THE CENTENNIAL ROTATION – COTTON/CORN/SOYBEAN SYSTEMS EFFECTS ON NUTRIENT UPTAKE AND REMOVAL IN THE MIDSOUTH (2004-2011)

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Abstract

In order to celebrate the centennial anniversary (1904-2004) of the Delta Branch Experiment Station, a long-term cotton-based rotation study was established at the Delta Research and Extension Center near Stoneville, MS. The study is planned for 100 years and has been designed to utilize the latest technology and biotechnology available to producers. The crops included in the study are cotton, corn, and soybean, with the only continuous crop as cotton. At the outset of the study, cotton was the dominant crop even though more soybeans were grown in the state. In the last several years, cotton acreage has declined and corn acreage has increased to more than 900,000 acres. The study has five rotation systems with each crop from each rotation grown each year and continuous cotton. The rotations include 1) continuous cotton, 2) cotton/corn [1:1], 3) cotton/cotton/corn [2:1], 4) corn/soybean [1:1], 5) soybean/corn/cotton [1:1:1], and 6) soybean/corn/cotton/cotton [1:1:2]. Each crop is grown each year in order for direct comparisons of the systems with respect to price. In many years, producers make their decision on crop mix in their operation based on commodity prices. After eight years, commodity prices have doubled or tripled for some crops. Grain prices are at all-time highs and this coupled with irrigation, early planting, and early harvest place the Mississippi producer with a distinct advantage. In the eight years of the study, the loan rate has been used to calculate cotton value in four of eight years while grain prices have been as much as two times the loan value. Cotton prices have been higher in the last two years. Rotations involving corn have resulted in higher yields for cotton compared to continuous cotton as expected and have resulted in the largest cash values. The lowest value rotation has been the corn/soybean rotation but has probably been the most profitable as the costs of production are substantially lower than cotton. After the 12th growing season all rotations will return to the beginning point. Some will have completed six cycles, others four cycles, and the last three cycles. At that time a complete economic evaluation will be completed.

Introduction

Crop rotation has been used in farming systems for hundreds of years with modern rotations (green manures) begun as early as 1730 in England. The benefits of crop rotation in the south can be 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. Before the extensive use of chemical fertilizers, maintenance and/or improvement of yields were best achieved by improving the base fertility of the soil in which the crop was grown. This usually required growing a legume crop to promote nitrogen fixation or applying manure to provide additional organic nutrients. Corn/cotton rotations were used through the first three to four decades of the 20th century as animal power on the farm was extremely important and corn was needed as feedstock for the animals. Mechanization and inorganic fertilizer materials reduced the need for some crops, crop rotation decreased, and mono-crop agriculture gained in popularity. With today's farm policies and programs, and the freedom to choose different crop mixes, rotations are coming back into prominence. Field research across the cotton producing states supported crop rotation. However, growers were reluctant to rotate cotton because of government payments and crop rotations complicated production practices and presented extra challenges for producers.

The Mississippi Legislature authorized the establishment of an experiment station in the Yazoo and Mississippi Delta. This marked the beginning of research in the region and 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 – that is 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. 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 record prices. Corn acreage has increased while cotton has decreased in response to profitability. Grain crops can be planted early. With irrigation, yield stability has led to shifts in the crop mix and some producers shifting from cotton altogether.

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. The objectives of this research were to: 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; and 4) demonstrate the long-term need for crop rotation for the next century.

Materials and Methods

The research study includes five crop rotation sequences along with 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.

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								

Each plot contains eight 40-in rows 200 ft. in length (100-ft plots with 15-ft alleys between subplots) 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. 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 field layout is shown in Figure 1. Irrigation is supplied from the center of the two fields with furrow irrigation established as soon as possible in the three-crop system. Nitrogen management for cotton and corn is applied as a split application of urea-ammonium nitrate (UAN) solution (32% N). Potassium is applied as muriate of potash (0-0-60) and phosphorus as concentrated superphosphate (CSP, 0-46-0) as needed. Soil test levels in the field at the onset of the study and are being monitored annually. Each crop is managed independent of the others as much as possible. All plots of each crop are harvested on the same day.

