TILLAGE PRACTICE EFFECTS EDAPHIC CONDITIONS IN PRODUCER FIELDS

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Abstract

Research was carried out at the farm level to assess edaphic, abiotic, leaf blade nutrient and color, and plant water status differences between conventionally tilled (CVT) and reduced-tilled (NT) cotton. In 1999, six farmer co-operators established both CVT and NT cotton in companion commercial fields in south Texas. Irrigation was used by one-half of the co-operators. Three sub-sampling areas within each tillage system (sub-plot) were established for access tube placement and sampling measurements. Continuous soil and air temperatures were recorded in each sub-plot between 7 June and 11 July. Results indicated that irrigated fields had lower plant canopy and soil temperatures at 5, 10 and 20 cm depths, higher soil moisture, lower water stressed leaf blades, lighter (less green) leaves, and higher N, P, Ca, and Zn leaf blade nutrient levels than did dry land cotton. No tillage fields had similar plant canopy temperatures, but cooler soil temperatures to 20 cm and less soil moisture at 25 and 50 cm depths (dryland, only) compared to CVT fields. Leaf blade diffusive resistance and Zn levels (irrigated, only) were lower in NT leaf blades than in CVT leaf blades. Lint yields were improved by NT ($P<0.24$) as was percent lint ($P<0.07$), compared to CVT fields. Lint yield was significantly correlated with leaf RWC ($r=0.71$), transpiration ($r=0.72$), and stomatal conductance ($r=0.89$). Plant stand was higher in NT fields supplied with irrigation.

Introduction

In Texas, the change from conventional to conservation tillage has been estimated to save soil losses of 1.2 t/ac/yr (Uri et al., 1998) The social benefits of conservation tillage are sometimes offset by diminished crop yields. In the case of cotton, economic returns per acre, because of reduced labor and equipment need, are usually similar or higher than those returns from conventional tillage (Keeling and Abernathy, 1993; Smart and Bradford, 1996). Additional benefits of conservation tillage include improved soil structure, increase soil biota and arthropods, cooler soil, and decreased pre-plant soil moisture loss.

In production areas where supra-optimal temperatures are prevalent, such as in south Texas, yields from reduced tilled cotton have often been the same or greater than yields of conventionally-grown cotton. Lu et al. (1998) observed that the highest yielding Pima cotton cultivars, which wee selected for such hot environments under irrigated conditions, also had the highest rates of water loss from their leaves. Thus, the availability of adequate soil moisture may be necessary for adequate plant cooling, optimum photosynthesis, and subsequent yields. McMichael and Burke (1994), growing ‘Paymaster HS26' seedlings, observed that both tap and lateral root growth was reduced by temperatures above 35 C.

Our 1999 objectives were to document both edaphic and abiotic conditions within commercial conventional and no-tilled cotton fields in order to better understand their relationships to plant water status and yield.

Materials and Methods

Six producer fields located in Cameron and Hidalgo Counties (Lat. 26^{o}) were used to establish both conventional and no-till practices. All fields had been conventionally cultivated in previous years. Cultivar, soil type and fertility, row spacing, and field equipment varied between location. However, these differences were treated as block effects in the analysis of variance. All dry land cotton was spaced on 0.91 m centers and all irrigated cotton was spaced on 0.76 m centers.

There were three sub-sampling sites with-in each treatment (six per location). Soil temperatures were measured hourly during the period 7 June to 11 July, inclusive, in each sub-plot with an Onset 4-channel data logger with thermisters located at 5, 10, and 20 cm depths and 30 cm above the soil within the plant canopy. The subsequent sampling and field measurements were made during the period 15 June to 15 July. Three plants/plot were collected in each sub-plot to determine phenological development. Soil surface temperatures were measured by an infra-red pyrometer. Soil moisture at 25, 50, and 100 cm depth was measured by neutron probe. Leaf porometry was done with a Li-Cor LI-1600 Steady State Porometer and leaf reflectance and transmittance by Minolta CR-200 and SPAD meters, respectively. Leaf measurements were made between 1000 and 14000 hrs. Leaves, which had been used for porometry and reflectance, were removed at the base of the leaf blade, placed into sealable plastic bags, and kept on ice, until leaf water potential and relative water content could be determined, which was usually within 3 hrs. of excision. The leaves used for water potential measurements were later frozen, lyophilize, ground through a 0.36 mm screen and used for chlorophyll and leaf blade nutrient analysis.

