The

Old Rotation

1996-1999

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Contents

This research report is a periodic update on the Old Rotation.
Crop yields and trends on the Old Rotation seem to reflect Alabama cotton producers' experiences each year.
The Old Rotation is an index of long-term sustainability of cotton production in Alabama.

ACKNOWLEDGMENTS

The Old Rotation exists as the world's oldest, continuous cotton plots, and the third oldest continuous field crop experiment on the same site in the United States because of the dedication and cooperation of many individual researchers and administrators at Auburn University. The support of the Alabama Agricultural Experiment Station, Dr. Luther Waters, Director, has been the main reason it has continued to exist.

The help of Mr. Dennis Delaney, Extension Associate, the staff at E.V. Smith Research Center, Dr. Jim Bannon, Director, and AAES's Research Operations on the AU campus has been necessary to plant, maintain, and harvest the plots. Most of the day-to-day work and maintenance is conducted by Mr. Charlie France, Research Technician, who has worked on these plots for more than 40 years. Many students have collected data from the plots that add to our knowledge of soil quality changes.

Recently, the USDA Soil Dynamic Laboratory staff (Dr. Wayne Reeves and Mr. Jeffrey Walker) and their equipment have played a major role in converting the Old Rotation to conservation tillage.

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The Old Rotation—1996-1999

Charles C. Mitchell, Wayne Reeves, and Michael D. Hubbs

The Old Rotation experiment on the campus of Auburn University is the oldest, continuous cotton experiment in the world. The test was started in 1896 by Professor J.F. Duggar to test and demonstrate his theories that sustainable cotton production was possible on Alabama soils if growers would use crop rotation and include winter legumes (clovers and/or vetch) to protect the soil from winter erosion and provide nitrogen (N) for the summer crop. The Old Rotation was placed on the National Register of Historical Places in 1988.

Since the centennial cropping year of the Old Rotation (1995), major technological modifications have been implemented in managing this experiment. These include switching to genetically modified crops, almost complete elimination of insecticide use, drastically reducing herbicide use, and switching to conservation tillage instead of conventional moldboard plowing and cultivation. This report will highlight yields and observations made during these transition years.

Objectives

The objectives today are very similar to Professor Duggar's original objective: to determine the effect of crop rotations and winter legumes on sustainable production of cotton in the southern United States. In addition, phosphorus (P) and potassium (K) fertilizer treatments initiated in 1925 allowed early researchers to evaluate the timing of P and K applications to cotton rotation systems.

Today, the site is also used as a field laboratory for researchers, students, and visitors interested in long-term, sustainable crop production systems in the southern United States. Since conversion to conservation tillage in 1997, soil quality changes are being monitored.

Methods

The site is at the junction of the Piedmont Plateau and Gulf Coastal Plain soil physiographic regions. The soil is identified as a Pacolet sandy loam (clayey, kaolinitic, thermic Typic Hapludults). There are 13 plots on one acre of land. Each plot is 136 feet long by 21.5 feet wide with a three-foot alley between each plot. Originally, each plot was a separate treatment, but today the following cropping systems are used: continuous cotton, cotton-corn rotation, and three-year rotation (Table 1).

Table 1. Current Cropping Systems Used On Old Rotation

Continuous cotton
No legume/no fertilizer N *(plots 1 & 6)*
Winter legumes (crimson clover and/or vetch) *(plots 2, 3, & 8)*
120 pounds N per acre (as ammonium nitrate) *(plot 13)*
Cotton-corn rotation
Winter legumes *(plots 4 & 7)*
Winter legumes + 120 pounds N per acre *(plots 5 & 9)*
Three-year rotation
Cotton (winter legumes) *(plots same as continuous cotton)*
Corn (small grain for grain) *(plots same as cotton-corn rotation)*
Soybeans *(plots 10, 11, & 12)*

Of minor interest today is the timing of fertilizer P and K. Originally, the soil was low in both P and K and the winter legume produced more biomass (and more N) with direct P and K applications. This provided more N for the following cotton crop, resulting in higher cotton yields.

Today, all soils test high in P and K, and there is no longer a differential response to the time of fertilizer application, although the treatments continue. They are as follows:

(1) P & K applied prior to planting cotton (plot 8)
(2) P & K applied to the winter legume in fall (plot 2)
(3) P & K split, i.e. 1/2 to cotton and 1/2 to legume (plot 3)
(4) P & K split between cotton and winter legumes in a cotton-corn rotation (plots 4,5,7, and 9)

All plots have received a total application of 80 pounds P_2O_5 and 60 pounds K_2O per acre per year since 1956. Fertilizer N or legume N is the only fertility variable. Lime is applied to each plot as determined by a soil test to maintain soil pH between 5.8 and 6.5. Soil samples are taken in even-numbered years.

