CROP ROTATIONS WITH INCREASED GRAIN CROP PRODUCTION

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Abstract

Crop rotations have been around for many years with references back into the 1730's in England with green manures. Rotations have been used in many areas of the world and have gained prominence in the Mid-South as grain crops have been re-introduced to compete with continuous cotton. Research at the Delta Research and Extension Center (DREC) has examined the effects of crop rotation from different perspectives. The first study was initiated in 2000 at the Delta Research and Extension Center and at the Tribbett Satellite Farm (TSF) near Tribbett, MS. The studies were designed to evaluate nitrogen (N) and potassium (K) management for cotton and corn production in the Mid-south. When averaged across all N and K treatments at DREC, the mean lint yields could be used to compare cotton following corn to cotton following cotton in rotation systems. Averaged across years (10 years), cotton following corn has averaged 139.2 lb lint/acre/year more than cotton following cotton. This translates to a lint yield increase of 17.1% per year but represents a range from -14.9 to +65.4%. At the Tribbett Satellite Farm (14 years), cotton lint yields following corn have shown an increase of 90.2 lb/acre/year (8.9%) and represents a range of -5.1 to +50.1% compared to cotton following cotton. Overall lint yields have been higher on the silty clay loam soils at TSF compared to the sandy soils at DREC. Rainfall distribution and cloudy weather are thought to be responsible for the negative rotational effects. The negative responses are usually in years where rainfall has been the greatest in the summer months and crop yields have been reduced due to boll rot. The Centennial Rotation was established in 2004 to commemorate the 100-year anniversary of the Delta Branch Experiment Station founded in 1904. Some of the initial research on the experiment station dealt with crop rotation and green manures. Rotations involving cotton, corn, and soybean were established as 2-year, 3-year, and 4-year rotations and compared to continuous cotton production. All crops within each rotation system are grown each year resulting in 15 "treatments" each year. Along with yield determinations, an estimate of nutrient uptake (N, K phosphorus [P], and sulfur [S]) and removal has been calculated and summarized. Continuous cotton has removed one-half to one-third of the N that the grain crops have removed. These rotation systems will begin repeating in the 13th growing season. As the higher nutrients are removed with the grain crops, the more fertilizer nutrients required to maintain productivity.

Introduction

Crop rotations date back hundreds and thousands of years with modern rotations (green manures) dating back to the 1730's in England. The benefits from crop rotation can be divided into three major areas that include 1) maintenance of crop yields; 2) control of diseases, insects, weeds, and other pests; and 3) 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 30 to 40 years 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 (now Delta Research and Extension Center) revolved around crop rotation (early 1900's). 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. The shift continues today with the introduction and adoption of biotechnology. Of the major crops grown today, only cotton continues to be grown in mono-crop culture. Corn and soybean maybe grown in consecutive years but tend to be rotated at some point. With the recent pressure from herbicide-resistant weeds, such as pigweed and perennial ryegrass, the need to rotate crops has become even more important.

Two major efforts in crop rotation research have been initiated at the Delta Research and Extension Center (DREC) and the Tribbett Satellite Farm (TSF). This research under irrigated conditions was designed to evaluate nitrogen (N) and potassium (K) management for corn, cotton following corn, and cotton following cotton. With these studies scientist were able to evaluate the long-term effects of crop rotation on cotton lint yields. The two locations had different soil types and therefore different yield potential. An evaluation of nematode dynamics was introduced into the rotation system in the latter years of the study in order to assess the impact of rotation on both reniform and rootknot nematodes. The project was funded through the support of the Mississippi Cotton Incorporated State Support Program. A second rotation research program (Centennial Rotation) was established in 2004 to commemorate the centennial year of the Delta Branch Experiment Station. This long-term research study was a cotton-based system (cotton as the only continuous crop) involving rotations with corn and soybean. Two-year, 3-year, and 4-year crop rotations were initiated in 2004 along with continuous cotton and a corn/soybean rotation. All rotations reach the same point after twelve years and the cycles repeat. All crops within a rotation system are included each year so that the value and profitability of the crop can be assessed for each year. The overall objectives of the studies were to 1) evaluate the overall impact of crop rotation on crop yield; 2) assess the profitability of crop rotation; and 3) evaluate the impact of crop rotation on nematode dynamics. The Centennial Rotation was designed to evaluate the latest technology available and includes twin-row planting for soybean, biotechnology cultivars, and irrigation. All cultural practices are maintained uniformly across a crop with pest control managed for each crop. The long-term effects of crop rotation are often cumulative with little difference or negative responses observed in some years.

