THE EFFECT OF COVER CROP AND CROP ROTATION ON COTTON: SOIL-PLANT RELATIONSHIP

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Abstract

In the lower Coastal Bend Region of Texas, rainfall during the critical fruiting and boll filling periods is often deficient in terms of cotton (*Gossypium hirsutum L.*) needs. Crop yield is closely related to stored soil moisture in dryland areas. Cropping strategies to improve infiltration and/or storage of rainfall in the soil would benefit the crop by providing more moisture at critical periods of growth. A field trial was conducted in 1995 (as part of a long-term cropping experiment) on a predominant Victoria Clay soil to investigate the effect of cover crop and crop rotation on soil water storage and cotton growth. The experimental design was a randomized complete block in a split plot arrangement, with four replicates. Cotton rotations comprised of continuous cotton, cotton/sorghum [*Sorghum bicolor* (L.) Moench], and cotton/soybean [*Glycine max* (L.) Merr] were the main plots and oat (*Avena sativa* L.) cover crop (cover and no-cover), the subplots. Cover crop was seeded on September 1994 at the rate of 170 kg/ha and terminated with herbicide on January 1995. Plots were 13.7m wide and 61m long. Soil moisture measurements were taken only on cotton/sorghum rotation every 15 days period during the growing season. Cotton cultivated under cover crop had its growth reduced when compared to cotton under no-cover. This effect was correlated to reduced amount of available soil N and less soil water storage at the cover system in the beginning of the growing season. The oat residue in the soil acted as a N sink through competition and/or immobilization instead of an N source to cotton. The time of cover termination was certainly responsible for more soil water use by the oat plants and a consequent less soil water storage in the beginning of the cotton growing season. Consequently, this effect was aggravated by the lack of adequate rainfall during the first period of cotton plant growth, i.e., from planting to blooming stage. Crop rotation had no significant effect on cotton growth, but plant height and DM yield were consistently higher under continuous cotton than under rotation.

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Introduction

It is well known that water and N are two factors of major influence on crop production. Cotton grown in rainfed conditions such as the lower Coastal Bend Region of Texas is subject to periods of drought stress during the growing season. Cropping strategies to improve infiltration and/or storage of rainfall in the soil, such as cover crop and crop rotation, would benefit the crop by providing more moisture at critical periods of growth.

The importance of cover crop has long been recognized in agriculture. Winter cover crops benefit cropping systems by increasing N supply for subsequent crop, reducing soil erosion, improving soil properties, improving soil water efficiency and conserving leachable plant nutrients (Holderbaum *et al*., 1990; Meisinger *et al*., 1991). In water deficient conditions, however, cover crop may deplete stored water and reduce yields of the following crop (Utomo *et al*., 1987; Campbell *et al*., 1984). The effectiveness of a cover crop in maintaining or improving soil and water quality depends on several factors: selecting the cover crop, planting method, stage of growth, growth rate, length of growth period, and leaving the crop as a mulch or green manure. All these aspects should be taken into consideration in cover crop management.

Crop rotation refers to the growing of different crops in a regular sequence and has been shown to increase crop yields. The cause of this effect is related to either increased soil fertility, improved soil physical properties and soil erosion control, improved weed control, and/or reduced incidence of disease and insect pests (Wesley *et al*., 1991; Heichel, 1987; Vess and Shrader, 1984; Elliot *et al*., 1987; Litsinger and Wood, 1976; Boquet *et al*., 1976; Young *et al*., 1986). Fahad *et al*. (1982) attributed the increase in crop yield to the soil's enhanced water infiltration rate caused by the rotation. The beneficial effect of rotation, however, is reported to be more pronounced in stress condition. Roger *et al*. (1989) found less stored soil water in August under rotated soybean or sorghum than under soybean or sorghum grown as monoculture. Peterson and Varvel (1989) detected no difference in soil water depletion due to rotation of sorghum, corn, or soybean compared with the respective continuous crop. Crookston and Kurle (1987) reported that the greatest relative increases in corn and soybean yield due to rotation over continuous cropping occurred in years when overall yields were low. The objective of this research was to investigate the effect of cover crop and crop rotation on soil water storage and cotton plant growth.

