LONG-TERM COTTON/CORN/SOYBEAN ROTATION SYSTEMS: THE EARLY YEARS

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Abstract

Long-term crop rotation studies were established at the Delta Research and Extension Center near Stoneville, MS to evaluate the contributions of rotations involving cotton, corn, and soybean. The most up-to-date technology has been used that incorporates the latest advances in biotechnology, herbicides, cultural practices, irrigation, and fertility. The five cropping sequences include 1) corn-cotton, 2) corn-cotton-cotton, 3) corn-soybean, 4) soybean-corn-cotton, and 5) soybean-corn-cotton-cotton with a continuous cotton system as the basis for comparison. Each crop in a rotation system has been grown each year giving a total of 15 'treatments' in the study with each replicated four times. The cropping sequences will reach the same point after 12 years and will repeat the cycles. Crop yields, nutrient uptake, and nutrient removal are calculated annually based on harvests made with commercial harvesters adapted for plot harvest. Continuous cotton yields have been lower than any other system that included cotton and thus has the overall lowest nutrient removal. Corn yields have ranged from 185 to 223 bu/acre depending upon the year. Soybean yields have ranged from 52 to 81 bu/acre over the first five years with water tending to be the most limiting factor. Timely irrigation is needed for consistent high yields. Nutrient removal has been strongly related to the crops being grown. Soybean removed the largest percentage of nitrogen (N) and potassium (K) while corn removed more phosphorus (P) from the system. With respect to soybean production, most of the N being removed is available to the plants through symbiotic fixation of atmospheric nitrogen. The economic impact of crop rotations is evident in most years just from the yield standpoint. As the cost of inputs continues to increase the more important crop rotation becomes.

Introduction

Crop rotation has been practiced in agricultural production for centuries and with modern rotations begun as early as 1730 in England. The benefits of rotating crops in the south have been divided into three major areas that include: a) maintenance of crop yields; b) control of diseases, insects, and weeds; and c) prevention of soil erosion. The use of crop rotation also provides for some distribution of labor and diversification of income. Before the extensive use of chemical fertilizers, maintenance or improvement of crop yields were best achieved by improving the base fertility of the soil. This usually required growing a legume crop to promote nitrogen fixation or applying manure to provide additional organic nutrients. Corn was rotated with cotton through the first three to four decades of the 20th century as animal power on the farm was extremely important. Mechanization of production and inorganic fertilizer materials eliminated the need for some crops and rotations and mono-crop agriculture gained in popularity. With today's farm policies and the freedom to choose different crop mixes, rotations are coming back into prominence as they should. Field research across the cotton producing states supported crop rotation. However, growers were reluctant to rotate cotton because of government payments and the rotations complicated production practices and presented extra challenges to management.

Initial research began in the Mississippi Delta in 1904 through an act of the Mississippi Legislature authorizing the establishment of a branch station in the Yazoo and Mississippi Delta. This marked the beginning of the Delta Branch Experiment Station which has now been in existent for more than 100 years. The station continues to meet the original objective of the experiment station and land-grant institution - to make agriculture a profitable enterprise. Early research in Mississippi included simple rotations and the use of manure on fields that had been used for cotton production. In the following years, mechanization shifted the agricultural industry from hand labor to machines and chemicals while today that shift continues with the introduction and acceptance of biotechnology. The shift from rotation to mono-cultural and gradually back to rotation brings us to the 21st century. Cotton, corn, soybean, grain sorghum, and rice production recorded record yields in recent years with the aid of new technology and advancements through research. Since 2001, cotton, corn, and soybean have had yields and in 2007 and 2008 record prices received for that crop. Corn yields in 2007 averaged 150 bu/ace on 940,000 harvested acres while soybean the same year had an average yield of 40.5 bu/acre on 1.44 million acres harvested. Cotton acreage has dropped in the last two years but since 2001 has reached 1.60 million acres with average yields as high as 1,024 lb/acre.

The purpose of this research project was to establish long-term rotations involving cotton, corn, and soybean with the crops to be grown with the most up-to-date technology available. It was designed to examine the impact of rotations on the whole-farm enterprise while monitoring soil nutrients, nematodes, and other pests. Several cooperators were identified to assist in the overall management of the project in order to assure maximum utilization of the data collected.

