


CROP ROTATION IN THE MID-SOUTH

Effect of Cropping Systems on Nutrient Uptake and Removal

M. Wayne Ebelhar
Research Professor and Agronomist
and
Davis R. Clark
Research Associate III

Mississippi State University
Delta Research and Extension Center
Stoneville, Mississippi


Introduction

Crop rotation has been used throughout the world for hundreds of years with modern rotations (green manures) begun as early as 1730 in England. The benefits of crop rotation can be 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. Before the introduction and use of chemical fertilizers, maintenance and/or improvement of 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/cotton rotations were used through the first half of the 20th century as animal power on the farm was extremely important. Corn was needed as feedstock for the animals. Farm mechanization and inorganic fertilizer materials reduced the need for some crops, rotations decreased, and mono-crop agriculture gained in popularity and profitability. 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.

Early research in the Yazoo-Mississippi River Delta included simple rotations and the use of manure on fields that had been selected 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 the turn of the century, cotton, corn, and soybean have had record yields along with record prices. Corn acreage has increased while cotton has decreased in response to profitability. Grain crops can be planted early and harvested earlier. With irrigation, yield stability has led to shifts in the crop mix with some producers shifting from away from cotton totally.

The overall objective of this research project (Centennial Rotation) 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 study 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 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. Each plot contains eight 102-cm rows. Row length is 61.0 m (includes two 30.5 m 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 arrangement of the research field is shown in Figure 1 (2011 Growing Season).

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

System	2004 1	2005 2	2006 3	2007 4	2008 5	2009 6	2010 7	2011 8	2012 9	2013 10	2014 11	2015 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

Figure 1: Centennial Rotation Layout, Delta Research and Extension Center, Stoneville, MS. Layout is specific for 2011 Cropping Season.

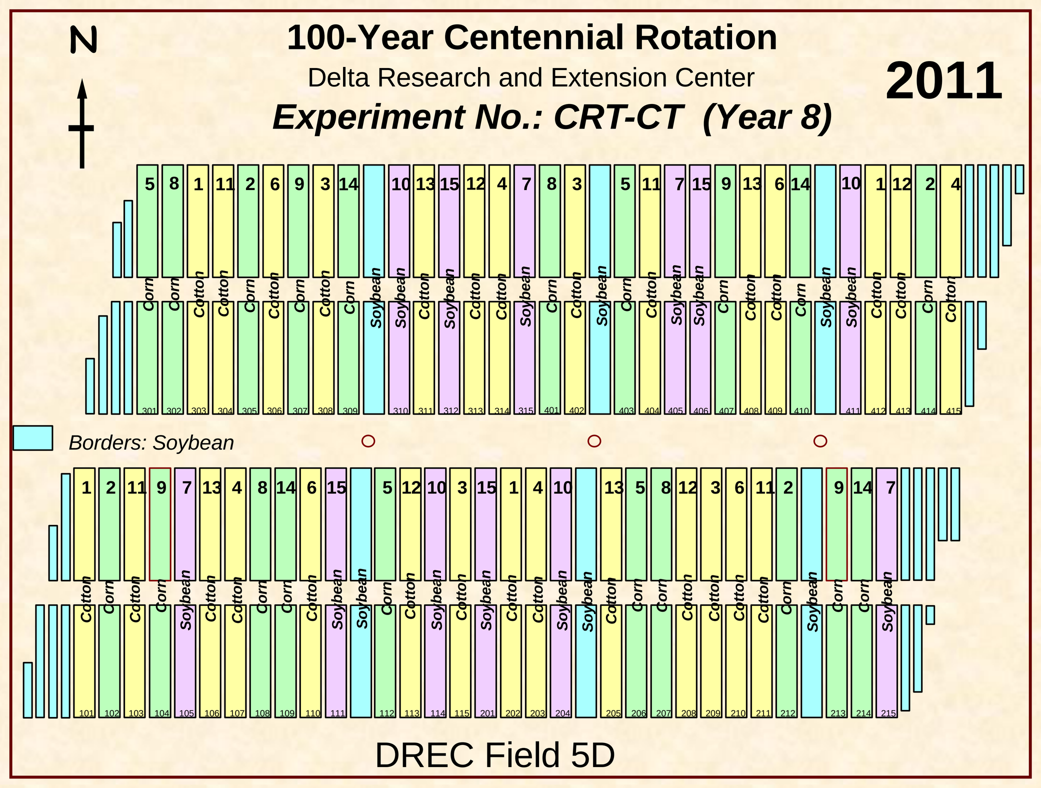

Figure 2: Estimated nutrient uptake and removal for specific crops based on selected yields.

