CONSERVATION TILLAGE IN IRRIGATED COASTAL PLAIN DOUBLE-CROP ROTATIONS

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Abstract. We conducted three tillage experiments involving small grain grown for grain and double-cropped with cotton, soybean, or peanut under irrigation. The soils were Tifton or Pelham loamy sand. The experiments utilized irrigation application technology and integrated pest management practices. Our objective was to compare strip-till, no-till, ridge plant or subsoil without seedbed preparation to moldboard tillage and to study the effects of these tillage practices on crop production. Each experiment was initiated by moldboard tillage and seeding small grain. The various tillages were established after harvesting the first small grain crop and continued for the duration of the experiments. In subsequent years, the small grain crop was seeded into the preceding crop residue. One experiment was maintained for 11 years with strip tillage for the summer row crop. The other experiments were conducted for 4 or 5 years and compared strip tillage, no-till, ridge plant, and subsoil without seedbed preparation to moldboard tillage. The initial moldboard tillage always resulted in the highest small grain yield. Crop production varied from year to year, but in general cotton, peanut, and soybean yield were similar for strip and moldboard tillage. No-till generally resulted in lower yields. No insecticides were applied on any crop after 1991. No unusual disease problems occurred, although Cylindrocladium blackrot (CBR) developed on strip-till peanuts in 1996 and 1997. Weed management relied heavily on post-emergence herbicide treatments. Yellow nutsedge was a much greater problem in moldboard than in any conservation tillage. Significant shifts in weed populations did not occur, although morningglory species appeared to be increasing in peanuts. Soil pH, Ca, and Mg in the profile were decreased when cotton was included in the rotation.

INTRODUCTION

In present day crop production, attention to reduce soil erosion, crop production inputs, and adverse environmental impact, and yet maintain productivity, has recently focused on conservation tillage technology. There are extensive literature citations on individual characteristics and aspects that influence the adoption and management of conservation tillage. Most of the reduced tillage database originated from research in the midwest. Although their review emphasized herbicide soil interactions, Locke and Bryson (1995), reviewed many of the factors and characteristics involved in conservation tillage, such as organic matter, physical characteristics, pH, moisture, and nutrients. Conservation tillage research to date has produced variable results in terms of potential crop yield and other factors, such as erratic weed management (Doub et al., 1988; Elmore and Moorman, 1988; Forcella and Lindstrom, 1988; Patterson et al., 1989; Reddy et al., 1995). While some research has been conducted on coastal plain soils, additional research is needed to identify and characterize management problems and ecological shifts in coastal plain soils (Brecke and Shilling, 1996; Clemens et al., 1996; Patterson et al., 1995). Crops grown with conservation tillage under irrigation may present very rapid ecological and plant community changes. Research on conservation tillage under sprinkler irrigation has been very limited (Keeling et al., 1995). The interaction on conservation tillage and irrigation within multiple cropping sequences has not been studied in detail under coastal plain conditions. The results reported herein, are specifically designed to evaluate that area.

The objective of this research was to establish and evaluate the success of reduced tillage cropping systems to crop rotations common in the southeastern coastal plain that utilized irrigation application technology and integrated pest management techniques.

MATERIALS AND METHODS

Field studies were conducted at three locations at or near the University of Georgia, Coastal Plain Experiment Station, Tifton, GA.

In December 1986, two rotation experiments were established on Tifton loamy sand. One identified hereafter as IPM Conservation Tillage Rotation was initiated on plots previously used for various integrated pest management multiple rotation studies. The rotation was initiated in December 1986 by moldboard plowing and planting triticale. The only subsequent tillage for the duration of the experiment (through 1997) was strip-till (in row subsoiling with row preparation) on the summer crop, and inverting peanuts at harvest. Three cropping sequences were established and listed in Table 1. The second experiment hereafter identified as RDC was established in 1986 by moldboard plowing the experimental area, establishing the ridge plant tillage, and planting triticale. After the triticale harvest in 1987, strip-till, no-till, and moldboard plow tillages were established in addition to the ridge plant tillage. In 1988, an adjacent plot planted to rye became available so we established a moldboard plow tillage after burning small grain residue, strip-till after burning small grain residue, strip-till and no-till practices and rotated the two areas between small grain, soybean, and cotton (Table 2). The RDC study was conducted through 1991.