Research Objectives:

1. Determine the effects of long-term crop rotation with respect to yield and profitability while utilizing state-of-the-art technology.
2. Assess the impact of crop rotation on the whole-farm enterprise.
3. Monitor changes in soil nutrient status, nematode numbers and types, and weed species.
4. Demonstrate the long-term need for crop rotation for the next century

Materials and Methods

The study includes five crop rotation sequences and continuous cotton as the base systems. All crops in a rotation sequence are grown each season thus establishing 15 distinct 'treatments' that are replicated four times. The five crop rotation sequences include 1) corn-cotton, 2) corn-cotton-cotton, 3) corn-soybean, 4) soybean-corn-cotton, and 5) soybean-corn-cotton-cotton and are summarize in Table 1. Each plot contains eight 40-in rows 200 ft in length with a minimum of four rows harvested for yield determinations. Fertility requirements are determined from soil tests each year. All cultural practices are maintained as uniformly as possible taking into consideration the technology that is available. The plots are harvested with commercial equipment adapted for plot harvests. Each plot is sampled for nutrient status and soil acidity (liming). The nutrient management and pesticide regimen is selected based on the committee expertise and recommendations. Production inputs and returns are then analyzed to determine the overall effects of rotation on whole-farm economics. With the current systems, it will take 12 years for all rotation systems to cycle back to the same point and the sequences will repeat. The actual arrangement of the research filed is shown in Figure 1.

Results and Discussion

The first five years of a planned 100-year rotation program has been completed. Long-term rotations and long-term research are limited in their scope in many areas of the world or are no longer in existence. The Morrow plots at the University of Illinois and The Old Rotation at Auburn University are some of the oldest continuous plots in the United States. In an effort to celebrate the centennial anniversary of the Delta Branch Experiment Station and a new era in agricultural technology, the Centennial Rotation was initiated at the Delta Research and Extension Center at Stoneville, MS. The "treatments" as outlined in Table 1 show the first 12 years of the rotations and the crops being grown each year. The project was originally setup as a cotton-based system due the historic significance of cotton to this region of the United States. Only one system (treatments 7 and 8) does not contain cotton and is meant to document the long standing advantages of corn/soybean rotations. The systems will not begin to repeat until the thirteenth season at which time some rotations will have completed six cycles, others four cycles, and the last system will have completed three cycles.

The summary of the first five years of crop yields are shown in Table 2. Cotton yields in the continuous cotton area have the overall lowest yields for cotton compared to the other systems. The greatest cotton yields follow corn production. Insect pressure and adverse weather conditions in 2007 resulted in the lowest cotton yields to date. In that year cotton yields were at least 18.6% higher where some other crop had been rotated compared to the continuous cotton system. Where cotton followed a year of soybean and a year of corn (Treatment 10), cotton yields were 41.8% (300 lb lint/acre) higher than the continuous cotton system. Soybean yields in 2007 ranged from 75.5 to 81.5 bu/acre for twin-row planted soybean grown in 40-in rows with irrigation. Corn yields throughout the history of the study have been at least 185 bu/acre and have reached 223 bu/acre in 2007. Adverse weather problems such as hurricanes have caused some problems (lodging) but the yields have still been harvestable. Timely irrigation is a key to successful and consistent corn production.

One of the areas of interest in the long-term rotation study deals with nutrient uptake and removal. Nitrogen (N), phosphorus (P), potassium (K), and sulfur (S) uptake and removal are being calculated for each of the systems. Figure 2 shows the estimated N, P, K, and S uptake for selected crops in the Mississippi Delta while Figure 3 gives an estimate of the N, P, K, and S removal by the crops based on the yields given. For cotton, corn, and soybean, the crops take up more nutrients than are actually removed from the field. Only the grain portion of corn and soybean are removed and the seed and lint portion of cotton along with some vegetative materials. Soybean removes the largest percentage of N and K while corn removes the largest percentage of P. These values have been used to calculate nutrient uptake and removal for the crop sequences that have been grown to date. The summary of nutrient uptake is shown in Table 3 and the summary of nutrient removal is shown in Table 4. As would be expected, the more cotton grown, the lower the N uptake and removal. The same is true for P and K also. The greatest N uptake and removal has occurred in the corn/soybean rotation system (Treatments 7 and 8). Much of the N that is removed in this system comes from symbiotic N fixation associated with soybean production and from high rates of fertilizer N addition for corn production. Phosphorus removal has been the greatest where corn has been grown three of the five years to date. For this system, more than 100 lb P/acre more phosphorus has been removed compared to continuous cotton.