Crop varieties planted have always been those common varieties recommended and used by growers. However, since 1997, varieties planted and dates harvested have reflected new, genetically modified crops that fit well with conservation till-

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age practices (Table 2). In 1999, cotton and soybean were both Roundup Ready® varieties, and corn was a Liberty Link® variety, allowing weed control using only two herbicides. All plots were managed with conventional tillage (moldboard plow, flatbed disk or chisel, field cultivate or harrow, and cultivation for weed control) from 1896 through 1996. In 1997, all plots were switched to conservation tillage (spring paratill under the row and plant using no till planter; no mechanical cultivation). A goal was to establish reseeding crimson clover in those plots planted to winter legumes. Table 3 presents the management sequence which is now used.

TABLE 2. CROPPING INFORMATION ON OLD ROTATION, 1996-99

Year	Crop	Cultivar	Date planted	Date harvested
1996	Crimson clover	AU Robin	9/28/95	4/12/96
	Corn	Pioneer 3167	5/2/96	9/25/96
	Cotton	DPL 35B	5/2/96	10/8/96
	Rye	Wrens Abruzzi	9/25/95	Not harvested
	Soybean(36"rows) after rye	Stonewall	5/6/96	11/5/96
1997	Crimson clover	AU Robin	10/31/96	3/31/97
	Corn (36" rows)	Pioneer 3167	4/23/97	9/16/97
	Cotton (36" rows)	DPL 35B	5/17/97	10/21/97
	Wheat	Wakefield	10/16/96	5/22/97
	Soybean drilled after wheat	Hartz H-7550'(RR)	5/6/96	11/19/97
1998	Crimson clover	AU Robin	11/19/97	No yield taken
	Corn (30" rows)	Pioneer 34A55 (LL)	4/6/98	8/26/98
	Cotton (30" rows)	Paymaster 1220BG/RR	5/15/98	10/6/98
	Rye	Wrens Abruzzi	11/19/97	6/2/98
	Soybean drilled after rye	Asgrow 6101 (RR)	6/10/98	10/30/98
1999	Crimson clover	AU Robin	10/30/98	4/10/99
	Corn (30" rows)	Pioneer34A55 (LL)	4/20/99	8/10/99
	Cotton (30" rows)	Paymaster 1220BG/RR	5/21/99	10/5/99
	Wheat	Pioneer 2684	10/30/98	5/20/99
	Soybean drilled after wheat	Asgrow 6101 (RR)	6/10/99	10/27/99

1996-99 RESULTS

A New Era Begins

Cotton yields in 1995 were the lowest recorded since a disaster year in 1946. Average yield on the five best plots was only 350 pounds lint per acre, compared to a 10-year average of 960 pounds lint per acre. Yields on the Old Rotation reflect general conditions throughout the rest of the state. Statewide average for 1995 was 409 pounds lint per acre, also a long-term record low. On the Old Rotation, low yields were a result of (1) replanting on May 10 after heavy rains damaged the first planting on April 21 and (2) uncontrollable insect pressure (bollworms and armyworms) late in the season.

The near statewide disaster in 1995 prompted Alabama farmers to quickly adopt the new Bollgard® genetically modified varieties commercially available for the first time in 1996. With the boll weevil controlled by the statewide Boll Weevil Eradication Program and genetically modified varieties containing the Bt gene for bollworm resistance, 1996 opened a new era for Alabama cotton producers and for the Old Rotation. Since then, only genetically modified cotton with bollworm resistance has been planted on the Old Rotation. Interestingly, no broadcast application of insecticides has been applied to the Old Rotation since then. This contrasts with more than eight applications made annually prior to this new era.

Roundup® resistant varieties were introduced in 1997 (soybean) and 1998 (cotton). In 1999, only two herbicides were used: Roundup® on cotton and soybean and Liberty® on corn, and no insecticides have been used since the 1995 season. Genetically modified crops and conservation tillage introduced a new millenium of crop production unlike anything imagined by Professor Duggar's generation in the 1890s.

