.

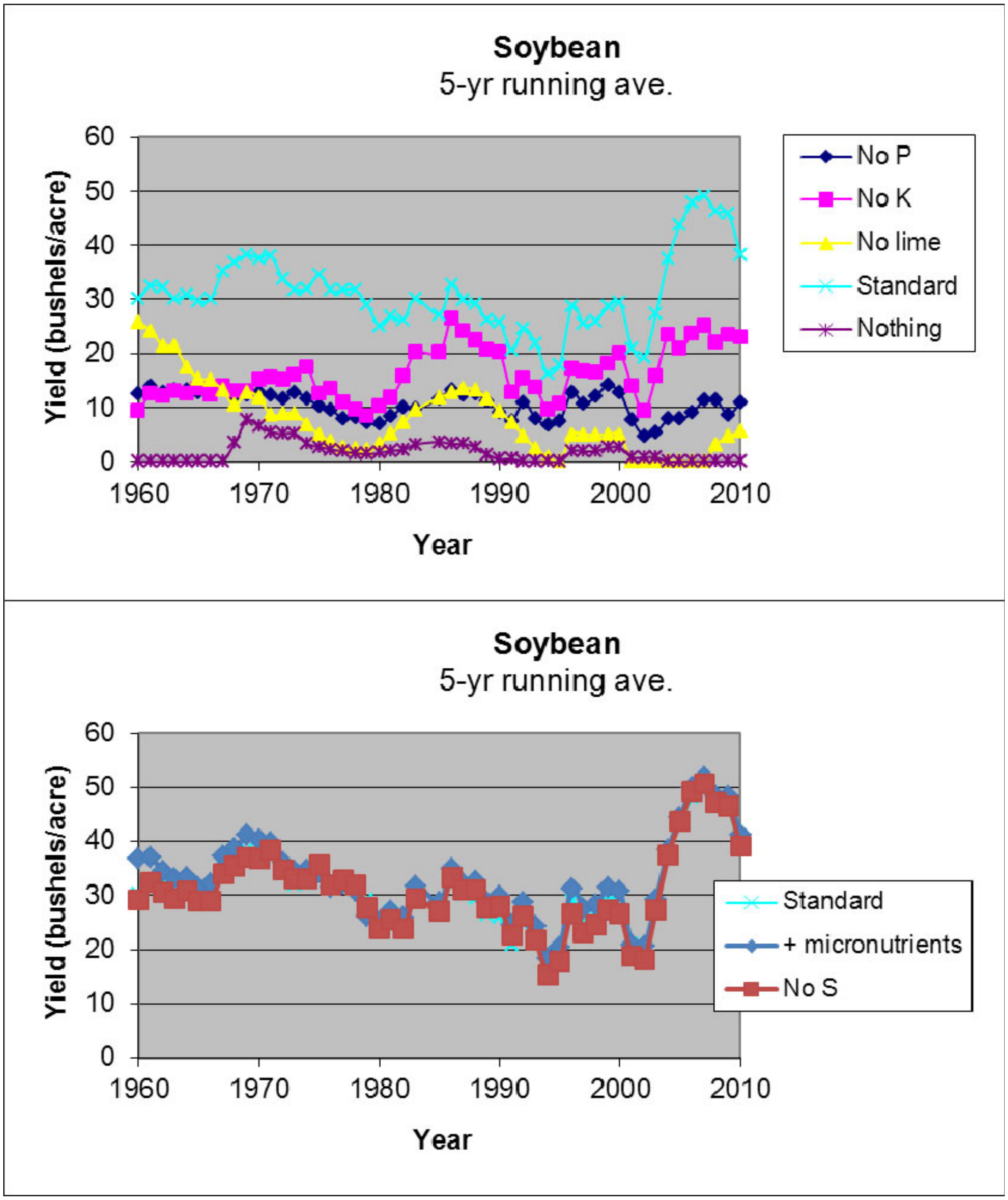


Fig. 4. Long-term soybean yield trends on selected treatments on the Cullars Rotation, 1960-2010. Each point is a 5-yr running average.

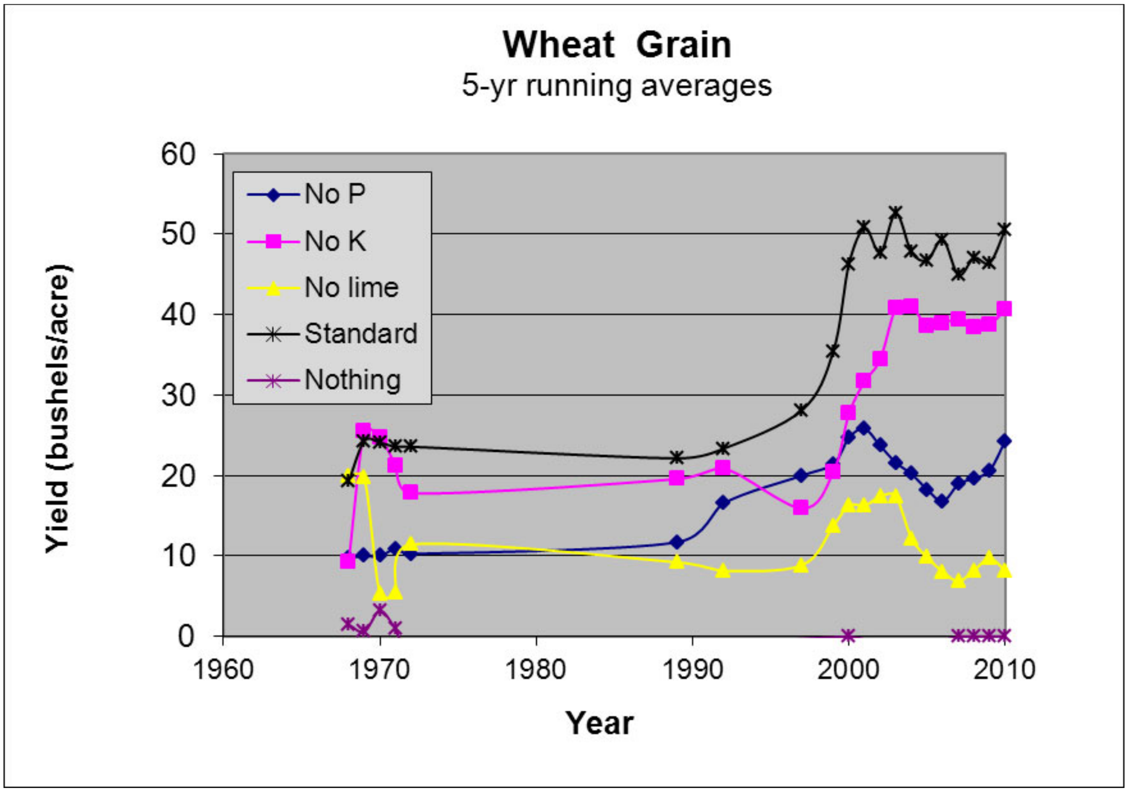


Fig. 5. Long-term wheat yield trends on selected treatments on the Cullars Rotation, 1968-2010. Each point is a 5-yr running average. Rye instead of wheat was grown from 1972-1988.