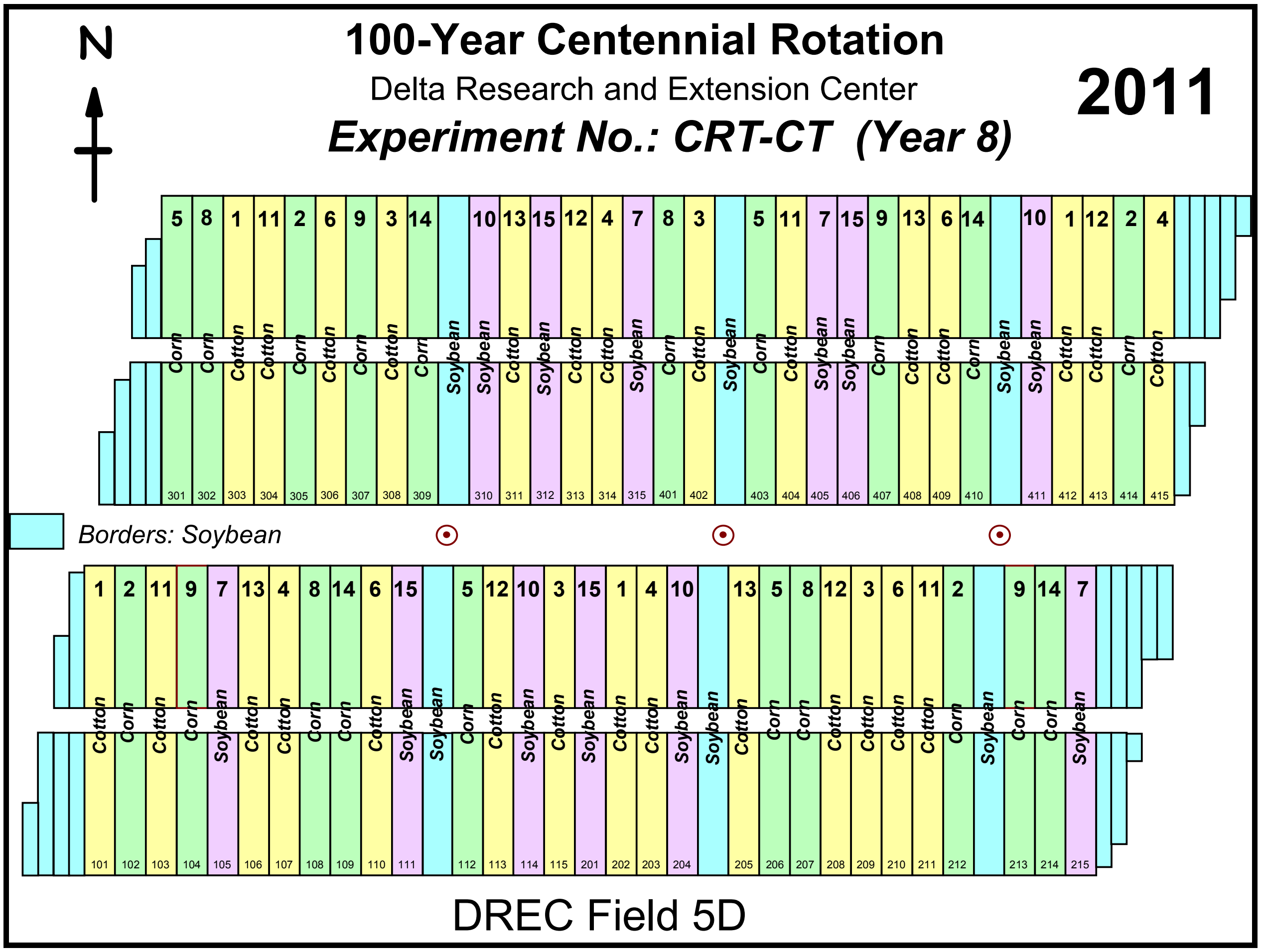

Figure 1. Plot layout for the Centennial Rotation, Delta Research and Extension Center, Mississippi Agricultural and Forestry Experiment Station, Stoneville, MS. Layout is specific for the 2011 cropping season.