In 1993, a wheat-peanut-cotton rotation was established on Tifton and Pelham loamy sand soils, hereafter identified as the ABAC and Bowen studies, respectively. The experimental areas were moldboard plowed and planted to wheat. Following the small grain harvest in the summer of 1994, both cotton-peanut and peanut-cotton rotations were established in the tillage practices of moldboard plow, strip-till, no-till, and subsoil without seedbed preparation and continued for 4 years (Table 3).

All tillage plots were 18 ft. wide and the row crops (peanut, cotton, soybean) were planted in 36" rows. Commercially available equipment was used in all experiments, except that a 6 ft. wide plot drill was modified to plant small grains in crop residue. All rotations were initiated under sprinkler irrigation. All experiments included a double-crop rotation; winter grain grown for grain and a summer crop of cotton, peanut, or soybean following the small grain. The small grain stubble was left at combine height for all tillages except for moldboard plow which was flail mowed and/or burned and disc before plowing. The crop varieties utilized were generally early maturing varieties recommended by the University of Georgia Extension Service and were seeded at recommended rates. Fertilizer programs were based on soil sampling and codebook recommendations established by the University of Georgia Extension Service. Fertilizer was applied through irrigation as were all other agrichemicals (herbicides, insecticides, and fungicides) whenever feasible. All pest management practices were based on scouting. After each tillage treatment was established they remained on the same plots for the duration of the experiment. In all experiments the small grain was drilled into the preceding crop residue without any tillage except for inverting peanuts.

A split plot in strips experimental design with six replications was used in the IPM rotation. A randomized complete block design with four replications was used in the other experiments. Data were collected from a 6 ft. wide, 25 ft. long strip in each tillage plot included crop stand, yield, weed population estimates, disease incidence, surface residues, and soil fertility analysis. Yield data were analyzed by ANOVA at the 0.05 probability level of significance.

In December 1997, soil samples were collected from the center plot of the IPM conservation tillage study to a depth of 16". The sampling sites were taken between the strip-till areas that had remained undisturbed since December 1986, except for peanut digging. These samples were analyzed for soil pH, phosphorus, potassium, calcium, and magnesium.

RESULTS

IPM Conservation Tillage Study

The crop yield summary of this study is shown in Table 4. In 1992, wheat was substituted for triticale and peanut was substituted for soybean. The 1987 triticale was drilled into a moldboard plowed seedbed, which resulted in excellent yield. In the subsequent years, the small grain was drilled into the preceding crop residue, which resulted in reduced small grain yield for the duration of the experiment. Cotton yield reflected year to year variation, but rotation did not affect cotton yield. The same was generally true for soybean and peanut. In 1994, rainfall in excess of 30" occurred on both peanut and cotton. Although other management practices were maintained, the growth of both crops was restricted and reflected in severe yield reduction. There was some year to year variation, but rotation had little effect on peanut or soybean production, except for peanut in 1996. This is partly the result of an increased incidence of Cylindrocladium black rot in rotation 2. Although Cylindrocladium was present in both rotations, it was much more severe in rotation 2, which also caused excessive pod loss at harvesting. The disease was also present in 1997 in rotation 2 peanut but not nearly as severe as in the previous year.

In December 1997, the undisturbed soil profile was sampled to a depth of 16" and analyzed for pH (water), and Mehlich-1 extractable, phosphorus, potassium, calcium, and magnesium. The results are shown in Tables 5, 6, and 7 and Figure 1. It is quite evident that a continuous conservation tillage rotation involving cotton decreased soil pH, Ca and Mg more than rotation with peanut or soybean. This was specifically true for the soil profile from 3 to 9".

RDC Conservation Tillage Study

The yield results of the RDC Conservation Tillage Rotations 1 and 2 are shown in Tables 8 and 9. Moldboard plow tillage consistently resulted in high triticale yield as compared to the other conservation tillages.

In general, tillage practices did not significantly affect cotton production, except for Rotation 1 moldboard burn in 1988 and no-till in Rotation 2 in 1989. Moldboard tillage resulted in consistently high yield.

Tillage practices did not influence soybean production except for ridge plant in Rotation 2. However, moldboard tillage consistently resulted in high yield over all years.

