MISSISSIPPI CENTENNIAL ROTATION
Yield, Nutrient Uptake and Removal, and Cropping System Value

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Introduction

Crop rotation has been practiced for centuries 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 and 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, improvement of crop yield was 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 early 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 feed crops and crop rotations with mono-crop production gaining in both popularity and practice. Herbicides were introduced to control weeds in monocrop systems and the need for crop rotation waned even more. With today's farm policies and the freedom to choose different crop mixes, rotations have come back into prominence, as they should. Field research across the cotton producing states has always supported crop rotation and in many areas, cover crops. However, growers were reluctant to rotate cotton because of government payments and the rotations complicated production practices and presented extra challenges to overall farm management.

Initial research studies began in the Mississippi Delta region in 1904 through an act of the Mississippi Legislature authorizing the establishment of a branch research 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 saw record yields in recent years with the aid of new technology and advancements through research. Since 2001, cotton, corn, and soybean have seen those record yields and in recent years record prices received for that crop. Corn yields in 2007 averaged 180 bu/ace on 910,000 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 significantly in the last three years to a low of 295,000 acres in 2009. Cotton reached 1.6 million acres in 2001. Record yields were achieved in 2004 (1,024 lb/acre). Higher grain prices and lower cotton prices have eroded the cotton base while corn production has increased in the last few years. Through the last three to four years cotton acreage fell to all-time lows but some rebound in acreage was evident in 2010. Corn and soybean production increased while cotton declined of late. Recent shifts to bio-fuels production has also strengthened grain markets and has boosted grain prices. 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 to assure maximum utilization of the data collected. This summary will only touch on the initial data collection and summary.

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. Determine the profit and loss potential for various cropping systems with different price structures.
4. Monitor changes in soil nutrient status, nematode numbers and types, and weed species.
5. Demonstrate the long-term need for crop rotation for the next century

Materials and Methods

The Centennial Rotation study has included five crop rotation sequences and continuous cotton as the base systems for comparison purposes. It also includes a non-cotton system with corn soybean on a 1:1 rotation that is common in areas outside the Cotton Belt. All crops in a rotation sequence are grown each season thus establishing 15 distinct 'treatments' that are replicated four times with the potential for expansion should the need arise. 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. The sixth "sequence' is continuous cotton. At present, each plot contains eight 40-in (102-cm) rows 200 ft (61 m) 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 and managed with conventional tillage. Both corn and cotton are planted in single-row configuration while soybean has been shifted to a twin-row system. Commercial equipment, adapted for plot harvests has been used for harvest. 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 field is shown in Figure 1 for the 2010 cropping year.

Figure 1: Field layout for long-term rotation. Crops listed for 2010 growing season

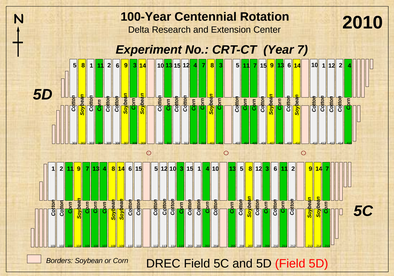

Table 2: Summary of crop yields for long-term rotation study.

CENTENNIAL ROTATION STUDY - SUMMARY OF CROP YIELDS (2004-2009) /ACRE

Rotation	Crop Year						2004	2005	2006	2007	2008	2009
System	2004	2005	2006	2007	2008	2009	Crop Yield	Crop Yield	Crop Yield	Crop Yield	Crop Yield	Crop Yield
	1	2	3	4	5	6						
1	CT	CT	CT	CT	CT	CT	1430.5	1101.8	978.9	718.5	927.6	877.6
2	CT	CR	CT	CR	CT	CR	1470.9	204.6	1185.4	200.8	1218.9	182.4
3	CR	CT	CR	CT	CR	CT	201.2	1334.3	185.1	942.2	194.9	961.3
4	CR	CT	CT	CR	CT	CT	197.2	1298.4	988.0	219.4	1314.9	975.3
5	CT	CR	CT	CT	CR	CT	1509.4	213.3	1202.1	866.7	206.8	984.7
6	CT	CT	CR	CT	CT	CR	1525.1	1148.4	191.1	909.3	982.5	194.8
7	CR	SB	CR	SB	CR	SB	193.9	57.8	199.3	78.4	205.8	73.3
8	SB	CR	SB	CR	SB	CR	60.3	212.3	62.5	208.8	56.1	205.1
9	SB	CR	CT	SB	CR	CT	61.4	212.6	1206.2	75.5	197.6	994.5
10	CT	SB	CR	CT	SB	CR	1447.5	61.5	194.6	1019.2	60.4	209.4
11	CR	CT	SB	CR	CT	SB	195.9	1268.2	64.4	207.6	1222.3	66.3
12	SB	CR	CT	CT	SB	CR	60.4	199.0	1152.6	852.2	57.5	195.9
13	CT	SB	CR	CT	CT	SB	1402.7	52.3	191.2	929.5	978.7	69.8
14	CT	CT	SB	CR	CT	CT	1446.6	1148.2	58.1	223.4	1240.5	929.3
15	CR	CT	CT	SB	CR	CT	200.5	1359.4	947.2	81.5	199.9	992.6

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

Figure 4: Commodity prices and loan values for rotation crops.