Results and Discussion

The first eight years of the Centennial Rotation program was completed in 2011 (100-yr rotation). Long-term cropping system 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 US. 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 in 2004 at the Delta Research and Extension Center near 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. With recent shifts to grain production, this system has become quite important. Comparisons of the value of the crops grown have shown that the all grain system has not produced the same value as rotation systems containing cotton. However, the cost of producing grain crops, even with irrigation, is much less than the cotton-containing systems. The systems will not begin to repeat in 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 eight 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, as expected, 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. Over the years the range has been 13.1 to 41.8% higher yields (115.0 to 387.3 lb. lint/acre) where cotton was in some rotation with corn compared to continuous cotton. Average cotton yields have varied across years ranging from 891.1 lb. lint/acre in 2007 to a high of 1461.8 lb. /acre. Corn yields in the same time frame have ranged from 192.3 to 212.0 bu/acre (excluding 2011). The 2011 yields (91.2 bu/acre) were way below average due to a lack of irrigation in a timely fashion. Soybean yields have ranged from 50.3 to 78.5 bu/acre with the lowest yields in 2011 (Table 2). 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 as evident in 2011. Timing of the first irrigation is critical.

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 expected, the more cotton produced, 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. Producers should take extra steps to insure adequate fertility when shifting from cotton production to rotations with grain crops. Nutrient removal, especially N, can be 3 to 4 times higher than 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. Twin-row production systems are being used for soybean and all systems are utilizing bio-technology seed. At present, glyphosate-resistant weed issues are being addressed with care taken to eliminate potential resistant plants. Crop rotation offers the best opportunity for rotating conventional herbicides should the need arise. Producers have become dependent on the glyphosate systems and have gotten away from the use of more traditional residual compounds. Also there are few new compounds coming on the market. This lack of new chemistry further emphasizes the need for crop rotation.

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

Table 2. Summary of crop yields from the Centennial Rotation Study (2004-2011) Delta Research and Extension Center, Mississippi Agricultural and Forestry Experiment Station, Stoneville, MS.

CENTENNIAL ROTATION STUDY - SUMMARY OF CROP YIELDS/ACRE (2004-2011)

Rotation	------------------------ Crop Year ------------------------								2004	2005	2006	2007	2008	2009	2010	2011
System	2004	2005	2006	2007	2008	2009	2010	2011	Crop	Crop	Crop	Crop	Crop	Crop	Crop	Crop
	1	2	3	4	5	6	7	8	Yield	Yield	Yield	Yield	Yield	Yield	Yield	Yield
1	CT	CT	CT	CT	CT	CT	CT	CT	1430.5	1101.8	978.9	718.5	927.6	877.6	1039.4	843.2
2	CT	CR	CT	CR	CT	CR	CT	CR	1470.9	204.6	1185.4	200.8	1218.9	182.4	1185.6	61.6
3	CR	CT	CR	CT	CR	CT	CR	CT	201.2	1334.3	185.1	942.2	194.9	961.3	194.7	965.4
4	CR	CT	CT	CR	CT	CT	CR	CT	197.2	1298.4	988.0	219.4	1314.9	975.3	201.8	982.2
5	CT	CR	CT	CT	CR	CT	CT	CR	1509.4	213.3	1202.1	866.7	206.8	984.7	1148.2	73.8
6	CT	CT	CR	CT	CT	CR	CT	CT	1525.1	1148.8	191.1	909.3	982.5	194.8	1234.7	841.9
7	CR	SB	CR	SB	CR	SB	CR	SB	193.9	57.8	199.3	78.4	205.8	73.3	207.2	52.6
8	SB	CR	SB	CR	SB	CR	SB	CR	60.3	212.3	62.5	208.8	56.1	205.1	65.7	101.8
9	SB	CR	CT	SB	CR	CT	SB	CR	61.4	212.6	1206.2	75.5	197.6	994.5	70.6	113.7
10	CT	SB	CR	CT	SB	CR	CT	SB	1447.5	61.5	194.6	1019.2	60.4	209.4	1199.0	47.9
11	CR	CT	SB	CR	CT	SB	CR	CT	195.9	1268.2	64.4	207.6	1222.3	66.3	209.0	963.0
12	SB	CR	CT	CT	SB	CR	CT	CT	60.4	199.0	1152.6	852.2	57.5	195.9	1239.2	849.3
13	CT	SB	CR	CT	CT	SB	CR	CT	1402.7	52.3	191.2	929.5	978.7	69.8	208.0	1059.2
14	CT	CT	SB	CR	CT	CT	SB	CR	1446.6	1148.2	58.1	223.4	1240.5	929.3	66.8	105.0
15	CR	CT	CT	SB	CR	CT	CT	SB	200.5	1359.4	947.2	81.5	199.9	992.6	1026.1	50.4

NOTE: Cotton Yield reported in lb lint/acre, Corn Yield reported in bu/acre @15.5%, Soybean Yield reported in bu/acre @ 13%

Table 3. Summary of total nutrient (N, P, K, S) uptake from the Centennial Rotation Study (2004-2011). Delta Research and Extension Center, Mississippi Agricultural and Forestry Experiment Station, Stoneville, MS.

