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BOR Regular Loan Book NEED B

AUTHOR:	Mitchell, C.C. Jr.
TITLE:	Highlights agr. res.
VOLUME/ISSUE/PAGES:	vol:Fall 1996. v. 43 (3) no:3
DATE:	Fall 1996
TITLE OF ARTICLE:	The past is still present: apply
ISSN:	0018-1668
OTHER NUMBERS/LETTERS:	IND20584210
CALL NUMBER:	100 A11H
DELIVERY:	E-mail Post to Web: dstark@uga.e
REPLY:	E-mail: dstark@uga.edu

This document contains 3 pages. This is NOT an invoice.

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legumes often led to low dry matter production and low cotton yields as a result of low N in the soil from the legume. This observation led to split P and K fertilizer applications, which continue today in some plots. However, since soil P has accumulated to high levels and soil K is in the medium range, deficiencies are no longer observed and there are no cotton yield differences due to split P and K applications.

When the Old Rotation was established 100 years ago, it was intended to address immediate production problems in agriculture. Duggar's initial goals were realized early in the history of the Old Rotation. It is, however, a vision that has been far-reaching and, luckily, has been carried on by Duggar's successors.

Today, the Old Rotation continues to provide new information for Alabama agriculture, but its monumental value lies in its rich historical base of information. Modern concerns about sustainable agricultural production may not have been on the mind of Duggar and his successors, but the Old Rotation's unique blending of the past and the future make it a remarkable and invaluable acre of land. It is a true testament to the value of history and farsightedness.

"The South will come into its own when its fields are green in winter."
HENRY GRADY

Mitchell is a Professor of Agronomy and Soils.

The Past Is Still Present:

Applying Old Rotations' Historical Data to Modern Production Issues

Charles C. Mitchell, Jr., Francisco J. Arriaga, D. Wayne Reeves, and James A. Entry

Data collected for 100 years from Auburn University's Old Rotation provide today's scientists and farmers with valuable information about the effectiveness of management strategies and also ideas about how to sustain agriculture for another century.

Yield Trends

Some of that helpful information can be found by tracking yield trends from the Old Rotation. For example, seed cotton yield records from plot 3 (cotton every year with only legume N) illustrate the wide yield variability expected under nonirrigated conditions as used in the Old Rotation and practiced by most Alabama growers (see figure). An interesting observation is that rarely are two consecutive years with very high yields observed in the Old Rotation. Likewise, two consecutive low-yielding years are also rare.

In addition to tracking production trends, yield data also have helped identify problems and offer solutions in cotton production. Five-year running average yields seemed to decline slightly during the first 25 years of the Old Rotation. No doubt some of this decline was due to the boll weevil, which entered Alabama in 1911 and became widespread by 1914. Some of this decline also was attributed to deficiencies in phosphorous (P) and potassium (K), and resulted in revisions of P and K rate recommendations for Alabama soils.

Winter Legumes and Nitrogen

Nitrogen (N) fertilization trends also can be traced through Old Rotation data. With no N fertilization and no winter legumes to supply N (plot 6), cotton yield potential gradually declined over a period of 15 to 20 years and then stabilized at about half of the beginning yields (Table 1). This is a reflection of the gradual breakdown of soil organic matter.

Old Rotation, continued on page 14

Including a winter legume (crimson clover and/or vetch) as the only source of N for the cotton crop (plots 3 and 8 in table) has consistently produced average yields higher than those produced from applying 120 pounds N per acre to a cotton monoculture (plot 13 in Table 1). The N-fertilized plot (plot 13) was added in 1956. Professor J.F. Duggar, founder of the Old Rotation, effectively demonstrated that winter legumes could improve yields of continuous cotton during the first few years of the Old Rotation. These data show that this trend has continued for 100 years.

Recent measurements on winter legumes indicate that between 80 and 150 pounds N per acre is fixed in the above-ground portion of the legume depending upon the legume growth. If most of this N is available to cotton, it will be adequate for nonirrigated cotton.

A nitrogen budget for the treatments in the Old Rotation (using yield, fertilization, and crop removal estimates during the past decade) suggest that N use efficiency is the same for continuous cotton regardless of the source of N. Nitrogen use efficiency appears higher for the three-year rotation because of the high N removal associated with soybean and because only 60 pounds of fertilizer N per acre was applied during the three-year period.