Materials and Methods

Studies were established at the Delta Research and Extension Center (DREC) on a Bosket very fine sandy loam (Mollic Hapludalfs) and at the Tribbett Satellite Farm (TSF) on a Forestdale and Dundee silty clay loams (Typic Endoaqualfs) in 2000 to assess the long-term effects of N and K management in corn and cotton productions as well as the long term effects of crop rotation. With respect to the N and K management, N rates for corn ranged from 120 to 280 lb N/acre (40-lb N/acre increments) applied 120 lb N/acre prior to planning (PPN) and the remained as a sidedress application (SDN). Nitrogen rates for cotton ranged from 60 to 180 lb N/acre (30-lb N/acre increments) with 60 lb N/acre applied PPN. The potassium was applied as a clear solution of 0-0-16 (muriate of potash, 1.3 lb K/gal)) at rates of 0, 40, 80, and 120 lb K/acre. The rates were the same for cotton and corn and applied as a sidedress application by knifing to either side of the row. The N and K treatments were arranged in a 5x4 factorial and replicated four or five times in a randomized complete block design. The center two rows of each 4-row corn or cotton plot was harvested with a commercial harvester adapted to plot harvest. Samples were taken at the time of corn harvest and used to determine harvest moisture, bushel test weight and seed index (100-seed weight) all corrected to 15.5% moisture. A grab sample was collected from each cotton plot at harvest and ginned (10-saw micro-gin) to calculate lint percentage and lint yield. All data was then subjected to Analysis of Variance (ANOVA) with means separation by Fisher’s Protected Least Significant Difference (SAS Institute, Cary, NC). In the years where nematode dynamics were evaluated, soil samples were taken from each plot shortly after planting, at mid-season, and again following harvest. The samples were stored in a cool environment and processed and analyzed for reniform and rootknot nematode content in the Nematode Laboratory at the Delta Research and Extension Center.

The Centennial Rotation was initiated in 2004 and 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 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. At the time of harvest, a sample is collected to determine harvest moisture, bushel test weight, and seed index (100-seed weight) for the grain crops. A grab sample of seedcotton is taken at harvest and used to calculate lint percentage (10-saw micro-gin) and lint yield. 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. As with the previous set of studies, all data is analyzed with an ANOVA (SAS Institute) with mean separations using Fisher's Protected Least Significant Difference.

Table 1. Cropping sequence for long-term cotton based rotation copping 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								

Results and Discussion

Cotton/Corn Rotation

The long-term cotton/corn rotation at DREC was evaluated from 2000 through 2011 and still continues at the TSF location. For the purpose of this report, the yields across N rates and K rates will used to assess the actual rotational effects. Varied responses to N rates were observed and little response to increasing K rates. The K rates were discontinued following 2008 growing season. A differential in soil test K had been established during the preceding years. Yield results for the DREC location are shown in Table 2 along with the rotational benefit from each year and averaged across the duration of the study. Corn grain yields have ranged from a low of 144.8 bu/acre in 2011 (2000 yields not included in average due to residual herbicide injury from preceding cotton crops) to a high of 244.4 bu/acre in 2007. Corn yields have 195.4 bu/acre for the eleven years. The 2000 yields were also not included in the cotton averages as there was no cotton following corn in 2000. The 2011 corn yields were included even though they were low as a result of delayed irrigation initiation. With the hot dry conditions, the plants never completely recovered and yields were significantly reduced. Cotton lint yields have ranged 729.8 to 1416.4 lb/acre for cotton following corn and 521.4 to 1186.9 lb/acre for cotton following cotton. The average lint yields (averaged across years) was 955.1 lb/acre for cotton following corn compared to 815.9 lb/acre where cotton followed cotton. The "rotation effect" has ranged from a negative 146.9 lb/acre (14.9%) to a positive 333.7 lb/acre (65.4%) (Table 2) with an average of 139.2 lb/acre/year. The rotation yield advantage is 17.1% increase. Of the eleven years of the study, only two years showed any negative response to crop rotation. In those years, mid- to late-season rainfall and cloudy weather contributed to increased boll rot in the cotton following corn. With these systems, the cotton crop had gotten a good early start and had a well-established root system.