The experiment was analyzed as a split-plot design with 6 locations (blocks). Three irrigated and three dry land locations were the main plots, and tillage system was the sub-plot. Sub-samples within a tillage treatment were averaged and treated as single observations.

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Results and Discussion

Supplemental Water

Plant canopy and soil temperatures at all sampled depths were significantly warmer in the dry land than irrigated soils over the 7 June through 11 July data collection period (Table 1). Discrete measurements of leaf and soil surface temperatures were not significantly different but soil moisture was greater in irrigated than non-irrigated soils at the time of sampling.

Leaf blades of irrigated cotton plants had higher relative water content (RWC), P<0.10, lower water potential (less stress), and transpiration and diffusive resistance means, which also suggested lower leaf water stress, compared to dry land cotton (Table 2). Non-destructive measurements of leaf lightness, ‘L’, greenness, ‘a’, and SPAD readings indicated leaves of dry land cotton were darker in color, a visual marker of water stress.

Leaf blades from cotton plants grown with irrigation were higher in N, P (four-fold), Ca, and Zn, and lower in Mg, S, Na, B, and Al than corresponding conventionally-grown leaf blades (Table 3). Leaf blade nitrates levels were not effected by either irrigation or tillage. Soil nutrient differences may also reflect soil type differences between sites (blocks).

Irrigation did not statistically improve yield over dry land production (978 vs 819 kg/ha), respectively (Table 4). Stand was improved by NT management under irrigation, but not under dry land conditions (data not shown). During the period 27 Mar. through 17 Aug., some sites received considerably more rainfall than others, increasing site (block) variability and thus reducing the statistical sensitivity of the analysis.

Tillage System

Conventionally-tilled fields had higher soil temperatures compared to NT fields (Table 1). Plant canopy temperatures at 30 cm and discrete leaf temperatures were similar between tillage treatments, but soil surface temperatures and soil moisture were lower in NT fields. Moisture in the 25 to50 cm zone was more depleted in NT fields grown by CVT than in irrigated fields (data not shown). The additional water removal from the soil may have been a reflection of plant maturation, as total boll count/plant was higher in NT-dry land cotton, than in other treatment combinations (P <0.21; data not shown).

Diffusive resistance was the only leaf water status measurement which indicated CVT plants were under more stress than NT plants at the time of sampling (Table 2). Tillage treatment did not affect leaf greenness attributes. There were no major differences in leaf blade nutrients due to tillage (Table 3). Under irrigation, Zn levels in leaf blades from CVT plants were higher than in Zn from NT leaf blades.

Lint yield was improved (P=0.24) by NT over CVT (921 vs 823 kg/ha), respectively, as was percent lint (Table 4).

The ability to acquire continuous temperature measurements was an improvement over the discrete measurements made in the past (Makus and Smart, 1998). However, in 1999, untimely rains and grower operations interfered with and reduced the frequency of sampling, which had a negative effect on the analysis of the limited data acquired.

Summary

In producer’s fields, irrigation can moderate soil and air temperatures and plant water stress. Edaphic and abiotic differences between conventional and no tillage fields were modest, but lint yield were improved by 12% by first time conversion to no till.