ABAC and Bowen Wheat-Peanut-Wheat-Cotton Rotation

The results from the ABAC and Bowen rotations from 1994 through 1997 are shown in Tables 10-13. Chemigate means that all production materials were applied through irrigation if feasible. Conventional means that all production materials except fertilizer were applied by ground application. All fertilizer to all crops was applied through irrigation.

Although there was some variation within year and also variation between years, chemigation and conventional application did not affect the yield of any crop at either location.

In most instances, tillage did not affect wheat yield at ABAC. In 1994, the cotton yield was extremely low. The greatest yield reduction occurred in the moldboard plow. At least in part, this yield reduction was the result of heavy rains that occurred after cotton planting which eroded plots and caused the soil to crust over which reduced cotton stands. From 1995 to 1997, peanut and cotton yields at the ABAC location were generally similar in the moldboard and strip-tillage and least in the no-till (Tables 10 and 11). The subsoil-till treatment yields were generally intermediate and somewhat inconsistent. However, in 1997, the highest peanut yield was in no-till tillage and lowest was in moldboard plow.

In the Bowen wheat-peanut-wheat-cotton rotation, moldboard plow generally resulted in the highest wheat, cotton, and peanut yields, but strip-till was similar in several instances. (Table 12). No-till resulted in the lowest cotton and peanut yield. This was also true in the Bowen wheat-cotton-wheat-peanut rotation (Table 13). However, peanut yield was lower in the moldboard tillage than in strip-till, subsoil-till, and no-till in 1995 and 1997. This may have been the result of sampling error because two replications of the moldboard tillage plots were extremely low.

DISCUSSION

There are many approaches that can be taken to utilizing conservation tillage in crop production systems of the southeastern coastal plain. The approach reported herein certainly cannot be adapted to all situations, but it does point out some factors that must be considered.

A primary factor in the utilization of successful conservation tillage is soil moisture. In the early 1970's, some limited studies were conducted on evaluating herbicides in no-till situations. Three out of four years were complete failures for a lack of soil moisture. Irrigation has not been promoted as a part of conservation tillage production, but it must be considered. All of the crops grown in these experiments were irrigated at least one time and as many as eleven times in certain situations. On several occasions, irrigation was utilized to establish crop stand. Soil moisture is also important at or soon after crop planting to activate soil applied herbicides. On the other hand, excessive soil moisture can be detrimental. In 1994, excessive rainfall soon after planting resulted in erosion and surfacing crusting of the soil, specifically in moldboard and strip-till tillages.

Timeliness of planting and establishing a good summer crop stand are extremely important for managing the crop during the growing season and obtaining consistent high yields. In our studies, planting small grain in early December and harvesting in mid to late May were consistent. However, for various reasons, we sometimes had to plant peanut or cotton as late as mid June. One to two week delay in planting has a significant affect on crop maturity in October or early November.

The interaction of cropping with soil depth for soil pH, Ca, and Mg indicates lower values when cotton was in the system. This is no doubt a result of increased application of ammoniacal nitrogen in the cotton crops, while no nitrogen was applied for the leguminous soybean or peanut crops (Fig. 1).

Insect management was not a major factor in these experiments. Insect application requirements for the boll weevil eradication program on cotton were followed through 1990. After 1991, no additional insecticide applications were made on cotton. The other crops required no insecticide applications during the duration of the experiments. There was no consistent monitoring of soil insects, but it did appear that the incidence of wire worm and southern corn root worm were increasing on peanuts on the IPM conservation rotations in 1996 and 1997. Observations would suggest that careful attention be paid to soil insect populations.

Weed control data were not presented, although some weeds were generally present at harvest for all crops. Scouting and reliance on post-emergence weed management programs were generally effective. Yellow nutsedge was a persistent problem, particularly in the moldboard plow peanut rotations. Yellow nutsedge was not a major problem in the reduced tillage rotations. Florida beggarweed and some morningglory species emerged later in the growing season and were present at peanut harvest. Most of the weeds present emerged in the crop row middles and were not competitive with the crop. The rotation sequence and weed management programs did not result in a major weed population shift. Weeds that were present in the initiation of experiments were generally the same weeds that were present when the experiments were terminated. It did appear that some morningglory species may have been increasing in the peanut rotations.