Similar information has been summarized for the TSF location and can be found in Table 3. This table shows results from 14 years of crop rotation research starting in 2000 and continuing through the past crop year. The silty clay loam soils at Tribbett have a better water holding capacity and more available water than the sandy soils at the DREC.

Table 2. Rotational effects from cotton/corn rotations averaged across N rate sand K rates. Delta Research and Extension Center, Stoneville, MS

Rotational Effects from Cotton/Corn Rotations

Delta Research and Extension Center: 2000-2011

YEAR	Corn (bu/A)	CR-CT	CT-CT	Response	% Change
		---- lb lint/acre	----	----	
2000	149.3	630.8	624.3	N/A	N/A
2001	237.8	729.8	661.7	68.1	10.3
2002	221.4	1198.3	1148.6	49.7	4.3
2003	208.7	1416.4	1186.9	229.5	19.3
2004	167.3	863.1	938.9	- 75.8	- 8.1
2005	196.6	791.2	521.4	269.8	51.7
2006	207.3	1077.6	782.6	295.0	37.7
2007	244.4	840.3	987.2	- 146.9	- 14.9
2008	172.5	783.8	524.2	259.6	49.5
2009	181.0	843.7	510.0	333.7	65.4
2010	167.2	1026.8	933.9	92.9	9.9
2011	144.8	934.6	779.2	155.4	19.9
Average*	195.4	955.1	815.9	139.2	17.1

* First year of study - No cotton following corn. Yields not included in averages.

Table 3. Rotational effects from cotton/corn rotations averaged across N rate sand K rates. Tribbett Satellite Farm. Tribbett, MS. (Part of Delta Research and Extension Center, Stoneville, MS)

Rotational Effects from Cotton/Corn Rotations
Tribbett Satellite Farm

YEAR	Corn (bu/A)	CR-CT	CT-CT	Response	% Change
		------------------- lb lint/acre		-------------------	
2000	141.0	960.7	660.2	300.5	45.5
2001	217.2	826.9	871.0	- 44.1	- 5.1
2002	159.3	1394.1	1276.0	118.1	9.3
2003	140.8	1138.2	1145.4	- 7.2	- 0.6
2004	159.9	1068.9	1074.4	- 5.5	- 0.5
2005	195.8	748.5	649.6	98.9	15.2
2006	204.2	1022.1	680.8	341.3	50.1
2007	221.4	1214.5	1156.4	58.1	5.0
2008	179.3	1152.9	1098.9	54.0	4.9
2009	156.9	908.8	883.1	25.7	2.9
2010	169.1	1271.8	1250.8	21.1	1.7
2011	182.7	1046.3	933.1	113.1	12.1
2012	189.8	1205.3	1097.2	108.1	9.9
2013	214.8	1488.4	1408.2	80.2	5.7
Average	180.9	1103.4	1013.2	90.2	8.9

Location. Average corn yields at TSF have ranged from 140.8 to 221.4 bu/acre and have an overall average of 180.9 bu/acre/year (Table 3). In some of the earlier years, weed competition and pressure from bermudagrass and johnsongrass reduced grain yield potential. It was also evident in cotton following corn and also resulted in limited rotational response. By the second year of cotton, the weed issues had been alleviated. With the use of glyphosate-ready corn cultivars, the weed issues were reduced.

Cotton yields have also been summarized in Table 3 with a range of 748.5 to 1488.4 lb lint/acre for cotton following corn as compared to 649.6 to 1408.2 lb lint/acre for cotton following cotton. The rotational response has ranged from a negative 5.1% to a plus 50.1%. When averaged across all years, the increase has been 90.2 lb lint/acre/year or an increase of 8.9%. The rotational advantages have not been as great on these soil at TSF. They tendto have more organic matter and a higher available water. These soils do respond more readily to irrigation than the sandy soil (DREC) that tends to seal over with reduced infiltration.

Several factors affect the benefits of crop rotation. These factors can be categorized as 1) climate/weather-related phenomena [rainfall total and distribution, solar radiation and cloudiness, humidity and air movement, and physical limitations such as drainage or irrigation]; 2) production-related problems [planting dates as related to harvest window, weed competition, antagonistic pesticides, and pesticide drift and/or residuals]; 3) nematodes or other insect pests; and 4) disease pressure. The factors that have been most evident are rainfall and cloudiness. In years where cotton following corn has not outpaced the cotton following cotton, cloudy weather and rainfall have significantly impacted the crop. Cotton following corn usually develops a stronger roots systems and tends to have better plant growth. If the growth goes uncontrolled (loss of fruit and shift back to vegetative growth) plants can grow bigger with a denser canopy and less air movement through the canopy. This has led to for boll rot and hard locks that ultimately lead to reduced yields.

