CROP YIELD, NUTRIENT UPTAKE, AND NUTRIENT REMOVAL IN MISSISSIPPI'S CENTENNIAL ROTATION

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Abstract

Long-term crop rotation studies can be useful tools in studying the effects of various practices over an extended period of times. Studies such as the Old Rotation at Auburn University and the Morrow Plots at the University of Illinois are some of the oldest continuous research in the country. For these studies, time is the only replication and allows for evaluating trends. In 2004, the Centennial Rotation was initiated on the Delta Research and Extension Center at Stoneville, MS to commemorate the 100-year anniversary of the experiment station. New technologies are rapidly being introduced and adopted and could also be evaluated in these long-term rotations. As production in the Mid-south moved into the 21st century, cotton was still the main crop for sandy soils. However, with the emphasis on bio-energy and bio-fuels, corn and soybean gained in prominence and prices increased. With increased grain prices, corn production in the Mid-south became more profitable and with a shift in infrastructure began replacing cotton on many farms. Cotton, corn, and soybean were included in the various rotational schemes in the Centennial Rotation. The systems included 2-year, 3-year, and 4-year rotations all compared to continuous cotton. At the initiation of the study a corn/soybean system was also included. All crops within a rotation system are grown each year allowing for direct comparisons of crops for a given year. In certain years with high corn prices, there could be an advantage to growing corn but the field was scheduled to be planted to cotton in the rotational scheme. The fifteen "treatments" are replicated four times with each one consisting of four 4-row subplots. The center rows are harvested to avoid border effects and samples taken at harvest in order to determine harvest moisture, bushel test weigh, and seed index of the grain crops and lint percentage and lint yield of the cotton plots. Once yields are calculated, total plant nutrient uptake and removal can be estimated based on standards. As would be expected the highest nutrient removal has been observed in the grain systems. For cotton over time, the lint yields have been much lower than the yield of cotton following corn. Nutrient removal for the continuous cotton system of nitrogen (N) and phosphorus (P) was 25 to 40% of the grain crop systems. Soil samples taken following harvest are used to monitor soil nutrient levels and the basis for P and potassium (K) applications. The corn crop returns far greater levels of residue to the soil than continuous cotton and should aid in the buildup of organic matter. In the 13th season, all system will be back to the same starting point as the first season and will start over.

Introduction

The concept of crop rotation is not new by any means but has returned to prominence after many years of continuous cotton in the Mid-south. Crop rotation has been used in farming systems for hundreds of years with modern rotations (green manures) begun as early as 1730 in England. Benefits from crop rotation can be divided into three major areas. These include: a) maintenance of crop yields; b) control of diseases, insects, weeds, and other pests; and c) prevention of soil erosion. Before the widespread use of chemical fertilizers, maintenance and/or improvement of crop yields were best accomplished by improving the base fertility of the soil where the crop was to be 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. Corn was needed as feedstock for the animals. Mechanization and inorganic fertilizer materials reduced the need for some animals and crops, rotations decreased, and mono-crop agriculture gained in popularity. With today's farm policies and programs, and the freedom to choose different crop mixes, rotations have returned to prominence. Field research across the cotton producing states supported crop rotation. However, growers were reluctant to rotate because of government payments and crop rotations complicated production practices and presented extra challenges.

Early research at the Delta Branch Experiment Station which has now been in existent for more than 100 years revolved around crop rotation. 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 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. 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 the past year with the aid of new technology and advancements through research. Since 2001, cotton, corn, and soybean have had record yields and record prices. Corn production has increased while cotton has decreased in response to price and profitability. Grain crops can be planted early and along with irrigation, yield stability has led to shifts in the crop mix.

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. The designed was implemented 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 research study has included 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. Each plot contains eight 40-in rows

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								

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. 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 field is shown in Figure 1 (2013 growing season).