Material and Methods

This study was part of a long-term rotation established at the Texas A&M Research Center at Corpus Christi, TX, on a predominate Victoria clay soil (fine montmorillonitic, hyperthermic, Typic Pellustert), with 1 to 2 percent slope.

The experimental design was a randomized complete block in a split plot arrangement with four replicates. Crop rotations were comprised of continuous cotton, cotton/sorghum, cotton/soybean, continuous sorghum, sorghum/cotton, sorghum/ soybean, soybean/cotton, and soybean/sorghum as the main plots and cover crop (oat cover crop and no-cover) as the subtreatments. Cover crop consisted of seeding feed grade oat late in September 1994 at the rate of approximately 170 kg/ha and receiving glyphosate [(N-phosphonomethy) glycine] and 2,4 D [(2,4-dichlorophenoxy) acetic acid] at the rate of 2,4 l/ha on January 13, 1995. The desiccated cover was allowed to remain in field to provide a surface mulch until spring planting preparation when was soil incorporated. Plant tissue samples were taken from the cover crop prior to extermination for dry matter yield and tissue analysis. Data presented in this paper was collected during the 1995 growing season using only cotton rotation sequences. Each plot was 13.7m wide and 61m long.

Cotton rotations received 34 kg/ha of N preplant. A starter fertilizer, 8-24-2, at a rate of 30 l/ha was also applied in a 10cm band over the seed furrow at planting. Cotton cultivar DPL-50 was sown in 96cm rows on March 24, 1995 at a population of approximately 100,000 plants/ha. Weeds were controlled with a pre-emergence application of metolachlor [2-chloro-N-ethyl-6-methylphenyl) -N- (2-methoxy - 1- methylethyl) acetamide] and fluometuron [N,N-dimethyl-N' - (3-trifluoromethyl - phenyl] urea at recommended rates. Two cultivations on April 24 and May 17 were needed to control reminiscent weeds.

Soil water content were monitored throughout the season using a neutron probe (Campbell Pacific Model 503; CPN Corp., Martinez, CA). Access tubes were installed in two locations (North and South) of each subplot at cotton/sorghum rotation of four replicates after plant emergence. The probe was calibrated at each site by obtaining 15cm incremental soil samples and determining the soil water content. The gravimetric data was converted to a volumetric basis by multiplying by the soil bulk density. Probe readings were taken twice a month during the growing season. Readings were taken from 0-15 cm to a depth of 75-90cm. Neutron probe readings were converted to volumetric soil water content by use of a regression equation to determine the amount of water in the soil profile. Volumetric soil values for the experimental area ranged from approximately 42 percent at saturation, to 34 percent at field capacity, to 18 percent at permanent wilting point (Lawlor and Landivar, 1992). Plant extractable water (PEW) was determined as the difference between the volumetric soil moisture (VSM) measured between dates when little or no rainfall occurred. This is a modified laboratory and field method used by Ratliff et al. (1983), Franzmeier et al. (1973), and Ritchie (1981) cited by Lawlor and Landivar (1992) to determine potential extractable water. Soil water depletion (WD) was determined as the difference between total water content on April 28 and on July 28. Evapotranspiration (ET) was calculated as the sum of soil water depletion (WD) in the whole profile and precipitation received during the same experimental period, i.e. ET = WD + rainfall. Water runoff was assumed negligible because the slope was < 2%. Water use efficiency (WUE) was calculated as gain yield (Y) divided by ET, or WUE = Y/ET (Tanner and Sinclair, 1983). Data was analyzed by the standard analysis of variance procedures.