Cotton Rotations

Data also show that there is a definite yield advantage to rotating cotton with other crops (Table 1). However, the two-year cotton-winter legume-corn rotation is as beneficial to cotton yields as the three-year rotation. Low yields for nonirrigated corn in Central Alabama have made a cotton-corn rotation less attractive to growers than continuous cotton.[1]

In the three-year rotation, soybeans have averaged 35 bushels per acre per year since 1956. Small grain (wheat or rye) harvested for grain prior to planting soybeans has averaged 27 bushels per acre for rye and 43 bushels per acre for wheat since 1975.

[1]An economic analysis of the cropping systems in the Old Rotation can be found in *Highlights* (1989) vol. 36(4), "Old Rotation Results Identify Least Risky Rotation"

"It is in fact impossible for any culture to be sound and healthy without a proper respect and proper regard for the soil, no matter how many urban dwellers think that their victuals come from groceries and delicatessens and their milk from cans."

ANDREW LYTHE

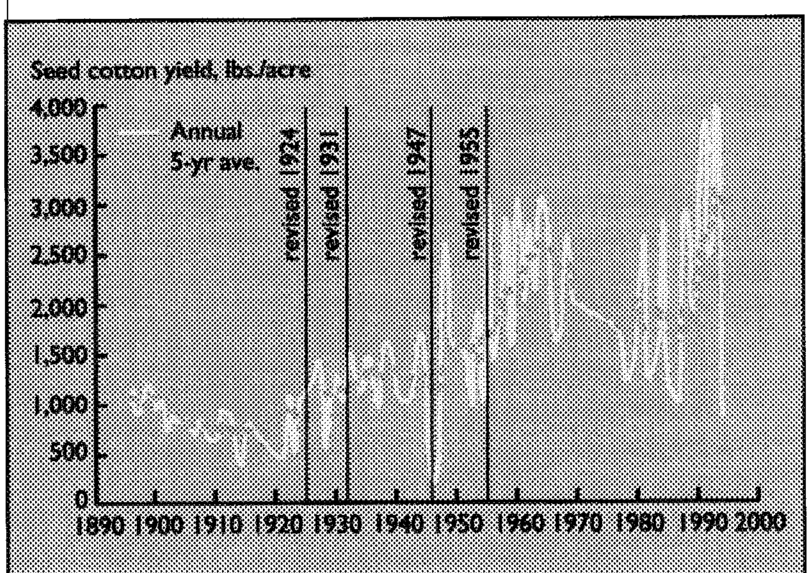
Soil Quality

Soil quality issues also have been addressed through the Old Rotation. Almost all definitions of "soil quality" include some aspect of enhancing productivity of the land while protecting the environment. Many factors affect soil quality and only recently have soil quality measurements been taken on soils from the Old Rotation. Although there are no records of the condition of this soil in 1896, researchers can compare present day differences among cropping systems (treatments).

Measurements related to soil quality include soil texture, bulk density, infiltration rate, water holding capacity, soil organic matter, and mineral nutrients (soil tests results).

Old Rotation data show that productivity has increased in all treatments.[2] Treatment differences in soil tilth also have been observed by individuals plowing, planting, and cultivating the Old Rotation. Soil on plot 13, which has been planted to cotton every year since 1956 with only commercial N fertilization, has a history of severe crusting after planting. Poor cotton stands frequently result when rains cause crusting prior to seedling emergence. The problem has also been observed on other plots planted to cotton every year with no winter legume (plots 1 and 6). Some

[2]See Highlights , Winter, 1994, "Old Rotation Documents Sustainable Cotton Production."



Annual and five-year running average seed cotton yields on plot 3 (annual cotton with winter legume N) on the Old Rotation, 1896-1995.

soil physical measurements suggest that the observed soil quality problems are due to long-term treatment effects.

In general, treatments with observed crusting problems (plots 1,6, and 13) had lower soil organic matter (SOM), higher cone penetrometer resistance, higher bulk density, fewer water stable aggregates, and lower hydraulic conductivity (Table 2). This confirms poor soil structure and soil compaction in these treatments compared to those treatments that use winter legumes and crop rotations.