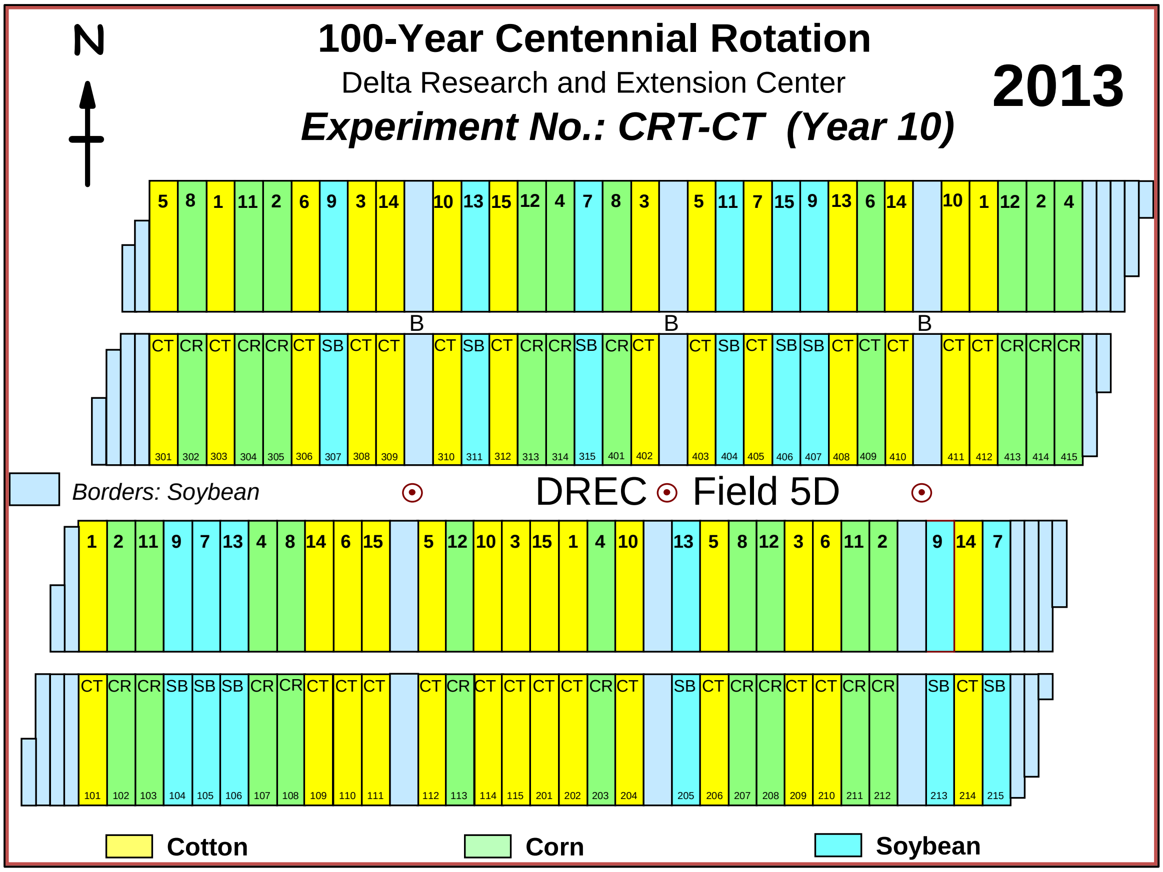

Figure 1. Plot layout for Centennial Rotation, Delta Research and Extension Center, Stoneville, MS. Layout is specific for the 2013 growing season.

Results and Discussion

Ten years of the Centennial Rotation program was completed in 2013 (100-yr rotation). Long-term cropping system rotations and long-term research are limited or non-existent in many areas of the world. The Morrow Plots (University of Illinois) and The Old Rotation (Auburn University) are some of the oldest continuous plots in the US. 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 at Stoneville, MS. The “treatments” outlined in Table 1 show the first 12 years (current years in red box) of the rotations and the crops being grown each year. The project was setup as a cotton-based system due the historic significance of cotton to this region of the US. Treatments 7 and 8 do not contain cotton and are included to document the long standing advantages of corn/soybean rotation. With recent shifts to grain production, this system has become quite important. The 12-yr cycle will repeat in the 13th season (2016) at which time some rotations will have completed six cycles, others four cycles, and the last system will have completed three cycles. The yield summary from the first ten years 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 2013 lint yields were the highest to date (Range: 718 to 1452 lb lint/acre). However, 2013 yields from rotation systems range from 78 to 500 lb lint/acre greater than the continuous cotton system. The greatest advantage (500 lb

Table 2. Summary of crop yields from the Centennial Rotation Study (2004-2013). [Adjusted to standard moisture] Delta Research and Extension Center, Stoneville, MS

CENTENNIAL ROTATION STUDY - SUMMARY OF CROP YIELDS/ACRE (2004-2013)