The results of these experiments indicate several items to be considered. Equipment utilized in conservation tillage, especially in planting, has improved greatly over the past several years. However, the precision needed to control planting depth still needs to be improved. The crop seed needs to be placed in good contact with the soil at the proper depth to obtain a uniform stand. Soil moisture at planting is also a critical factor. Irrigation can provide some consistency in soil moisture. The full implication of maintaining adequate fertility levels in conservation tillage is not fully understood. Our results would indicate we are not fully utilizing the fertilizers applied. Our results would also indicate we are not effectively managing the soil moisture through the growing season. The insect management program in these experiments were minimal. More extensive monitoring of soil insects would be desirable. Weeds are still a major factor in conservation tillage production systems. Weed management in these experiments were acceptable and did not appear to produce any major ecological shifts. This was based partially on crop rotation and also on rotation of herbicides. There is also some limitation for weed management in double-cropping conservation tillage systems because of potential herbicide carryover from one crop the a next. This may restrict use of some effective and economical herbicides. All of these experiments were initiated by moldboard plowing and planting small grain. This initial tillage always resulted in our best small grain production. It would appear that some tillage for producing small grains may be desirable if yield is important.

An extensive economic analysis of these experiments has not been conducted. If equipment is available, timeliness of planting, especially in conservation tillage, and harvesting were feasible in our rotation systems. However, it would appear that more consistent high crop yields are necessary to make conservation tillage economically feasible.

Agricultural technology has changed tremendously since these experiments were initiated. Recent advancements in biotechnology, new pest management chemistry, and new varieties require that research be continued in conservation tillage cropping systems.

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Table 1. Crop Rotations in IPM Conservation Tillage Study.

Year	Crop rotation 1	Crop rotation 2	Crop rotation 3
1987	triticale-cotton	triticale-soybean	triticale-cotton

1988	triticale-cotton	triticale-soybean	triticale-soybean
1989	triticale-cotton	triticale-soybean	triticale-cotton
1990	triticale-cotton	triticale-soybean	triticale-soybean
1991	triticale-cotton	triticale-soybean	triticale-cotton
1992	wheat-cotton	wheat-peanut	wheat-peanut
1993	wheat-cotton	wheat-peanut	wheat-cotton
1994	wheat-cotton	wheat-peanut	wheat-peanut
1995	wheat-cotton	wheat-peanut	wheat-cotton
1996	wheat-cotton	wheat-peanut	wheat-peanut
1997	wheat-cotton	wheat-peanut	wheat-cotton

Table 2. Crop Rotations in RDC Conservation Tillage Study.

Year	Rotation 1	Rotation 2
1987	-------	triticale-cotton
1988	rye-cotton	triticale-soybean
1989	triticale-soybean	triticale-cotton
1990	triticale-cotton	triticale-soybean
1991	triticale-soybean	triticale-cotton

Table 3. Crop Rotation in ABAC and Bowen Conservation Tillage Study.

Year	Rotation 1	Rotation 2
1994	wheat-peanut	wheat-cotton
1995	wheat-cotton	wheat-peanut
1996	wheat-peanut	wheat-cotton
1997	wheat-cotton	wheat-peanut

Table 4. Crop Yield Summary for Ipm Conservation Tillage Study.

Year	Crop rotation 1		Crop rotation 2		Crop rotation 3		
	triticale Bu/A	cotton lint lb/A	triticale Bu/A	soybean Bu/A	triticale Bu/A	cotton lint lb/A	soybean Bu/A
1987	56	854	50	26	72	712	--
1988	35	799	45	29	43	--	31
1989	30	666	30	29	29	715	--
1990	33	741	43	25	30	--	25
1991	21	360	17	31	14	551	--
	wheat Bu/A	cotton lint lb/A	wheat Bu/A	peanut lb/A	wheat Bu/A	cotton lint lb/A	peanut lb/A
1992	30	470	42	2867	33	--	2649
1993	18	578	24	2332	24	611	--
1994	31	253	38	1120	30	--	1156
1995	23	666	37	2194	23	666	--
1996	30	786	33	1062	30	--	2314
1997	16	583	26	2243	25	575	--

Table 5. Anova of Selected Soil Analysis in IPM Conservation Tillage Study.[1]

Source	pH	P	K	Ca	Mg
Block	**	**	**	**	**
Crop Sys	**	**	ns	**	**
Depth	**	**	**	**	**
Crop Sys ×depth	**	ns	ns	**	**

[1] pH was measured in water, P, K, Ca and Mg were extracted by Mehlich-1.