MISSISSIPPI - 2004-2009
Cotton-Corn-Soybean Price Received

	Average Price Received and Loan Rate					
	2004	2005	2006	2007	2008	2009
Cotton	0.447	0.497	0.484	0.613	0.566	0.600
Cotton LR	0.525	0.525	0.525	0.525	0.525	0.525
Corn	2.43	2.22	2.84	3.68	4.60	3.55
Corn LR	1.95	1.95	1.95	1.95	1.95	1.95
Soybean	6.20	5.92	6.23	8.36	8.75	9.50
Soybean LR	5.00	5.00	5.00	5.00	5.00	5.00

Table 1: Cropping sequence for long-term cotton-based rotation cropping system.

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 3: Summary of crop value based on average or loan price.

CENTENNIAL ROTATION STUDY - SUMMARY OF CROP VALUE (2004-2009)

Rot.	Crop Year						2004	2005	2006	2007	2008	2009	TOTAL
Sys.	2004	2005	2006	2007	2008	2009	Crop ($)	Crop ($)	Crop ($)	Crop ($)	Crop ($)	Crop ($)	Crop Value
	1	2	3	4	5	6							
1	CT	CT	CT	CT	CT	CT	751.03	578.46	513.92	440.44	525.04	526.57	**3335.46**
2	CT	CR	CT	CR	CT	CR	772.20	454.21	622.35	738.94	689.88	647.52	**3925.10**
3	CR	CT	CR	CT	CR	CT	488.92	700.51	525.68	577.57	896.54	576.77	**3766.00**
4	CR	CT	CT	CR	CT	CT	479.20	681.68	518.72	907.39	744.21	585.20	**3816.39**
5	CT	CR	CT	CT	CR	CT	792.45	473.53	631.08	531.26	951.28	590.83	**3970.43**
6	CT	CT	CR	CT	CT	CR	800.69	603.14	542.72	557.38	556.10	691.54	**3751.57**
7	CR	SB	CR	SB	CR	SB	471.18	342.18	566.01	655.42	946.68	696.35	**3677.82**
8	SB	CR	SB	CR	SB	CR	373.86	471.31	389.38	768.38	490.88	728.11	**3221.91**
9	SB	CR	CT	SB	CR	CT	380.68	471.97	633.23	631.18	908.96	596.69	**3622.71**
10	CT	SB	CR	CT	SB	CR	759.94	364.08	552.66	624.79	528.50	743.37	**3573.34**
11	CR	CT	SB	CR	CT	SB	476.04	665.78	401.21	763.97	691.82	629.85	**3628.66**
12	SB	CR	CT	CT	SB	CR	374.48	441.78	605.14	522.39	503.13	695.45	**3142.35**
13	CT	SB	CR	CT	CT	SB	736.41	309.62	543.01	569.76	553.96	663.10	**3375.85**
14	CT	CT	SB	CR	CT	CT	759.44	602.78	361.96	822.11	702.15	557.56	**3806.01**
15	CR	CT	CT	SB	CR	CT	487.22	713.66	497.27	681.34	919.54	595.57	**3894.61**

Results and Discussion

The first six years of a planned 100-year rotation program has been completed prior to 2010. 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 in 2004. 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 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 observed in other regions. With the current shift to grain crops (related to high prices and energy), this system may be more important than originally thought for the South. The systems will not begin to repeat until the thirteenth season at which time some rotation will have completed six cycles, others four cycles, and the last system will have completed three cycles.

The yield summary of the first six years is 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. 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 (hurricanes and drought) have caused some problems such as lodging but the yields have still been harvestable. Timely irrigation is a key to successful and consistent corn production. Hybrid selection has been made based on the performance of the in the Southern region of the US.

The economic impact of crop rotation is a complicated issue as producers must make the decision on crop mix in a constantly changing market. In the last few years fertilizer, planting seed, and fuel prices have reached levels never witnessed before. In 2004, 2005, and 2006 the average market price was below loan rate (LR) for cotton (Fig. 4) while market price has been above LR for the grain crops. Corn and soybean prices have risen above long-term averages and represent the highest prices producers have experienced. While corn prices have fallen off some in 2009, average soybean prices continue at all-time highs. Thus the shift to grain crops continues. As cotton prices rebound, then cotton production should increase.