Results and Discussion

Oat Dry Matter and Nitrogen Content

Dry matter yield (DM) and N concentration are measurements of the N content in the above ground portion of a cover crop. These values represent N uptake from residual soil inorganic N, mineralized soil organic N, and biologically fixed N in legume cover crop. Mean values of oat DM and N content harvested in January 1995 are given in Table 1. Oat yield ranged from 1,584 kg/ha to 2,167kg/ha. Rotation did not significantly affect oat DM yield. Yields were lower under rotations. Cotton/sorghum was the crop sequence that reduced most cover crop yield. For N content, the highest mean was registered under cotton/soybean rotation (25.58g/kg) which differed significantly ($p<0.05$) only from cotton/sorghum sequence. This result was somewhat expected due to N fixation by soybean over the years.

Soil Organic Matter and Soil Nitrogen

Results of organic matter (OM) and total soil N determinations are given in Table 2. ANOVA indicates that only the main effect of depth was significant on OM ($p<0.01$). Means of organic matter averaged over rotations and cover treatments (data not shown in this Table) decreased consistently and significantly with depths. Neither rotation nor cover had a consistent effect on this variable. Despite the close relationship between soil organic matter and soil N (Haas et al., 1957; Hobbs and Brown, 1965; and Unger, 1968) there was no trend among N concentration and organic matter in relation to depth. Soil N consistently increased with depth. Analysis of variance of this variable indicates a significant rotation x cover interaction ($p<0.05$). Soil N was consistently higher at no-cover but a significant difference was observed only at continuous cotton (Table 2). This effect seems to be correlated to oat residue C/N ratio (Scheppers and Mosier, 1991) and the stage of cover termination (January 95). The cover residue in the soil acted as an N sink instead of an N source to the summer crop. The non-leguminous cover crop reduced N availability through competition and/or immobilization.

Soil Water Content and Crop Water Use

Rainfall from March to August 1995 was 96 percent of the 15-yr average precipitation of 369mm. Temperature and weekly cumulative precipitation data registered during the growing season are shown in Table 3. Seasonal variations in the amount and distribution of rain occurred throughout the season. Severe soil moisture deficit was observed at the critical stage of plant development, i.e., from planting to first blooming stage (1-63 days after planting).

Conservation of soil moisture by cover crop during the summer growing season is closely related to decreasing surface runoff, increasing soil organic matter, and decreasing evapotranspiration. For the data collected in this trial, analysis of variance of soil moisture content indicates no significance ($p>0.05$) for the main effect of cover crop, neither for the cover x depth interaction at any stage of the crop growth (Tables 4a and 4b). Cover crop did not show any consistent beneficial effect on soil water storage at any depth throughout the growing season, except for 75-90cm profile. Lower soil moisture storage means under cover crop were registered at the first two readings (April 28 and May 9) on basically all depths, and in the 15-30cm profile at the last four readings. At 75-90cm profile, soil water content was consistently but not significantly higher under cover crop at all readings (Tables 4a,b and 5). Percent differences at this site varied from 2.45 to 10.13 (Table 5). As the season advanced, the crop increased soil water depletion at that profile and an increase in percent difference among cover treatments was also observed. This result appears to make sense because as the cotton plants grow, their demand for water increased and the water supplied by rain was not sufficient to compensate that deficit. It also suggests that more rain could be captured under cover treatment at the deepest profile. For dryland farming areas, especially during periods of drought, this effect seems to be beneficial. No trend, however, was found between this effect and plant extractable water and water use efficiency. Values of plant extractable water for periods with little or no rainfall showed no significant effect of cover crop on this variable over the whole growing season (Table 6). Water use efficiency of cotton plants under cover crop was even smaller than that under no cover treatment. However, no significant difference was obtained between cover and no-cover means (Table 7).

The absence of cover crop benefit on soil moisture storage in the upper profiles, in plant extractable water and water use efficiency by cotton plants may be correlated to cover termination date. Cover crop was killed on January 13, oat cover reduced water storage for its own vegetative growth instead of having a beneficial effect. This effect was emphasized more during the growing season due to the lack of rainfall, particularly from planting to first blooming stage. Data in Table 3 shows that the cotton plants used only 32mm of water to germinate, to grow and to initiate blooming. According to Waddle (1984), cotton plants demand 80mm of water to grow from planting to flower bud initiation in order to produce 0.75 bales/ha of cotton.