A. Nutrient Uptake for Selected Crops

Crop	Yield (kg/ha)	N	P	K	S
		kg/ha			
Corn	10000	238	45	197	30
Soybean	4000	349	29	189	22
Wheat	5000	155	25	141	22
Cotton	1200	192	25	139	29
Rice	8000	128	30	159	14

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

B. Nutrient Removal for Selected Crops

Crop	Yield (kg/ha)	N	P	K	S
		kg/ha			
Corn	10000	161	35	43	14
Soybean	4000	267	23	79	7
Wheat	5000	96	20	24	5
Cotton	1200	77	14	40	7
Rice	8000	80	22	26	7

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

Results and Discussion

The first eight years of the Centennial Rotation study was completed in 2011 (100-yr rotation). Long-term crop rotations and long-term research are limited in their scope in many areas or are no longer in existence. The Morrow plots (University of Illinois) and The Old Rotation (Auburn University) are some of the oldest continuous plots in the USA. To celebrate the 100-yr 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 project was originally established as a cotton-based system due the historic significance of cotton to this region of the USA. Only one system (treatments 7 and 8) does not contain cotton and is intended to document the long standing advantages of corn/soybean rotations. With recent shifts to grain production in the Midsouth, this system has become quite important. The systems will 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. Lint yields in the continuous cotton area (treatment 1) have the overall lowest yields compared to the other systems. The greatest lint yields as expected, follow corn in rotation. Year-to-year variations have been evident and influenced by insect pressure and/or adverse weather conditions. Over the years the range has been 13.1 to 41.8% higher yields (128.8 to 433.8 kg lint/ha) where cotton was in some rotation with corn compared to continuous cotton. Average cotton yields have varied across years ranging from 998.0 kg lint/ha in 2007 to a high of 1637.2 lkg/ha. Corn yields in the same time frame have ranged from 12.06 to 13.30 Mg/ha excluding 2011. The 2011 yields (5.72 Mg/ha) were way below average due to a lack of irrigation in a timely fashion. Soybean yields have ranged from 3.38 to 5.28 Mg/ha 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 and soybean production. Timing of the first irrigation is critical.

Nutrient uptake and removal are areas of interest in the long-term rotation study. 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 (A) and removal (B) for selected crops in the Mississippi Delta at selected yield levels. 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 (Figure 2) have been used to calculate 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 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. 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 cost of inputs continue to rise, 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.


Table 3: Summary of total nutrient (N, P, K, S) uptake from the Centennial Rotation Study (2004 – 2011). Delta Research and Extension Center, Stoneville, Mississippi

NUTRIENT UPTAKE

Trt	2004	2005	2006	2007	2008	2009	2010	2011	N Uptake (kg/ha)	P Uptake (kg/ha)	K Uptake (kg/ha)	S Uptake (kg/ha)
	Crop Sequence											
1	CT	CT	CT	CT	CT	CT	CT	CT	1418.8	186.2	1028.7	212.8
2	CT	CR	CT	CR	CT	CR	CT	CR	1876.7	300.9	1461.6	257.3
3	CR	CT	CR	CT	CR	CT	CR	CT	1912.0	316.1	1506.8	257.8
4	CR	CT	CT	CR	CT	CT	CR	CT	1919.5	303.9	1487.9	264.9
5	CT	CR	CT	CT	CR	CT	CT	CR	1761.0	272.6	1353.6	245.7
6	CT	CT	CR	CT	CT	CR	CT	CT	1766.6	264.3	1340.8	250.6
7	CR	SB	CR	SB	CR	SB	CR	SB	2740.1	352.9	1830.0	248.3
8	SB	CR	SB	CR	SB	CR	SB	CR	2520.9	322.6	1677.6	227.2
9	SB	CR	CT	SB	CR	CT	SB	CR	2393.0	299.2	1593.1	234.4
10	CT	SB	CR	CT	SB	CR	CT	SB	2255.5	281.7	1515.3	237.3
11	CR	CT	SB	CR	CT	SB	CR	CT	2299.6	316.2	1621.8	256.0
12	SB	CR	CT	CT	SB	CR	CT	CT	2014.2	264.1	1394.9	227.8
13	CT	SB	CR	CT	CT	SB	CR	CT	2094.8	273.8	1449.5	237.6
14	CT	CT	SB	CR	CT	CT	SB	CR	2076.3	264.6	1422.0	236.0
15	CR	CT	CT	SB	CR	CT	CT	SB	2145.0	277.9	1476.3	240.3

Table 2: Summary of crop yields from the Centennial Rotation Study (2004 – 2011) Delta Research and Extension Center, Stoneville, Mississippi