Rotation	---- Crop Year ----										2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
System	'04	'05	'06	'07	'08	'09	'10	'11	'12	'13	Crop	Crop	Crop	Crop	Crop	Crop	Crop	Crop	Crop	Crop
	1	2	3	4	5	6	7	8	9	10	Yield	Yield	Yield	Yield	Yield	Yield	Yield	Yield	Yield	Yield
1	CT	CT	CT	CT	CT	CT	CT	CT	CT	CT	1430.5	1101.8	978.9	718.5	927.6	877.6	1039.4	843.2	1076.4	1452.1
2	CT	CR	CT	CR	CT	CR	CT	CR	CT	CR	1470.9	204.6	1185.4	200.8	1218.9	182.4	1185.6	61.6	1237.4	216.8
3	CR	CT	CR	CT	CR	CT	CR	CT	CR	CT	201.2	1334.3	185.1	942.2	194.9	961.3	194.7	965.4	242.6	1952.1
4	CR	CT	CT	CR	CT	CT	CR	CT	CT	CR	197.2	1298.4	988.0	219.4	1314.9	975.3	201.8	982.2	1098.1	228.8
5	CT	CR	CT	CT	CR	CT	CT	CR	CT	CT	1509.4	213.3	1202.1	866.7	206.8	984.7	1148.2	73.8	1194.3	1691.6
6	CT	CT	CR	CT	CT	CR	CT	CT	CR	CT	1525.1	1148.8	191.1	909.3	982.5	194.8	1234.7	841.9	244.7	1803.8
7	CR	SB	CR	SB	CR	SB	CR	SB	CR	SB	193.9	57.8	199.3	78.4	205.8	73.3	207.2	52.6	241.3	58.3
8	SB	CR	SB	CR	SB	CR	SB	CR	SB	CR	60.3	212.3	62.5	208.8	56.1	205.1	65.7	101.8	42.9	232.5
9	SB	CR	CT	SB	CR	CT	SB	CR	CT	SB	61.4	212.6	1206.2	75.5	197.6	994.5	70.6	113.7	1105.0	72.1
10	CT	SB	CR	CT	SB	CR	CT	SB	CR	CT	1447.5	61.5	194.6	1019.2	60.4	209.4	1199.0	47.9	244.0	1902.2
11	CR	CT	SB	CR	CT	SB	CR	CT	SB	CR	195.9	1268.2	64.4	207.6	1222.3	66.3	209.0	963.0	46.6	234.2
12	SB	CR	CT	CT	SB	CR	CT	CT	SB	CR	60.4	199.0	1152.6	852.2	57.5	195.9	1239.2	849.3	45.6	229.2
13	CT	SB	CR	CT	CT	SB	CR	CT	CT	SB	1402.7	52.3	191.2	929.5	978.7	69.8	208.0	1059.2	1052.8	66.9
14	CT	CT	SB	CR	CT	CT	SB	CR	CT	CT	1446.6	1148.2	58.1	223.4	1240.5	929.3	66.8	105.0	1194.0	1529.9
15	CR	CT	CT	SB	CR	CT	CT	SB	CR	CT	200.5	1359.4	947.2	81.5	199.9	992.6	1026.1	50.4	242.3	1857.7

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

/acre) occurred in the CR/CT (1:1) rotation system. Corn yields in 2013 were lower than those observed in 2012, yet averages were above 215 bu/acre. Corn following soybean in 2013 were about 10 bu/acre greater than corn following cotton. Average cotton yields have varied across years ranging from 891.1 lb lint/acre in 2007 to a high of 174.3 lb/acre in 2013. Corn yields in the same time frame have ranged from 192.3 to 243.0 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. Corn yields in both 2012 and 2013 were extremely good with the state average at 165 bu/acre and 180 bu/acre for the two respective years.

A key area 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. The continuous cotton system has resulted in the lowest nutrient removal for N, P, K, and S. After ten years, the greatest N uptake and removal has occurred in the corn/soybean rotation system (Treatments 7 and 8) where each crop has been grown five times (Table 4). The two treatments are different because yields have been different from year to year. Much of the N that is removed in the CR/SB system comes from symbiotic N fixation when soybean is grown, Also, higher N fertilizer rates are used for corn compared to cotton. 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 P and K removal rates are also highest for the CR/SB system. When examining uptake and removal, N

uptake can be as much as 300 lb N/acre depending on the crop and yield. As long as the residue is returned to the soil and not burned, most of the nutrients not removed in the grain or seed can be recycled and thus reused for future crops. If residue is removed for feed stocks related to bio-energy, the available nutrient pool in the soil and organic matter can be further reduced as well.

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 2. Estimated nutrient uptake 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

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

Table 3. Summary of total nutrient (N, P, K, S) uptake from the Centennial Rotation Study (2004-2013). Delta Research and Extension Center, Stoneville, MS.