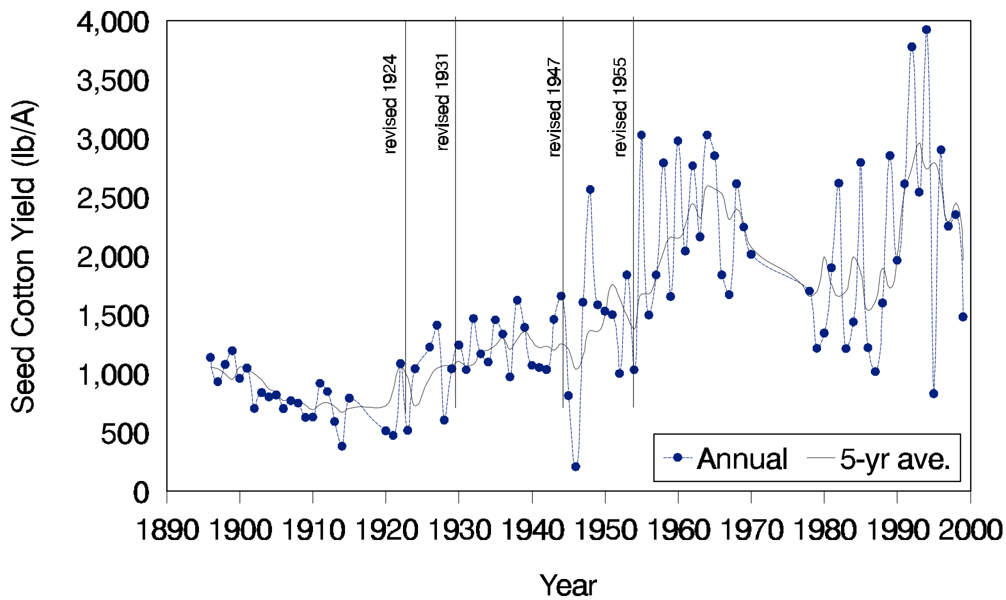
TABLE 3. CURRENT MANAGEMENT SEQUENCE USED ON OLD ROTATION

Time of year	Managment activity
Early April	Clip winter legumes for dry matter yield
Early to late April	Paratill (subsoil) cotton and corn plots Broadcast appropriate fertilizers and/ or lime Strip plant corn into clover using row cleaners
Late April to early May	Strip plant cotton into mature clover us ing row cleaners and no-till planter Use Roundup® on cotton or Liberty® on corn to control emerged weeds
Late May/early June	Harvest small grain for grain Drill soybean into grain residue Apply Roundup® or Liberty® as appropriate
Summer	Scout cotton and apply appropriate insecticides if necessary
Late August	Harvest corn for grain
October-November	Paratill and plant small grain following corn
Early October	Harvest cotton Overseed with winter legumes if necessary (plots should have reseeded, and clover seedlings will be emerging at this time) Apply fall fertilizer to appropriate plots
Late October	Chop cotton stalks when winter legumes are established Harvest soybean
November-March	Enjoy football, hunting, and basketball Write reports
February	Topdress small grain on plot 10, 11, or 12 with 60 lb. N/acre

Crop Yields

Year-to-year cotton yields continue to be extremely erratic due to uncontrollable environmental factors, mainly moisture. As an example, annual seed cotton yields since 1896 are plotted in Figure 1. Interesting, rarely does one see two extremely bad years in a row or two extremely good years in a row.

Figure 1. Yields from plot 3 (continuous cotton with winter legumes) are an example of the yield trends over the 100 years of the Old Rotation. Year-to-year yields are extremely erratic for non-irrigated cotton. However, rarely does an exceptionally high yielding year follow another high yielding year. The same is true for low yielding years. While 1994 was one of the highest yielding years on record, 1995 was one of the worst. The five-year running average gives an indication of yield trends.



In past decades, there seemed to be a slight advantage to rotating cotton with corn or other crops. During the 1990s, this statistical advantage disappeared (Table 4). The highest numerical average (more than two bales per acre) was produced with a cotton-corn rotation using winter legumes plus N fertilizer (plots 5 and 9). Winter legumes (crimson clover) versus fertilizer N resulted in no differences in 10-year average cotton yields.