Plant Growth

Plant growth estimated by plant height and cotton dry matter production is presented in Table 8. ANOVA shows that at 70 DAP the main effect of cover crop on plant height and the interaction cover crop x rotation on DM were significant ($p<0.05$). Plant height was consistently but not significantly higher under continuous cotton. Cover crop significantly reduced plant height (main effect). Similar results were observed on DM production at this stage of growth. Consistent higher DM yield was registered on cotton/cotton sequence, while cover crop reduced it. However, significant difference was observed only within rotations. At 95 DAP, analysis of variance of plant height and DM shows significance only for the cover x rotation interaction ($p<0.05$). At this stage of growth, plant height was consistently higher on cotton/cotton sequence, and cover crop reduced this variable only within rotation. A significant difference, however, was observed only on continuous cotton. In this crop sequence (cotton/cotton), plants were significantly higher under the cover regime (interaction effect). For DM, higher means were registered on cotton/cotton rotation and under crop rotation regime. However, a significant difference was registered only on cotton/soybean rotation.

The lack of a beneficial effect of cover crop and crop rotation on plant growth was probably due to a reduced amount of available N and less soil water storage under cover treatment at the beginning of the growing season. Data collected in the same experiment in 1994 showed a significant cover-crop effect on growth and yield of cotton (Moseley et al., 1995). Since the treatments and cotton cultivars were the same and that the only difference among years were the weather conditions and the cover-crop extermination date (12/21/93 for 1994 experiment and 01/13/95 for 1995 trial) one could conclude that the date of extermination was the factor responsible for the lack of cover-crop beneficial effect on cotton in the 1995 season.

Conclusion

Cotton cultivated under cover crop had its growth reduced when compared to cotton cultivated under no cover system. This result was due to the reduced amount of available soil N and probably less soil water storage under this treatment, particularly at the beginning of the growing season. The oat residue with a high C/N ratio (exterminated on January 13th 1995) served to immobilize residue soil N (NO_3 and NH_4), added fertilizer N, and tissue N by organisms making it unavailable for immediate use for cotton plants. The delay on cover termination was also responsible for more soil water use by the oat plants for their own vegetative growth and consequently less soil water storage under no-cover treatment, particularly in the beginning of the growing season. The above effect was more critical because of the lack of adequate rainfall during the first nine weeks of the growing season. Lower mean values of plant extractable water and water use efficiency confirmed the absence of the beneficial effect of the cover treatment on cotton growth. Crop rotation had no significant effect on cotton growth. Plant height and dry matter yield however, were consistently higher under continuous cotton. This effect seems to be correlated to a significantly higher availability of soil N concentration under continuous cotton than under rotations.

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Table 1. Dry matter yield and N concentration of oat leaves at harvest. Corpus Christi, TX, 1995.

Rotation Sequence	Dry Matter Yield	Nitrogen Content
	kg/ha	g/kg
Cotton/Cotton	2,167.50	24.50a +
Cotton/Sorghum	1,584.38	19.93b
Cotton/Soybean	1,748.13	25.58a
Mean	1,833.33	23.33
LSD (0.05)	NS	3.87
CV (%)	17.62	9.60

NS Indicates test F nonsignificant at p<0.05.
\+ Mean values followed by the same letter are not significantly different at p<0.05 as determined by LSD test.

Table 2. Influence of rotation and cover crop on soil OM and N. Corpus Christi, TX, 1995.