With respect to nematode numbers and the effects of crop rotation, adding corn into the rotation has been shown to reduce the incidence of reniform nematodes. In the studies being discussed, rootknot nematode were rarely detectable and were not evident in later years. Reniform nematode numbers were lower following corn and were always higher at the end of the season where cotton followed cotton. This was true for both locations. When corn followed two years of cotton the early season numbers were up but tended to decline as the years progressed since corn was not an alternate host.

The Centennial Rotation

Long-term studies can be valuable tools in understanding the long-term effects of particular cropping practices. The Old Rotation at Auburn University and the Morrow Plots at the University of Illinois have been providing information to researchers for over a hundred years. The Centennial Rotation was established in 2004 to commemorate the 100-year anniversary of the Delta Branch Experiment Station now home of the Delta Research and Extension Center. The cropping systems were designed while cotton was still king with the anticipation of cotton remaining a viable crop for the Mid-south. In recent years, grain crops, especially corn, has replaced cotton on many acres in the Mid-south. The re-introduction of corn back into the crop mix has opened up new avenues for crop rotation. New technologies and new production systems are also rapidly changing the face of the Delta. Biotechnology in planting seed development has greatly impacted public variety development to the extent that most planting seed now comes from the private sector. The cost of planting seed has increased tremendously to the point that the cost of planting seed is one of the highest costs of production. Planting seed cost of more than $100/acre is common for corn throughout the Delta. The Centennial Rotation was designed to incorporate new technology as it is developed and adopted by producers. While conservation tillage is used in some areas of the Mid-south, this research area remains conventionally tilled. The twin-row production system, on wide-row raised beds, has been adopted and used by many producers for soybean production and has been accepted for corn production with little machinery modifications. For the Centennial Rotation, twin-row production is the accepted practice while single-row corn has been retained along with single-row cotton.

Table 1 has outlined the rotation systems and the current progress of the study. At the end of the twelfth growing season, the 1:1 rotations [2-yr cycle: CR-CT, and CR-SB] will have completed six cycles; the 2:1 or 1:1:1 [3-year cycle: CT-CT-CR and SB-CR-CT] will have completed four cycles; and the 1:1:2 rotation [4-year cycle: SB-CR-CT-CT] will have completed three cycles. Each component of each crop rotation sequence is grown during each growing season. This allows direct comparisons of all crops. In some years such as 2012 and 2013, weather conditions through the growing season has been favorable for corn production and record yields were achieved in each season. Corn yields in 2011 were much below normal. The plots for the study consist of eight rows on 40-in centers. Each plot is then subdivided into four subplots, 100 ft in length. This large plot configuration could provide opportunities down the road for additional research should the need arise. The general layout of the whole area is shown in Figure 1.