Except for poor cotton yields in 1995 and in 1999 (hot and dry August and September), the decade of the 1990s has produced the highest cotton yields in the 104-year history of the Old Rotation (Table 5). In 1999, a record corn grain yield of 236 bushels per acre was produced on the three-year rotation with only legume N. This was attributed to paratilling and residue left on the soil surface, less water runoff and more infiltration, narrow rows (30-inch rows), a high plant population, and very high rainfall in June during silking and pollination. Paratilling and a cool, dry spring were responsible for the record high wheat grain yield (79 bushels per acre) in 1999. The record soybean yield in 1996 (67 bushels per acre) was attributed to early planted, full-season beans planted into rye stubble and very favorable moisture during pod fill. Due to a late freeze in 1996, the rye crop was not harvested for grain, which allowed for early planting of soybean. Nor-

TABLE 4. CROP YIELDS ON OLD ROTATION, 1996-1999

Plot	Treatment	1996	1997	1998	1999	10-yr mean
Cotton lint yields *(pounds/acre)* [1]						
1	No N	430	360	450	320	390 b
2	+ legume	1100	1130	890	710	900 a
3	+ legume	1100	860	890	560	940 a
4 & 7	Cotton-corn+legume	1090	1160	870	660	970 a
5 & 9	Cotton-corn+legume+120 N	1250	1090	1010	910	1020 a
6	No N	650	250	330	320	410 b
8	+ legume	1130	1190	860	740	950 a
10,11,12	3-yr rotation	1090	920	980	700	910 a
13	+120 N	900	1250	880	840	830 a
Corn grain yields *(bushels/acre)*						
4 & 7	Cotton-corn + legume	108	123	50	182	95 a
5 & 9	Cotton-corn + legume + 120 N	129	148	93	207	120 a
10,11,12	3-yr rotation	97	82	89	236	113 a
Small grain (wheat and rye) yields *(bushels/acre)*						
10,11,12	3-yr rotation	0 (rye)	49 (wheat)	46 (rye)	79 (wheat)	36±23
Soybean yields *(bushels/acre)*						
10,11,12	3-yr rotation	67	33	30	34	35±19
Winter legume dry matter yields *(pounds/acre)*						
All plots	Average of all plots	1040 ±220	3600 ±110	No data	5540 ±990	3550 ±1080

[1] Cotton lint yields are calculated from seed cotton yields by assuming 38% lint. Mean values followed by the same letter are not statistically different at P<0.10.

mally, soybean is planted after grain harvest in late May or early June.

Soil Quality

Interest in sustainable agricultural systems and soil quality prompted a new look at these factors in the Old Rotation. Surprisingly, little effort has been directed over the past 100 years toward documenting the effects of the cropping systems on soil organic matter and its effect on yields. Soil organic matter was first measured on plots of the Old Rotation in 1988. Since then, measurements have been repeated. As expected, the long-term treatments have had a dramatic effect on the buildup or depletion of soil organic matter. This is reflected in the yields. Yields in 1988, 1992, and 1994 were closely correlated with soil organic matter measurements (Figure 2). In 1997, just prior to conversion to conservation tillage, additional soil physical and chemical measurements were taken to serve as a benchmark for future comparisons (Table 6). As crop rotation increased and more biomass was returned to the soil in the form of crop residue, we saw increases in soil water holding capacity, hydraulic conductivity (K_{sat}), respiration, total carbon (C), total N, cation exchange capacity (CEC), and water-stable aggregates. All these indicate improvements in soil quality.

CONCLUSIONS

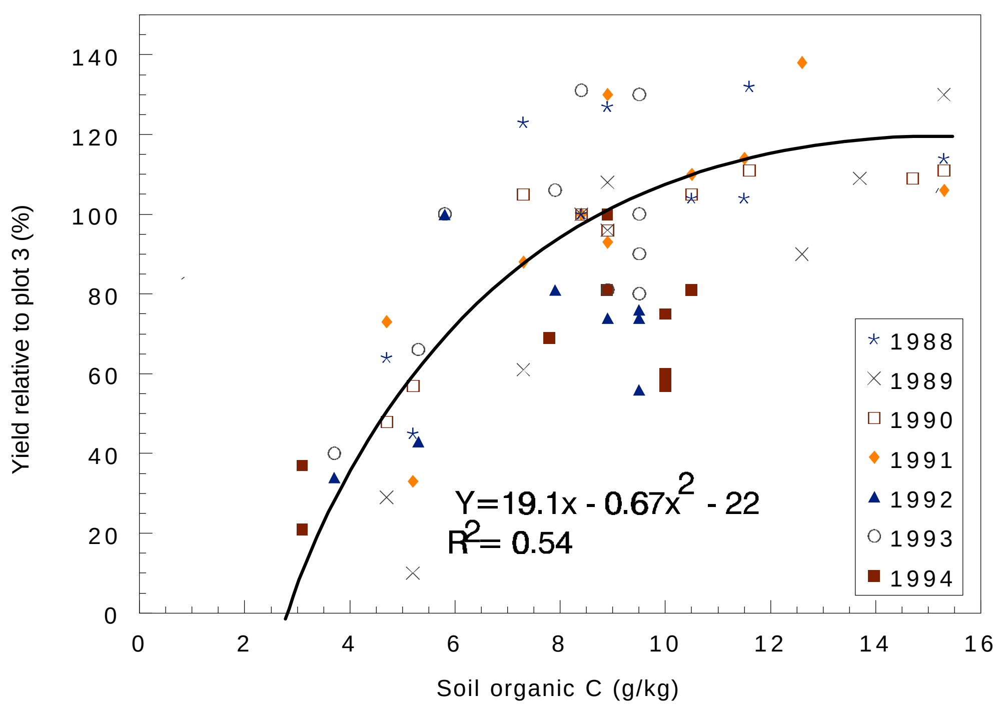
After 104 cropping years, the Old Rotation continues to document the long-term effects of crop rotation and winter legumes on sustainable cotton production in the Deep South.