Rotation Sequence	Cover Crop	Organic Matter (%)	Nitrogen (mg/kg)
Cotton/Cotton	Cover	0.65	8.85b +
	No-Cover	0.68	15.90a
Cotton/Sorghum	Cover	0.61	5.55a
	No-Cover	0.58	6.60a
Cotton/Soybean	Cover	0.66	4.80a
	No-Cover	0.57	7.20a
Mean Values			
Ct/Ct		0.66	12.37
Ct/Sg		0.59	6.07
Ct/Sy		0.61	6.00
	Cover	0.63	6.40
	No-Cover	0.61	9.90
Treatment Effects			
Rotation Sequence (RS)		NS	**
Cover Crop (CC)		NS	**
Depth (DT)		**	**
CC x RS		NS	*

*, ** Indicates significance at p<0.05 and p<0.01 respectively.
NS Indicates non significant at p<0.05.
\+ Mean values followed by the same letter within rotation sequence are not significantly different at p<0.05.

Table 3. Weekly mean temperature and cummulative precipitation during the growing season. Corpus Christi, TX, 1995.

Month	Week+	Day	Temperature	Precipitation Weekly	Sum
			C		mm
	1	1-7	19.10	11.00	11.00
March					
April	2	8-14	19.40	3.00	14.00
	3	15-21	21.30	4.0	18.00
	4	22-28	24.10	0.00	18.00
	5	29-35	20.70	0.00	18.00
May	6	36-42	24.10	1.00	19.00
	7	43-49	25.50	5.00	24.00
	8	50-56	27.80	8.00	32.00
	9	57-63	24.60	0.00	32.00
June	10	64-70	26.30	66.00	98.00
	11	71-77	27.50	1.00	99.00
	12	78-84	24.90	32.00	131.00
	13	85-91	25.30	14.00	145.0
	14	92-98	26.90	10.00	155.00
July	15	99-105	27.90	3.00	158.00
	16	106-112	27.80	0.00	158.00
	17	113-119	28.20	47.00	205.00
	18	120-126	29.90	0.00	205.00
August	19	127-133	28.80	36.00	241.00
	20	134-140	29.10	1.00	242.00

\+ Beginning 24 March and ending 8 August 1995.

Table 4a. Volumetric soil moisture as influenced by cover crop and depth. Corpus Christi, TX, 1995 (March 28-June 6, 1995).

Depth	March 28 Cover	March 28 N/C	May 9 Cover	May 9 N/C	May 23 Cover	May 23 N/C	June 6 Cover	June 6 N/C
cm	----------------------------------m^3/m^3 *100-----------------------------------							
0-15	14.87	14.71	10.66	12.16	------	------	-----	------
15-30	27.02	27.47	26.61	27.72	23.33	22.45	25.95	25.03
30-45	28.10	28.28	28.25	28.63	26.19	25.11	25.97	24.68
45-60	27.85	28.17	28.55	29.12	27.45	27.08	26.67	24.62
60-75	27.51	27.35	28.18	28.33	27.73	27.77	27.11	25.58
75-90	27.16	26.51	28.36	27.54	28.22	27.21	28.33	26.17
Mean	25.42	25.41	25.11	25.59	26.58	25.92	26.81	25.22
Trt. Effect								
C	NS		NS		NS		NS	
D	*		**		**		NS	
CxD	NS		NS		NS		NS	

*,** Indicates significance at p<0.05 and p<0.01 respectively.
NS Indicates test F nonsignificant at p<0.05.

Table 4b. Volumetric soil moisture as influenced by cover crop and depth. Corpus Christi, TX, 1995 (June 20-July 28, 1995).

Depth	June 20		July 5		July 18		July 28	
	Cover	N/C	Cover	N/C	Cover	N/C	Cover	N/C
cm	-----------------------------m^3/m^3 *100--------------------------------							
0-15	31.16	30.34	-----	------	------	------	----	------
15-30	22.45	23.79	14.82	15.42	12.36	13.19	11.50	12.11
30-45	23.11	23.02	17.22	17.12	15.18	14.82	13.65	13.81
45-60	23.78	22.83	19.03	18.81	16.87	15.94	15.26	14.38
60-75	24.62	24.24	21.35	20.19	18.98	18.02	17.06	16.21
75-90	26.64	25.27	25.02	22.96	22.49	20.49	21.08	19.19
Mean	25.29	24.91	19.49	18.91	17.18	16.49	15.71	17.13
Trt. Effect								
C	NS		NS		NS		NS	
D	**		**		**		**	
CxD	NS		NS		NS		NS	

*,** Indicates significance at $p<0.05$ and $p<0.01$ respectively.
NS Indicates test F nonsignificant at $p<0.05$.