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

Rotation System	2004 1	2005 2	2006 3	2007 4	2008 5	2009 6	2010 7	2011 8	2010 7	2011 8	2004 Crop Yield	2005 Crop Yield	2006 Crop Yield	2007 Crop Yield	2008 Crop Yield	2009 Crop Yield	2010 Crop Yield	2011 Crop Yield
	Crop Year																	
1	CT	CT	CT	CT	CT	CT	CT	CT	CT	CT	1602	1234	1096	805	1039	983	1164	944
2	CT	CR	CT	CR	CT	CR	CT	CR	CT	CR	1647	12835	1328	12596	1365	11442	1328	3866
3	CR	CT	CR	CT	CR	CT	CR	CT	CR	CT	12621	1494	11611	1055	12226	1077	12214	1081
4	CR	CT	CT	CR	CT	CT	CR	CT	CR	CT	12370	1454	988	13763	1473	1092	12659	1100
5	CT	CR	CT	CT	CR	CT	CT	CR	CT	CR	1691	13380	1346	971	12972	1103	1286	4631
6	CT	CT	CR	CT	CT	CR	CT	CT	CT	CT	1708	1287	11988	1018	1100	12220	1383	943
7	CR	SB	CR	SB	CR	SB	CR	SB	CR	SB	12163	3884	12502	5268	12910	4926	12998	3535
8	SB	CR	SB	CR	SB	CR	SB	CR	SB	CR	4052	13317	4200	13098	3770	12866	4415	6387
9	SB	CR	CT	SB	CR	CT	SB	CR	SB	CR	4126	13336	1351	5074	12395	1114	4744	7133
10	CT	SB	CR	CT	SB	CR	CT	SB	CT	SB	1621	4133	12207	1142	4059	13136	1343	3219
11	CR	CT	SB	CR	CT	SB	CR	CT	CR	CT	12289	1420	4328	13023	1369	4455	13110	1079
12	SB	CR	CT	CT	SB	CR	CT	CT	CT	CT	4059	12483	1291	954	3864	12289	1388	951
13	CT	SB	CR	CT	CT	SB	CR	CT	CR	CT	1571	3515	11994	1041	1096	4691	13048	1186
14	CT	CT	SB	CR	CT	CT	SB	CR	SB	CR	1620	1286	3904	14014	1389	1041	4489	6588
15	CR	CT	CT	SB	CR	CT	CT	SB	CT	SB	12577	1522	1061	5477	12540	1112	1149	3387

NOTE: Cotton Yield reported in kg lint/ha, Corn Yield reported in kg/ha @15.5%, Soybean Yield reported in kg/ha @ 13%

Table 4: Summary of total nutrient (N, P, K, S) removal from the Centennial Rotation Study (2004 – 2011). Delta Research and Extension Center, Stoneville, Mississippi

NUTRIENT REMOVAL

Trt	2004	2005	2006	2007	2008	2009	2010	2011	N Removal (kg/ha)	P Removal (kg/ha)	K Removal (kg/ha)	S Removal (kg/ha)
	Crop Sequence											
1	CT	CT	CT	CT	CT	CT	CT	CT	567.6	106.4	292.6	53.2
2	CT	CR	CT	CR	CT	CR	CT	CR	1017.3	209.5	360.8	90.6
3	CR	CT	CR	CT	CR	CT	CR	CT	1083.4	225.5	362.9	95.8
4	CR	CT	CT	CR	CT	CT	CR	CT	1021.9	209.4	370.9	91.2
5	CT	CR	CT	CT	CR	CT	CT	CR	907.3	184.3	343.2	81.4
6	CT	CT	CR	CT	CT	CR	CT	CT	865.1	173.3	348.7	78.3
7	CR	SB	CR	SB	CR	SB	CR	SB	1986.9	278.3	563.1	99.6
8	SB	CR	SB	CR	SB	CR	SB	CR	1829.6	253.3	519.0	90.8
9	SB	CR	CT	SB	CR	CT	SB	CR	1615.4	225.0	496.5	83.7
10	CT	SB	CR	CT	SB	CR	CT	SB	1430.6	203.8	468.6	78.9
11	CR	CT	SB	CR	CT	SB	CR	CT	1241.0	221.5	464.8	91.2
12	SB	CR	CT	CT	SB	CR	CT	CT	1219.7	187.2	413.2	75.1
13	CT	SB	CR	CT	CT	SB	CR	CT	1262.7	193.5	430.2	77.8
14	CT	CT	SB	CR	CT	CT	SB	CR	1232.2	184.5	429.5	74.6
15	CR	CT	CT	SB	CR	CT	CT	SB	1304.5	197.0	441.8	78.7