TABLE 5. RECORD YIELDS ON THE OLD ROTATION

Crop	Rank	Year	Plot	Yield[1]
Cotton	1	1994	3	1490
	2	1993	9	1270
	3	1997	13	1250
Corn	1	1999	11	236
	2	1997	5	148
	3	1991	10	148
Wheat				
(1961-present)	1	1999	12	79
	2	1997	11	49
	3	1992	10	48
Oat				
(before1960)	1	1958	11	109
	2	1937	12	97
	3	1956	10	87
Rye				
(1978-present)	1	1981	12	55
	2	1988	11	48
	3	1979	11	40
Soybean				
(1957-present)	1	1996	12	67
	2	1992	10	61
	3	1983	10	55
Winter legume	1	1981	11	7250
	2	1999	3	6410
	3	1993	11	5790

[1] Yields are measured as follows: cotton = pounds of lint per acre, corn = bushels per acre, wheat = bushels per acre, soybean = bushels per acre, winter legume = pounds dry matter per acre.

Figure 2. Long-term treatments have resulted in significant differences in soil organic carbon (organic C x 1.7 = soil organic matter). These differences are reflected in soil structure, water holding capacity of the plow layer, and increased soil buffering capacity, e.g. increased cation exchange capacity, total mineralizable N, etc. Soil organic C was measured in 1988, 1992, and 1994 and regressed against plot yield relative to plot 3 (continuous cotton and winter legumes). There is a definite trend toward higher yields with increased soil organic matter.



Long-term yields suggest that winter legumes are just as effective as fertilizer N in producing optimum cotton yields. Yields are also highly correlated with soil organic matter that reflects the long-term treatments. In the past, crop rotation benefits have had a small effect on cotton yields, considering yield levels and crop value. These benefits should be enhanced under conservation tillage. Soil quality differences, e.g., aggregation and soil tilth, due to rotations and cover cropping are dramatic and are likely to increase under conservation tillage.

TABLE 6. SELECTED SOIL PHYSICAL AND CHEMICAL MEASUREMENTS MADE ON TREATMENTS FROM THE OLD ROTATION IN 1997 BEFORE CONVERSION TO CONSERVATION TILLAGE

Treatments	Bulk density *g/cm^3*	Soil water *%*	K_{sat} *inches/min*	Soil respiration *lb. C/a/day*
Continuous cotton				
No N/no legumes	1.66	7.69 c	0.37	22 b
+ winter legumes	1.66	7.47 b	0.43	44 ab
+120 lb. N/acre	1.73	9.40 bc	0.04	36 ab
Two-yr rotation				
+ winter legumes	1.68	10.11 ab	0.57	60 a
+ legumes/+120lb N/acre	1.62	11.67 a	0.33	45 ab
Three-yr rotation	1.65	11.47 a	1.22	60 a
Treatments	Total C *%*	Total N *%*	C.E.C. *$cmol_c/kg$*	Water stable aggregates *%*
Continuous cotton				
No N/no legumes	0.50 d	0.02 c	3.1 c	49.8 b
+ winter legumes	0.84 c	0.04 ab	4.3 b	52.2 b
+120 lb. N/acre	0.87 c	0.04 abc	5.6 a	34.7 c
Two-yr rotation				
+ winter legumes	0.85 c	0.05 ab	4.6 b	53.2 b
+legumes/+120lb N/acre	1.09 b	0.06 a	5.4 a	48.9 b
Three-yr rotation	1.27a	0.05ab	5.5 a	64.1a

Values followed by the same letter are not statistically different at P<0.10