Table 5. Mean volumetric soil moisture content at 90cm profile on cotton/sorghum rotation. Corpus Christi, TX, 1995.

Day	Volumetric Soil Moisture Cover	N/C	Percent Difference &
	m^3/m^3*100+		
4/28	27.16	26.51	2.45
5/09	28.36	27.54	2.98
5/23	28.22	27.21	3.71
6/06	28.33	26.17	8.25
6/20	26.64	25.27	5.42
7/05	25.02	22.96	8.97
7/18	22.49	20.49	9.76
7/28	21.08	19.14	10.13

\+ F test non significant at $p<0.05$ for main effect of cover crop at all individual soil moisture readings.
& Calculated as [(C/NC - 1.00) * 100]

Table 6. Mean profile plant extractable water as influenced by cover crop on cotton/sorghum rotation. Corpus Christi, TX, 1995.

Date	Plant Extractable Water Cover	N/C	Percent Difference &
	m^3/m^3*100+		
4/28-7/28	10.32	11.06	-6.69
5/09-7/05	8.68	9.32	-6.84
5/09-7/28	12.38	13.05	-5.13
5/23-7/18	9.47	9.38	0.96
5/23-7/28	10.88	10.82	0.55
5/05-7/28	3.79	3.76	0.81
7/18-7/28	1.49	1.67	-13.17

\+ F test nonsignificant at $p<0.05$ for the main effect of cover crop at all individual analysis.
& Calculated as [(C/NC - 1.00) * 100]

Table 7. Cotton seed yield (Y), water depletion (WD), evapotranspiration (ET), and water use efficiency (WUE) as affected by cover crop on cotton/sorghum rotation. Corpus Christi, TX, 1995.

Cover Treatment	Y	WD+	ET++	WUE+++
	Mg/ha	------------mm -----------		kg/ha/mm
Cover	2.21	9.71	214.71	10.29
No-Cover	2.26	10.28	215.28	10.50
F test	NS	NS	NS	NS

NS Indicates F test nonsignificant at $p<0.05$ for the main effect of cover crop.
\+ Calculated as initial soil water content minus final soil water content in the whole profile.
++ Calculated as WD plus precipitation.
+++ Calculated as Y/ET.

Table 8. Cotton plant height and dry matter production as affected by crop rotation and cover crop. Corpus Christi, TX, 1995.

Rotation Squence	Cover Crop	Days After Planting+			
		70.00	95.00	70.00	95.00
		Plant Height,cm		DM,Mg/ha	
Cotton/Cotton	Cover	51.11	90.85a	1.89a	8.13a
	No-Cover	53.67	78.85b	1.94a	6.59a
Cotton/Sorghum	Cover	46.62	74.55a	1.66b	7.51a
	No-Cover	52.42	74.65a	1.91a	5.79b
Cotton/Soybean	Cover	45.67	74.02a	1.39b	7.04a
	No-cover	55.95	82.55a	1.88a	8.31a
Mean Values					
Ct/Ct		52.38	84.85	1.91	7.86
Ct/Sg		49.52	74.81	1.78	6.64
Ct/Sy		48.81	78.28	1.63	7.68
	Cover	47.81b	79.94	1.64	7.57
	No-Cover	52.68a	78.69	1.91	6.91
Trt. Effects					
Rotation Sequence (RS)		NS	NS	NS	NS
Cover Crop (CC)		*	NS	**	NS
CC x RS		NS	*	*	*

*,** Indicates significance at $p<0.05$ and $p<0.01$ respectively.
NS Indicates nonsignificant at $p<0.05$.
\+ Mean values followed by the same letter within rotation are not significantly different at $p<0.05$.