The economic impact of crop rotations is evident in most years just from the yield standpoint. However, as the costs of inputs continue to escalate, particularly with respect to technology fees, the more important rotation becomes. The increase in herbicide-resistant weed species across the country could lead to even more emphasis on crop rotation and herbicide rotation. This is only the beginning…..!

Table 1: Cropping sequence for long-term cotton-based rotation cropping system. All crops in each sequence to be grown each year. MAFES-DREC Stoneville, MS

CENTENNIAL ROTATION STUDY												
	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
System	1	2	3	4	5	6	7	8	9	10	11	12
1	CT	CT	CT	CT	CT	CT	CT	CT	CT	CT	CT	CT
2	CT	CR	CT	CR	CT	CR	CT	CR	CT	CR	CT	CR
3	CR	CT	CR	CT	CR	CT	CR	CT	CR	CT	CR	CT
4	CR	CT	CT	CR	CT	CT	CR	CT	CT	CR	CT	CT
5	CT	CR	CT	CT	CR	CT	CT	CR	CT	CT	CR	CT
6	CT	CT	CR	CT	CT	CR	CT	CT	CR	CT	CT	CR
7	CR	SB	CR	SB	CR	SB	CR	SB	CR	SB	CR	SB
8	SB	CR	SB	CR	SB	CR	SB	CR	SB	CR	SB	CR
9	SB	CR	CT	SB	CR	CT	SB	CR	CT	SB	CR	CT
10	CT	SB	CR	CT	SB	CR	CT	SB	CR	CT	SB	CR
11	CR	CT	SB	CR	CT	SB	CR	CT	SB	CR	CT	SB
12	SB	CR	CT	CT	SB	CR	CT	CT	SB	CR	CT	CT
13	CT	SB	CR	CT	CT	SB	CR	CT	CT	SB	CR	CT
14	CT	CT	SB	CR	CT	CT	SB	CR	CT	CT	SB	CR
15	CR	CT	CT	SB	CR	CT	CT	SB	CR	CT	CT	SB
CT = Cotton		CR = Corn		SB = Soybean								

Table 2: Summary of crop yields from long-term rotation cropping system. MAFES-DREC

Trt	CROP YIELD 2004	2005	2006	2007	2008	2004 Crop Yield	2005 Crop Yield	2006 Crop Yield	2007 Crop Yield	2008 Crop Yield
1	CT	CT	CT	CT	CT	1430.5	1101.8	978.9	718.5	927.6
2	CT	CR	CT	CR	CT	1470.9	204.6	1185.4	200.8	1218.9
3	CR	CT	CR	CT	CR	201.2	1334.3	185.1	942.2	194.9
4	CR	CT	CT	CR	CT	197.2	1298.4	988.0	219.4	1314.9
5	CT	CR	CT	CT	CR	1509.4	213.3	1202.1	866.7	206.8
6	CT	CT	CR	CT	CT	1525.1	1148.8	191.1	909.3	982.5
7	CR	SB	CR	SB	CR	193.9	57.8	199.3	78.4	205.8
8	SB	CR	SB	CR	SB	60.3	212.3	62.5	208.8	56.1
9	SB	CR	CT	SB	CR	61.4	212.6	1206.2	75.5	197.6
10	CT	SB	CR	CT	SB	1447.5	61.5	194.6	1019.2	60.4
11	CR	CT	SB	CR	CT	195.9	1268.2	64.4	207.6	1222.3
12	SB	CR	CT	CT	SB	60.4	199.0	1152.6	852.2	57.5
13	CT	SB	CR	CT	CT	1402.7	52.3	191.2	929.5	978.7
14	CT	CT	SB	CR	CT	1446.6	1148.2	58.1	223.4	1240.5
15	CR	CT	CT	SB	CR	200.5	1359.4	947.2	81.5	199.9

Note: Yield for cotton in lb/acre and yield for corn and soybean in bu/acre

Table 3: Summary of nutrient (N, P, K, and S) uptake from long-term rotation cropping system.