NUTRIENT UPTAKE											N	P	K	S
	Crop Sequence										Uptake	Uptake	Uptake	Uptake
Trt	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	(lb/acre)	(lb/acre)	(lb/acre)	(lb/acre)
1	CT	CT	CT	CT	CT	CT	CT	CT	CT	CT	1671.4	219.4	1211.8	250.7
2	CT	CR	CT	CR	CT	CR	CT	CR	CT	CR	2162.6	348.8	1688.2	295.5
3	CR	CT	CR	CT	CR	CT	CR	CT	CR	CT	2343.0	383.9	1840.0	317.5
4	CR	CT	CT	CR	CT	CT	CR	CT	CT	CR	2194.7	351.6	1708.9	301.0
5	CT	CR	CT	CT	CR	CT	CT	CR	CT	CT	2034.0	304.0	1543.3	288.7
6	CT	CT	CR	CT	CT	CR	CT	CT	CR	CT	2192.2	335.0	1676.9	307.8
7	CR	SB	CR	SB	CR	SB	CR	SB	CR	SB	3073.4	400.7	2065.9	281.4
8	SB	CR	SB	CR	SB	CR	SB	CR	SB	CR	2785.3	364.7	1876.4	255.9
9	SB	CR	CT	SB	CR	CT	SB	CR	CT	SB	2690.6	321.5	1754.8	259.8
10	CT	SB	CR	CT	SB	CR	CT	SB	CR	CT	2643.5	352.5	1843.4	298.2
11	CR	CT	SB	CR	CT	SB	CR	CT	SB	CR	2609.3	361.0	1839.0	283.1
12	SB	CR	CT	CT	SB	CR	CT	CT	SB	CR	2342.7	312.9	1628.1	256.8
13	CT	SB	CR	CT	CT	SB	CR	CT	CT	SB	2389.2	295.6	1606.0	259.7
14	CT	CT	SB	CR	CT	CT	SB	CR	CT	CT	2289.7	293.5	1585.6	276.1
15	CR	CT	CT	SB	CR	CT	CT	SB	CR	CT	2535.5	347.7	1801.5	299.5

Table 4. Summary of total nutrient (N, P, K, S) removal from the Centennial Rotation Study (2204-2013). Delta Research and Extension Center, Stoneville, MS.

NUTRIENT REMOVAL											N	P	K	S
	Crop Sequence										Removal	Removal	Removal	Removal
Trt	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	(lb/acre)	(lb/acre)	(lb/acre)	(lb/acre)
1	CT	CT	CT	CT	CT	CT	CT	CT	CT	CT	668.6	125.4	344.7	62.7
2	CT	CR	CT	CR	CT	CR	CT	CR	CT	CR	1182.6	244.0	414.8	105.2
3	CR	CT	CR	CT	CR	CT	CR	CT	CR	CT	1310.6	271.9	446.4	116.2
4	CR	CT	CT	CR	CT	CT	CR	CT	CT	CR	1188.6	244.6	422.1	105.8
5	CT	CR	CT	CT	CR	CT	CT	CR	CT	CT	994.8	199.2	401.7	90.0
6	CT	CT	CR	CT	CT	CR	CT	CT	CR	CT	1108.1	224.0	429.4	99.7
7	CR	SB	CR	SB	CR	SB	CR	SB	CR	SB	2224.4	315.8	629.4	113.5
8	SB	CR	SB	CR	SB	CR	SB	CR	SB	CR	2014.4	286.4	569.7	103.5
9	SB	CR	CT	SB	CR	CT	SB	CR	CT	SB	1801.3	239.4	563.1	88.6
10	CT	SB	CR	CT	SB	CR	CT	SB	CR	CT	1618.6	252.2	539.5	100.8
11	CR	CT	SB	CR	CT	SB	CR	CT	SB	CR	1505.2	259.6	526.0	104.3
12	SB	CR	CT	CT	SB	CR	CT	CT	SB	CR	1477.7	227.7	477.7	89.5
13	CT	SB	CR	CT	CT	SB	CR	CT	CT	SB	1462.5	208.8	498.0	82.5
14	CT	CT	SB	CR	CT	CT	SB	CR	CT	CT	1274.5	197.5	473.4	83.0
15	CR	CT	CT	SB	CR	CT	CT	SB	CR	CT	1501.7	245.3	513.7	100.3

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. Glyphosate-resistance has been documented for several weed species in the growing area and has necessitated the shift back to residual herbicides for controlling weeds. Different herbicide technologies are being used to assist with this problem but crop rotation can play a major role in the future.