Table 6. Effect of Cropping Systems on Soil Analysis in IPM Conservation Tillage Study.

Cropping system	pH	P	K	Ca	Mg
	-----------------------PPM--------------------				
1	6.0 b	21 a	47	226 b	41 b
2	6.2 a	10 b	46	287 a	58 a
3	5.9 b	18 a	41	236 b	45 b

Within columns, any means followed by the same letter aree not significantly different. No letter shown when ANOVA indicates no significant difference at P = 0.05 level.

Table 7. Effect of Depth on Soil Analysis in IPM Conservation Tillage Study.

Depth	pH	P	K	Ca	Mg
0-3	6.6 a	27 a	45 b	455 a	97 a
3-6	6.3 b	24 ab	38 bc	214 c	42 b
6-9	5.8 cd	21 b	35 c	144 d	27 c
9-12	5.7 d	14 c	39 bc	183 c	30 c
12-16	5.9 c	01 d	61 a	250 b	44 b

Within columns, any means followed by the same letter aree not significantly different. No letter shown when ANOVA indicates no significant difference at P = 0.05 level.

Table 8. Crop Yield for RDC Conservation Tillage Study Rotation 1.

TRITICALE BU/A					
Tillage	1987	1988	1989	1990	1991
Strip-Till	----	----	20c	39b	20c
No-Till	----	----	15c	38b	19c
Strip-Till Burn	----	----	23b	56a	25b
Moldboard Burn	----	----	34a	53a	30a

COTTON LINT LB/A					
Tillage	1987	1988	1989	1990	1991
Strip-Till	----	583b	----	798	----
No-Till	----	533b	----	838	----
Strip-Till Burn	----	530b	----	942	----
Moldboard Burn	----	754a	----	829	----

SOYBEANS BU/A					
Tillage	1987	1988	1989	1990	1991
Strip-Till	----	----	30	—	40
No-Till	----	----	31	----	37
Strip-Till Burn	----	----	37	----	37
Moldboard Burn	----	----	33	----	39

Within columns, any means followed by the same letter aree not significantly different. No letter shown when ANOVA indicates no significant difference at P = 0.05 level.

Table 9. Crop Yield for RDC Conservation Tillage Study Rotation 2.

TRITICALE BU/A					
Tillage	1987	1988	1989	1990	1991
Ridge Plant	39	35	24c	33	20ab
No-Till	39	38	30b	29	18b
Strip-Till	43	43	31b	27	19b
Moldboard	48	43	37a	32	25a

COTTON LINT/A					
Tillage	1987	1988	1989	1990	1991
Ridge Plant	767	----	527ab	----	769
No-Till	760	----	380b	----	717
Strip-Till	719	----	629ab	----	678
Moldboard	852	----	728a	----	841

SOYBEANS BU/A					
Tillage	1987	1988	1989	1990	1991
Ridge Plant	----	27b	----	11b	----
No-Till	----	33ab	----	18a	----
Strip-Till	----	35ab	----	18a	----
Moldboard	----	41a	----	22a	----

Within columns, any means followed by the same letter aree not significantly different. No letter shown when ANOVA indicates no significant difference at P = 0.05 level.

Table 10. Effect of Tillage and Chemigation on Crop Yield in Abac Wheat-peanut-wheat-cotton Rotation.

	Crop					
	Wheat, Bu/A		Peanut, lb/A		Cotton, Lint lb/A	
Tillage	Chemigate	Conventional	Chemigate	Conventional	Chemigate	Conventional
1994						
Moldboard	49		1538	1740		
Strip-Till			1481	1300		
Subsoil-Till			1592	1350		
No-Till			1631	1517		
1995						
Moldboard	38	40			997 a	863 a
Strip-Till	40	36			908 a	691 ab
Subsoil-Till	39	43			769 b	865 a
No-Till	41	45			737 b	648 b
1996						
Moldboard	35	35	3523 a	3615 a		
Strip-Till	30	30	2986 ab	2955 bc		
Subsoil-Till	35	35	2864 b	3467 ab		
No-Till	29	28	2639 c	2530 c		
1997						
Moldboard	37 a	29			815 a	706 a
Strip-Till	32 ab	23			682 b	704 a
Subsoil-Till	30 b	26			468 c	590 b
No-Till	28 b	30			353 d	403 c

Within columns and years, any means followed by the same letter aree not significantly different. No letter shown when ANOVA indicates no significant difference at P = 0.05 level.