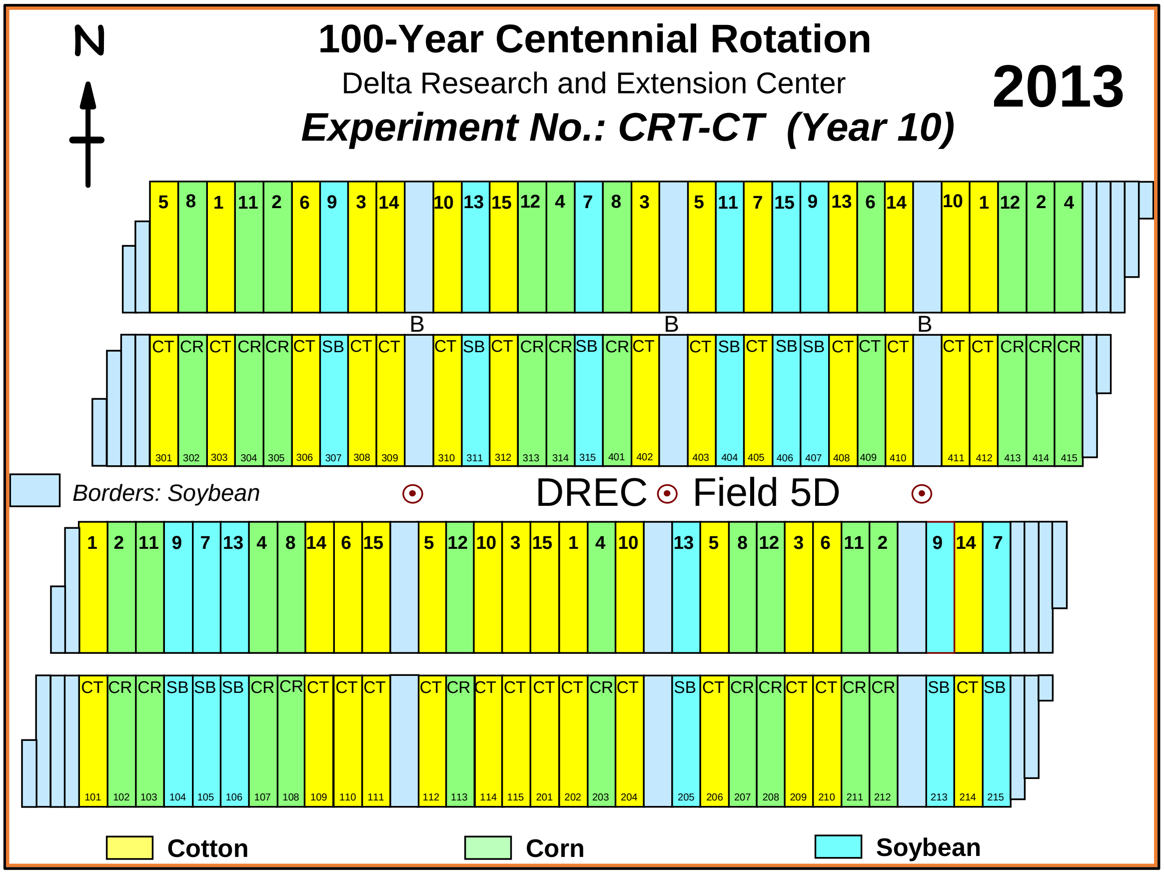

Figure 1. Field design and plot layout for the Centennial Rotation for 2013. Delta Research an Extension Center, Stoneville, MS.

Each year of the study, crop yields are calculated and summarized for every system (Table 4). Once the yields have been measured, calculations are made for nutrient uptake (Table 5) and then nutrient removal (Table 6). In the continuous cotton plots, cotton yields with time have decreased compared to the cotton rotation plots. The highest cotton yields are found where cotton follows corn as would be expected. In the ten years to date, the lowest corn yields were measured in 2011. Rainfall totals for that year and the previous year had been far below normal with little subsoil recharge during the non-crop season. Once the 2011 growing season got under way, higher than normal temperatures accompanied drier than normal moisture patterns. The initial irrigation was much too late and the corn crop was unable to recover. Corn yields ranged from 62 bu/acre where corn followed two years of cotton to 102 and 114 where corn followed soybean. Average corn yields were over 240 bu/acre in 2012 reached 234 bu/acre in 2013.

Summary

With the recent shifts in grain production in the Mid-South and significant changes to the infrastructure of the region, corn and soybean production will continue. Planting intentions in 2013 for Mississippi indicate a million acre of corn for the first time since 1960. Adverse weather conditions in the spring resulted in less corn planted but with the highest yields on record for the region. In recent months, prices have fallen for corn but are still high enough for profitable corn production. As crop acreage for grain crops increase, the better the chances for crop rotation. Research has shown a significant increase in cotton yield sin the rotation systems, but has also shown the significant increase in nutrient being removed in the grain crops. If future removal of stover biomass for bio-energy is practiced, then even greater nutrient replacement will be required. Even though some years have shown a negative benefit or disadvantage to crop rotation, the overall advantages and yield gains far surpass the risk associated with certain years. If one could

Table 4. Summary of crop yields for the Centennial Rotation Study by year and treatment at the 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%

Table 5. Summary of N, P, K, and S uptake estimates for rotations systems in the Centennial Rotation based on standard concentrations. 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

predict those years in advance, then steps could be taken. Unfortunately, Mother Nature has a will of her own. The clear cut advantages to crop rotation are especially evident in the presence of reniform nematodes. Because corn is an alternate host for rootknot nematodes, other steps must be taken. All in all, crop rotation pays.

Table 6. Summary of N, P, K, and S removal estimates for rotation systems in the Centennial Rotation based on standard concentrations. 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