Soil Organic Matter

Soil organic matter is an important indicator of soil quality because it influences soil structure, which affects soil stability and its capacity to provide water, and it is the controlling factor in nutrient cycling.

No records were kept of SOM measurements on the Old Rotation before 1988. Measurements in the plow layer were made in 1988, 1992, and in 1994 (Table 2). Results of this investigation show that long-term planting of winter legumes and crop rotations significantly increase SOM.

The plots with the highest SOM are also the highest yielding plots. Increased SOM can be viewed as a consequence of improved production. However, the relationship between SOM and yield suggests that SOM may also be viewed as a predictor of relative crop yield. There is a significant trend toward higher cotton yields in plots with higher SOM.

These results show that cover crops grown on cropland in the southeastern United States are beneficial as they maintain SOM, improve soil physical and chemical characteristics, supply the soil with additional N and reduce erosion of topsoil during the high rainfall winter months — all factors relating to soil quality.

These results also show the value of long-term research for agriculture. After 100 years, the Old Rotation continues to provide valuable information for a sustainable Alabama agriculture.

Mitchell is a Professor and Arriaga is a Research Associate, Reeves is an Adjunct Professor and USDA Research Scientist, and Entry is an Assistant Professor of Agronomy and Soils.

Table 1. Ten-year Average Seed Cotton and Corn Grain Yields, 1896-1995

Treatment (plots)	1896-1905	1906-1915	1916-1925	1926-1935	1936-1945	1946-1955	1956-1965	1966-1975	1976-1985	1986-1995
				Seed cotton yields (lb./a.)						
I. Continuous cotton										
A. No N/no leg. (#6)	800	630	340	510	370	510	620	710	610	930
B+ legumes (#3,#8)	860	680	640	160	1,230	1,580	2,360	2,100	1,840	2,230
C. 120 lb. N/acre (#13)	——	——	——	——	——	——	1,960	2,040	1,630	1,860
II. Cotton-corn rotation										
A. +legumes (#4,#7)	870	750	770	1,260	1,440	1,950	2,640	2,410	1,850	2,290
B. +leg./+N (#5,#9)[1]	890	950	1,150	1,190	1,170	1,680	2,500	2,030	2,170	2,560
III. Three-yr. rotation (#10,#11,#12)	740	804	704	1,150	1,140	1,690	2,640	2,390	2,210	2,240
				Corn grain yields (bu./a.)[2]						
I. Continuous corn										
A. No N/no leg (#2)	18	11	9	10	——	——	——	——	——	——
B. +legumes (#1)	19	16	18	26	——	——	——	——	——	——
II. Cotton-corn rotation										
A. +legumes (#4,#7)	18	13	15	29	34	40	69	39	33	73
B. +leg/+N (#5,#9)[1]	——	——	——	——	——	——	——	[3]	42	96
III. Three-yr. rotation (#10,#11,#12)	16	13	15	29	36	47	86	68	33	107

[1]120 pounds N per acre added as ammonium nitrate since 1956 to cotton and corn. Prior to this, a summer legume (cowpea) was planted in rotation with cotton and winter legumes.
[2]Corn grain yields are calculated using 56 pounds per bushel at 15.5% moisture.
[3]Insufficient data.

Table 2. Long-term Treatment Effects in the Old Rotation on Selected Soil Physical Measurements

Treatment	Plots	Cation exchange capacity	Plow-layer N	Organic matter	Bulk density 0-30cm	Cone penetrometer resistance to 30 cm	Water stable aggregates	Hydraulic conductivity (K-sat)
		meq/100g	*pct.*	*pct.*	*g/cm³*	*bars*	*pct.*	*x 10^{-3} cm s^{-1}*
I. Continuous cotton								
A. No legumes	1,6	3.9	0.11	0.8	1.84	29	24	1.37
B. +legumes	2,3,8	4.7	0.14	1.8	1.85	28	38	1.39
C. 120 lb. N/acre	13	5.4	0.10	1.6	1.73	20	22	2.89
II. Two-yr. rotation								
A. +legumes	4,7	4.4	0.13	1.8	1.75	19	40	2.56
B. +leg./+120 lb. N/acre	5,9	5.1	0.11	2.1	1.66	20	38	2.84
III. Three-yr. rotation	10,11,12	4.9	0.14	2.3	1.56	19	39	3.66