The economic value of the rotated crops are shown in Table 3. The crop sequence value is calculated based on yield and the average market value (LR if higher than market value). The value of each "treatment" has been summarize as Total Crop Value (TCV). This analysis will only consider the value of the crop and not the cost of production. Cotton remains the most expensive crop to produce followed by corn followed by soybean. Technology fees continue to play an important role in the cost of production. In 2004, the highest value crop was cotton even with lower cotton prices. However, as grain prices increased in 2006 and thereafter, the value of the corn and soybean crop both exceeded the value of the cotton crop. Coupled with higher costs of production, corn and soybean production increased and cotton decreased. After six years, the greatest value of crop has come from a 2:1 cotton/corn rotation, but this was only the case when corn was grown in certain years (Table 3). The value of the rotation system depends greatly on the year that the crop was grown and the price received that year. The lowest crop sequence value so far has been with a soybean/corn/cotton/cotton (4-yr rotation) system in which corn and soybean were grown when commodity prices were lower. In comparing treatments 7 and 8 (Table 3), there was a difference of $455 even though both crops were grown for three years. Further economic analysis is forthcoming as we continue to take a closer look at the cost of production and how input cost greatly affect the profitability of a particular crop sequence.

One area of interest in long-term rotation 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 yield. For cotton, corn, and soybean, uptake exceeds the amount of nutrients that are 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 4 and the summary of nutrient removal is shown in Table 5. As 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 six years to date. For this system, more than twice as much P 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 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.

Table 4: Summary of total nutrient (N, P, K, S) uptake in above-ground crop.

NUTRIENT UPTAKE	Crop Sequence						N	P	K	S
Trt	2004	2005	2006	2007	2008	2009	Uptake (lb/acre)	Uptake (lb/acre)	Uptake (lb/acre)	Uptake (lb/acre)
1	CT	CT	CT	CT	CT	CT	965.6	126.7	700.1	144.8
2	CT	CR	CT	CR	CT	CR	1403.8	228.3	1099.4	191.0
3	CR	CT	CR	CT	CR	CT	1293.1	213.3	1018.1	174.6
4	CR	CT	CT	CR	CT	CT	1287.7	200.3	991.5	179.3
5	CT	CR	CT	CT	CR	CT	1290.2	200.8	993.7	179.5
6	CT	CT	CR	CT	CT	CR	1245.0	192.4	956.3	173.9
7	CR	SB	CR	SB	CR	SB	1895.0	240.5	1255.8	169.7
8	SB	CR	SB	CR	SB	CR	1771.3	234.1	1199.2	164.0
9	SB	CR	CT	SB	CR	CT	1615.5	208.1	1096.7	166.8
10	CT	SB	CR	CT	SB	CR	1571.3	205.6	1078.2	167.2
11	CR	CT	SB	CR	CT	SB	1620.5	209.8	1105.3	170.6
12	SB	CR	CT	CT	SB	CR	1464.2	191.9	1003.2	153.2
13	CT	SB	CR	CT	CT	SB	1423.6	170.2	941.4	152.0
14	CT	CT	SB	CR	CT	CT	1364.3	181.1	964.3	171.0
15	CR	CT	CT	SB	CR	CT	1487.2	204.7	1056.3	173.1

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 5: Summary of total nutrient (N, P, K, S) removed with harvested crop.

NUTRIENT REMOVAL	Crop Sequence						N	P	K	S
Trt	2004	2005	2006	2007	2008	2009	Removal (lb/acre)	Removal (lb/acre)	Removal (lb/acre)	Removal (lb/acre)
1	CT	CT	CT	CT	CT	CT	386.27	72.42	199.15	36.21
2	CT	CR	CT	CR	CT	CR	776.96	160.80	268.30	68.97
3	CR	CT	CR	CT	CR	CT	730.32	151.87	245.68	64.64
4	CR	CT	CT	CR	CT	CT	667.92	135.92	250.56	59.86
5	CT	CR	CT	CT	CR	CT	670.22	136.44	250.94	60.05
6	CT	CT	CR	CT	CT	CR	639.52	129.83	242.86	57.41
7	CR	SB	CR	SB	CR	SB	1377.10	189.80	391.00	67.54
8	SB	CR	SB	CR	SB	CR	1279.19	183.38	361.30	66.59
9	SB	CR	CT	SB	CR	CT	1057.55	154.07	332.61	58.81
10	CT	SB	CR	CT	SB	CR	1008.96	150.82	322.16	58.43
11	CR	CT	SB	CR	CT	SB	858.33	145.56	333.25	59.40
12	SB	CR	CT	CT	SB	CR	955.31	142.10	300.01	54.54
13	CT	SB	CR	CT	CT	SB	872.40	119.63	299.43	46.95
14	CT	CT	SB	CR	CT	CT	738.47	120.96	279.36	51.78
15	CR	CT	CT	SB	CR	CT	897.43	145.97	300.97	59.09