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Table 1. Abiotic conditions in conventional(CVT) and no-till(NT) producer fields during mid-summer, 1999.[1]

	Temperature (° C)					Surface soil	Soil moisture (kg m^{-3})		
	canopy (30 cm)	soil (5 cm)	soil (10 cm)	soil (20 cm)	leaf	temp. (° C)	(25 cm)	(50 cm)	(100 cm)
Irrigation (I):									
No	29.8	29.9	29.5	29.6	36.4	41.6	160	172	223
Yes	27.9	27.3	27.1	27.6	34.2	41.6	282	340	345
	**[2]	*	**	**	NS	NS	**	**	**
Tillage (T):									
CVT	28.7	28.6	28.6	28.7	34.7	43.7	278	256	283
NT	28.6	28.1	27.6	28.1	34.8	39.5	215	256	285
	NS	0.07[3]	*	*	NS	0.07	**	NS	NS
Interaction:									
I x T		NS	NS	0.08	0.07	0.21	NS	0.06	*NS

[1] Average hourly temperature between 7 June and 11 July, inclusive. Leaf, soil surface temperatures and soil moisture were measured on plant sampling dates (see text).
[2] NS, *, ** = Not significant or significant at P> 0.05 and P> 0.01, respectively.
[3] Prob. > 'F' value.

Table 2. Effect of on-farm tillage systems on plant water status and leaf greenness.[1]

	RWC[1] (%)	Water Potential (-bars)	Transpiration (µg cm^{-2} s^{-1})	Diffusive resistance (s cm^{-1})	Reflectance values 'L'	'a'	'b'	SPAD value	Leaf chlorophyll (mg g^{-1})
Irrigation (I):									
No	73.4	-25.6	10.2	4.4	37.7	-11.2	13.7	44.0	5.2
Yes	82.5	-18.0	14.0	2.1	42.7	-17.1	24.6	34.6	4.6
	0.10[2]	*[3]	NS	NS	*	*	*	0.15	NS
Tillage (T):									
CVT	77.8	-22.0	12.2	3.2	40.4	-14.5	20.0	38.0	4.7
NT	78.2	-21.7	12.1	2.1	40.1	13.8	18.3	40.7	5.1
	NS	NS	NS	0.06	NS	NS	NS	0.20	NS
Interaction:									
I x T	NS	0.14	NS	0.13	NS	NS	NS	NS	NS

[1] RWC = Relative water content percent by weight.
[2] Prob. > 'F' value.
[3] NS, *, ** = Not significant or significant at P> 0.05 and P> 0.01, respectively.

Table 3. Plant leaf blade nutrients from producer conventional (CVT) and no-till (NT) fields, 1999. [1]

	N	P	K	Ca	Mg	S	Total Na	Fe	Mn	Zn	Cu	B	Al
				%						µg/g			
Irrigation (I):													
No	2.88	0.14	1.58	4.33	0.78	1.31	2813	90.7	90	20.2	9.6	135	237
Yes	3.88	0.52	1.50	3.34	0.52	1.01	1849	77.9	118	30.9	11.0	52	198
	**[2]	**	NS	**	*	**	0.08[3]	NS	0.13	**	0.19	**	0.07
Tillage (T):													
CVT	3.36	0.32	1.46	3.89	0.65	1.20	2123	86.8	100	26.5	10.4	94.8	222
NT	3.40	0.35	1.61	3.78	0.65	1.12	2538	81.8	108	24.7	10.2	92.4	214
	NS	NS	0.20	NS	NS	NS	0.16	NS	NS	*	NS	NS	NS
Interaction:													
I x T	NS	NS	0.25	0.07	0.17	NS	NS	0.18	NS	*	NS	NS	NS

[1] Same leaves as those sampled in Table 2. Nitrate levels (367 µg/g) were not significantly different.
[2] NS, *, ** = Not significant or significant at P=0.05 or P=0.01, respectively.
[3] Prob. > 'F' value.

Table 4. Agronomic response to conventional (CVT) and no-tillage (NT) in South Texas producer fields in 1999.

	Plant Stand (X10^4/ha)	Lint yield (kg/ha)	Lint (%)
Irrigation (I)			
No	12.3	819	39.2
Yes	13.8	978	39.2
	NS[1]	NS	NS
Tillage (T):			
CVT	12.6	823	39.2
NT	13.4	921	39.3
	NS	0.24[2]	0.07
Interaction:			
I x T	*	NS	NS

[1] NS, * = Not significant or significant at P=0.05, respectively.
[2] Prob. > 'F' value.