	NUTRIENTS					N	P	K	S
						Uptake	Uptake	Uptake	Uptake
Trt	Crop Sequence					lb/acre	lb/acre	lb/acre	lb/acre
1	CT	CT	CT	CT	CT	825.2	108.3	598.3	123.8
2	CT	CR	CT	CR	CT	1160.6	182.7	897.7	160.6
3	CR	CT	CR	CT	CR	1139.3	193.1	906.6	151.5
4	CR	CT	CT	CR	CT	1131.6	179.8	878.3	155.9
5	CT	CR	CT	CT	CR	1132.6	180.2	879.5	155.9
6	CT	CT	CR	CT	CT	985.3	143.7	740.9	141.4
7	CR	SB	CR	SB	CR	1511.4	208.8	1048.1	145.2
8	SB	CR	SB	CR	SB	1497.8	182.8	972.4	129.8
9	SB	CR	CT	SB	CR	1456.4	187.2	981.3	143.0
10	CT	SB	CR	CT	SB	1292.1	153.3	846.7	132.3
11	CR	CT	SB	CR	CT	1273.5	181.1	917.5	148.5
12	SB	CR	CT	CT	SB	1203.0	143.0	786.6	120.6
13	CT	SB	CR	CT	CT	1058.3	140.0	743.6	128.8
14	CT	CT	SB	CR	CT	1215.6	161.6	856.5	148.7
15	CR	CT	CT	SB	CR	1328.4	183.9	941.1	149.3

Table 4: Summary of nutrient (N, P, K, and S) removal from long-term rotation cropping system.

	NUTRIENTS					N	P	K	S
						Removal	Removal	Removal	Removal
Trt	Crop Sequence					lb/acre	lb/acre	lb/acre	lb/acre
1	CT	CT	CT	CT	CT	330.1	61.9	170.2	30.9
2	CT	CR	CT	CR	CT	612.8	125.3	224.7	54.8
3	CR	CT	CR	CT	CR	668.8	140.3	214.0	58.9
4	CR	CT	CT	CR	CT	605.5	124.2	218.4	54.0
5	CT	CR	CT	CT	CR	607.2	124.6	218.4	54.1
6	CT	CT	CR	CT	CT	464.2	92.0	196.3	42.3
7	CR	SB	CR	SB	CR	1083.9	164.1	304.3	60.2
8	SB	CR	SB	CR	SB	1094.6	143.5	312.3	50.6
9	SB	CR	CT	SB	CR	993.9	142.1	299.8	52.8
10	CT	SB	CR	CT	SB	820.5	110.1	272.1	42.1
11	CR	CT	SB	CR	CT	780.1	130.9	254.8	52.8
12	SB	CR	CT	CT	SB	779.0	104.0	253.2	39.3
13	CT	SB	CR	CT	CT	593.2	95.2	216.8	40.0
14	CT	CT	SB	CR	CT	679.0	109.8	248.7	46.2
15	CR	CT	CT	SB	CR	833.9	134.1	268.2	53.1