Table 11. Effect of Tillage and Chemigation on Crop Yield in Abac Wheat-cotton-wheat-peanut Rotation.

	Crop					
	Wheat, Bu/A		Peanut, lb/A		Cotton, Lint lb/A	
Tillage	Chemigate	Conventional	Chemigate	Conventional	Chemigate	Conventional
1994						
Moldboard	55	53			162 c	121 b
Strip-Till					377 b	234 a
Subsoil-Till					335 b	313 a
No-Till					539 a	367 a
1995						
Moldboard	36	36	2434	2835 a		
Strip-Till	38	35	2479	2660 a		
Subsoil-Till	38	38	2075	1826 b		
No-Till	38	36	2254	2516 a		
1996						
Moldboard	46 a	35 ab			1188 a	1169 a
Strip-Till	29 ab	44 a			986 b	1152 a
Subsoil-Till	39 b	39 a			829 b	834 b
No-Till	29 c	28 b			834 b	840 b
1997						
Moldboard	32 a	31 a	1652	1793		
Strip-Till	29 ab	31 a	1504	2124		
Subsoil-Till	26 bc	28 ab	1623	1869		
No-Till	23 c	25 b	1833	1906		

Within columns and years, any means followed by the same letter aree not significantly different. No letter shown when ANOVA indicates no significant difference at P = 0.05 level.

Table 12. Effect of Tillage and Chemigation on Crop Yield in Bowen Wheat-peanut-wheat-cotton Rotation.

	Crop					
	Wheat, Bu/A		Peanut, lb/A		Cotton, Lint lb/A	
Tillage	Chemigate	Conventional	Chemigate	Conventional	Chemigate	Conventional
1994						
Moldboard	50	51	1329 a	1220 a		
Strip-Till			1092 a	610 b		
Subsoil-Till			730 b	661 b		
No-Till			548 b	722 b		
1995						
Moldboard	31	35			890 a	981 a
Strip-Till	35	37			581 b	736 b
Subsoil-Till	32	34			615 b	750 b
No-Till	33	31			489 c	632 b
1996						
Moldboard	44 a	38 a	2628	2897 a		
Strip-Till	28 c	33 ab	2719	2660 ab		
Subsoil-Till	33 b	29 b	2414	2283 b		
No-Till	18 d	29 b	2403	2261 b		
1997						
Moldboard	22 a	22			734 a	735 a
Strip-Till	19 ab	21			764 a	588 ab
Subsoil-Till	15 b	23			580 b	487 bc
No-Till	16 b	23			474 b	335 c

Within columns and years, any means followed by the same letter aree not significantly different. No letter shown when ANOVA indicates no significant difference at P = 0.05 level.

Table 13. Effect of Tillage and Chemigation on Crop Yield in Bowen Wheat-cotton-wheat-peanut Rotation.

	Crop					
	Wheat, Bu/A		Peanut, lb/A		Cotton, Lint lb/A	
Tillage	Chemigate	Conventional	Chemigate	Conventional	Chemigate	Conventional
1994						
Moldboard	52	50			743a	434
Strip-Till					646a	330
Subsoil-Till					371b	440
No-Till					349b	305
1995						
Moldboard	37	41a	748b	1035ab		
Strip-Till	36	31b	1746a	1517a		
Subsoil-Till	37	34b	1688a	1198ab		
No-Till	30	31b	1165b	966b		
1996						
Moldboard	31a	40a			921a	881a
Strip-Till	29ab	25b			909a	895a
Subsoil-Till	24b	22b			909a	678b
No-Till	22b	23b			685b	812ab
1997						
Moldboard	18	18	1361b	1477ab		
Strip-Till	17	16	2120a	2124a		
Subsoil-Till	17	21	2142a	1369bc		
No-Till	21	22	1532a	1234c		

Within columns and years, any means followed by the same letter aree not significantly different. No letter shown when ANOVA indicates no significant difference at P = 0.05 level.