NUTRIENT UPTAKE									N	P	K	S
	Crop Sequence								Uptake	Uptake	Uptake	Uptake
Trt	2004	2005	2006	2007	2008	2009	2010	2011	(lb/acre)	(lb/acre)	(lb/acre)	(lb/acre)
1	CT	CT	CT	CT	CT	CT	CT	CT	1266.8	166.28	1266.83	190.00
2	CT	CR	CT	CR	CT	CR	CT	CR	1675.6	268.63	1675.63	229.69
3	CR	CT	CR	CT	CR	CT	CR	CT	1707.2	282.25	1707.17	230.18
4	CR	CT	CT	CR	CT	CT	CR	CT	1713.9	271.34	1713.87	236.48
5	CT	CR	CT	CT	CR	CT	CT	CR	1572.3	243.40	1572.28	219.39
6	CT	CT	CR	CT	CT	CR	CT	CT	1577.3	235.97	1577.29	223.73
7	CR	SB	CR	SB	CR	SB	CR	SB	2446.5	315.12	2446.54	221.73
8	SB	CR	SB	CR	SB	CR	SB	CR	2250.8	288.00	2250.83	202.86
9	SB	CR	CT	SB	CR	CT	SB	CR	2136.6	267.10	2136.59	209.30
10	CT	SB	CR	CT	SB	CR	CT	SB	2013.8	251.56	2013.81	211.90
11	CR	CT	SB	CR	CT	SB	CR	CT	2053.2	282.29	2053.23	228.54
12	SB	CR	CT	CT	SB	CR	CT	CT	1798.4	235.79	1798.36	203.35
13	CT	SB	CR	CT	CT	SB	CR	CT	1870.4	244.48	1870.40	212.12
14	CT	CT	SB	CR	CT	CT	SB	CR	1853.9	236.28	1853.87	210.72
15	CR	CT	CT	SB	CR	CT	CT	SB	1915.2	248.09	1915.15	214.52

Table 4. Summary of total nutrient (N, P, K, S) removal from the Centennial Rotation Study (2004-2011). Delta Research and Extension Center, Mississippi Agricultural and Forestry Experiment Station, Stoneville, MS

NUTRIENT REMOVAL									N	P	K	S
	Crop Sequence								Removal	Removal	Removal	Removal
Trt	2004	2005	2006	2007	2008	2009	2010	2011	(lb/acre)	(lb/acre)	(lb/acre)	(lb/acre)
1	CT	CT	CT	CT	CT	CT	CT	CT	506.75	95.01	506.75	47.51
2	CT	CR	CT	CR	CT	CR	CT	CR	908.28	187.01	908.28	80.87
3	CR	CT	CR	CT	CR	CT	CR	CT	967.33	201.31	967.33	85.57
4	CR	CT	CT	CR	CT	CT	CR	CT	912.40	186.95	912.40	81.45
5	CT	CR	CT	CT	CR	CT	CT	CR	810.13	164.57	810.13	72.68
6	CT	CT	CR	CT	CT	CR	CT	CT	772.42	154.75	772.42	69.87
7	CR	SB	CR	SB	CR	SB	CR	SB	1773.98	248.50	1773.98	88.92
8	SB	CR	SB	CR	SB	CR	SB	CR	1633.61	226.17	1633.61	81.08
9	SB	CR	CT	SB	CR	CT	SB	CR	1442.28	200.89	1442.28	74.71
10	CT	SB	CR	CT	SB	CR	CT	SB	1277.29	181.97	1277.29	70.41
11	CR	CT	SB	CR	CT	SB	CR	CT	1108.06	197.76	1108.06	81.44
12	SB	CR	CT	CT	SB	CR	CT	CT	1088.98	167.16	1088.98	67.07
13	CT	SB	CR	CT	CT	SB	CR	CT	1127.39	172.78	1127.39	69.49
14	CT	CT	SB	CR	CT	CT	SB	CR	1100.21	164.76	1100.21	66.63
15	CR	CT	CT	SB	CR	CT	CT	SB	1164.70	175.92	1164.70	70.29