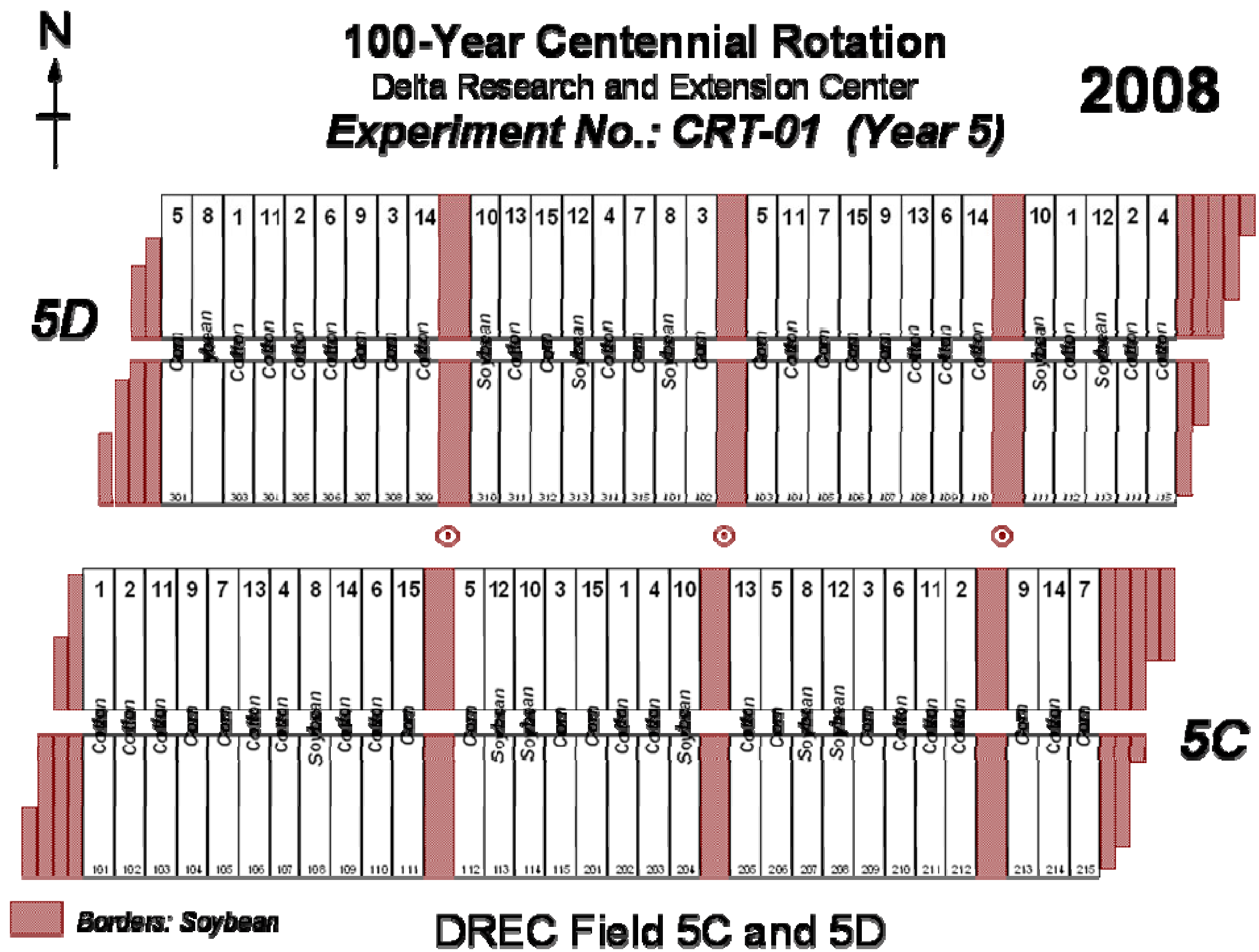

Figure 1: Field layout for long-term rotation. Crops listed for 2008 growing season

Figure 2: Estimated nutrient uptake for specific crops based on selected yields.

Nutrient Uptake for Selected Crops

Crop	Yield	N	P	K	S
	bu or lb/A	------------------	lb/A	------------------	
Corn	180	240	45	199	30
Soybean	60	314	26	170	20
Wheat	80	149	24	135	21
Cotton	1000	160	21	116	24
Rice	7000	112	26	139	12

To Convert P to P_2O_5 multiply by 2.29
To Convert K to K_2O multiply by 1.20

Figure 3: Estimated nutrient removal for specific crops based on selected yields.

Nutrient Removal for Selected Crops

Crop	Yield	N	P	K	S
	bu or lb/A	------------------	lb/A	------------------	
Corn	180	162	35	43	14
Soybean	60	240	21	71	6
Wheat	80	92	19	23	5
Cotton	1000	64	12	33	6
Rice	7000	70	19	23	6

To Convert P to P_2O_5 multiply by 2.29
To Convert K to K_2O multiply by 1.20