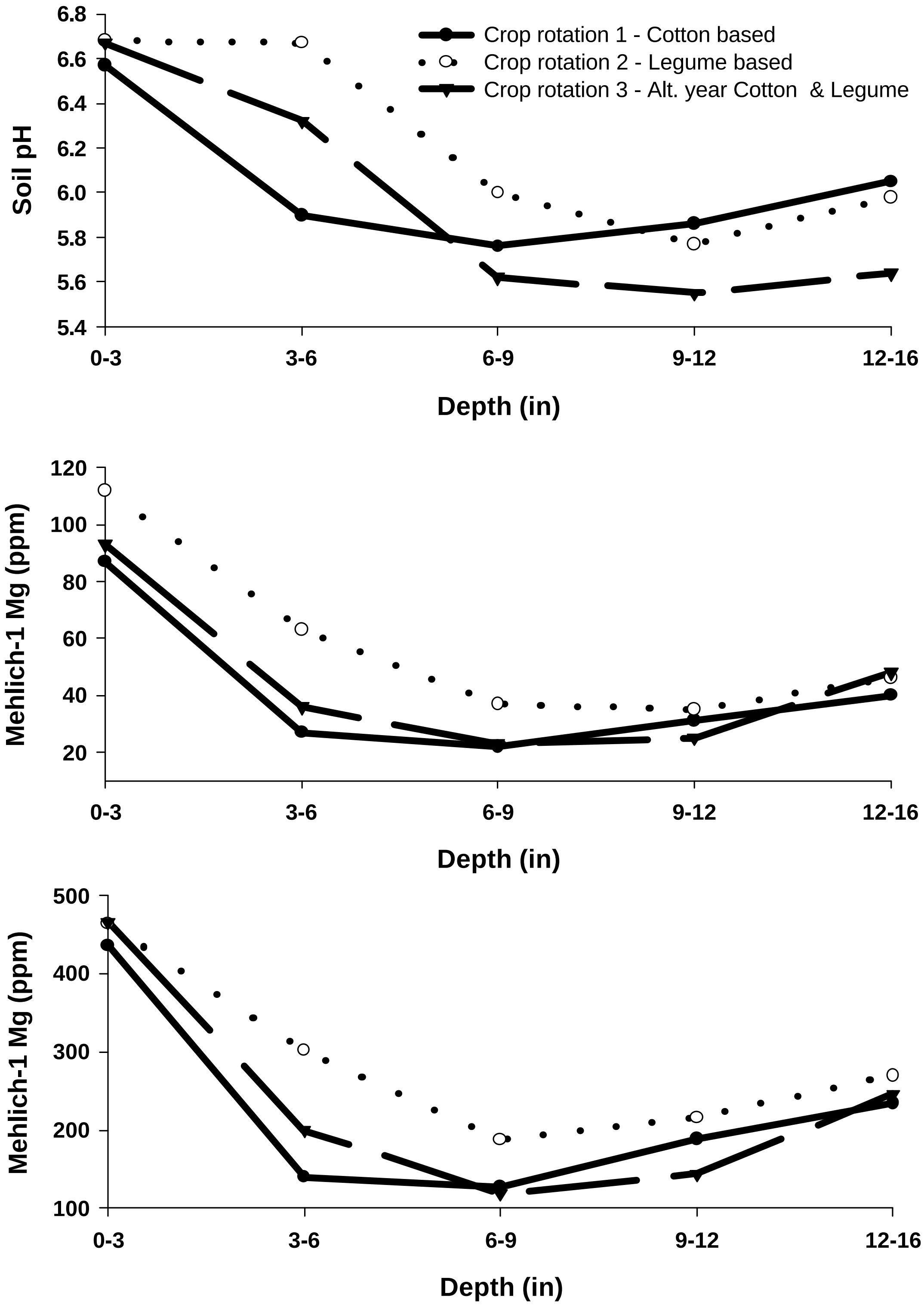

Fig. 1. Interaction of cropping system and soil depth on pH, Ca and Mg in the IPM Conservation Tillage Study (see Table 1 for full crop rotation descriptions from 1987 to 1997.