ON-FARM TILLAGE AND IRRIGATION PRACTICES EFFECT COTTON PLANT WATER STATUS AND SOIL ENVIRONMENT

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Abstract

Research was carried out at the farm level to assess plant water status differences between conventionally tilled and reduced-tilled cotton. Also, two non-destructive reflectance/transmittance instruments were evaluated for their correlation potential with plant water stress. In 1998, six farmer co-operators established both conventional and reduced tillage 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 were established for thermocouple and access tube placement. Fields were visited the weeks of 8 June and 29 June. Leaves of plants within the sub-sampling area were evaluated by porometry, non-destructive light measurement, and then sampled leaves/plants were returned to the lab for psychrometric and gravimetric measurements. Edaphic measurements were made at the time of sampling. Results indicate that plant water stress is reduced by both irrigation and reduced tillage. Porometric measurements consisting of leaf transpiration, stomatal conductance, diffusive resistance and leaf temperature, and leaf water potential (LWP) were correlated with light reflectance 'L' values determined non-destructively with a Minolta CR-200. Leaf relative water content was correlated with leaf greenness, 'a' values, and hue (color saturation) but not with leaf porometric values. Non-destructive Minolta SPAD readings were weakly correlated with LWP and plant canopy temperature. Irrigated plants had improved water content, leaf number and area, and yield. Crop leaf area index was greater in no-till compared to conventionally tilled cotton, but mean lint yields were statistically similar (422 vs. 348 kg/ha, respectively). Soil moisture at 25 cm was slightly higher ($P<0.14$) and mid-day surface soil temperature lower in no-till fields when compared to conventionally tilled fields.

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 needs, 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, increased soil biota and arthropods, cooler soil, and decreased pre-plant soil moisture loss.

In production areas where supa-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 that the highest yielding Pima cotton cultivars, which were 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.

Non-destructive measurement of plant leaves by light absorbing devices have been useful in estimating leaf N content in cotton (Wallace, 1997). Changes in leaf water potential, like N status, can evoke visual changes in leaves which also should be measurable by such devices. A Minolta CR-100, which measures color by reflectance, was found to be useful in separating leaf color differences in mulched (less stressed) and unmulched (stressed) okra (Makus et al., 1994).

Our 1998 objectives were to document plant water status and edaphic soil conditions in conventional and no-tilled commercial cotton fields. A second objective was to determine if measurements from non-destructive reflectance and absorbance instruments were correlated with plant water status.

Material and Methods

Six producer fields in Cameron County, Tex. (Lat. 26°) were used to establish both conventional and no-till practices on commercial farms in order to evaluate the effect of these tillage environments on plant water status, edaphic soil conditions, and agronomic performance. Some producers irrigated, others did not. With one exception, tillage in prior years was done conventionally. 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.

There were three sub-sampling sites with-in each treatment (six per location). Soil temperature was measured at depths of 5, 10, 20, and 30 cm by pre-planted thermocouples. Soil surface temperature and plant canopy temperature 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. Net radiation was recorded with a model Q-7 (Radiation & Energy Balance Systems, Seattle) at the same time soil temperatures were

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recorded. All measurements were made between 1000 and 1400 hrs. Leaves, which had been used for porometry, were removed at the base of the leaf blade, placed into sealable plastic bags and kept on ice, until leaf water potential (Campbell et al., 1966) and relative water content (Barrs and Weatherley, 1962) could be determined, which was usually within 3 hrs. of excision. The remainder of the above ground portion of the plant was used for determination of plant water content and agronomic attributes (see Table 1). Two locations were sampled each day during the weeks of 8 Jun and 29 Jun. Leaf area index (LAI) was measured on 17 Jun and 13 Jul. On 13 Jul leaves were collected for total N (Plank et al., 1992) and chlorophyll (Welburn et al., 1984) analysis and plant stand was determined.

The fourth fully expanded axial leaf was used during the first sampling week. This was changed to the third leaf during the second sampling week in order to use leaves of similar physiological maturity. An extended period of no rainfall reduced growth rates or caused a cessation of growth in plants grown under dry land conditions. The experiment was analyzed as a split-split plot design with 5 locations (blocks). Six locations were used in the correlations between leaf water status and non-destructive light measurements. Three irrigated and two dry land locations were main plots, tillage systems were sub-plots and sampling date were sub-sub plots. Sub-sampling within a tillage treatment were averaged and treated as single observations.

Results and Discussion

Supplemental Water

Irrigation improved plant fresh (not shown) and dry wts., leaf number and area, and lint yield (Table 1.). Yield components, such as numbers of bolls, blooms and squares at sampling, were numerically higher in irrigated plants. Plant stand differences ($P<0.08$) are probably due to seeding rates differences used in irrigated and non-irrigated cotton production. Plant water content was about 10% higher in irrigated plants ($P<0.18$). Only leaf number from irrigated plants increased between sampling dates (data not shown). Plant water content dropped 14% between sampling dates under dry land conditions and only 3% under irrigation (data not shown).

Irrigated plant leaves were higher in leaf water potential (less negative bars), lower in leaf diffusive resistance (DR), leaf and plant canopy temperatures, and higher in leaf stomatal conductance (CD), transpiration, leaf chlorophyll and total leaf N ($P<0.14$) than were non-irrigated cotton leaves (Table 2). There were no significant non-destructive leaf color attributes between leaves from irrigated and non-irrigated plants (Table 3).

Irrigation reduced surface soil temperature (Fig. 1). Soil moisture was higher in the upper profile of irrigated fields (Table 5).

Tillage System

Tillage had no effect on agronomic observations, but no-till improved LAI ($P<0.06$), which may reflect plant growth compensation because of potentially fewer plants/ha observed under no-till management. Leaves from no-till plants were less stressed than leaves from conventionally grown plants. Leaf RWC, transpiration rates and stomatal conductance ($P<0.06$) were higher and diffusive resistance (DR) and LWP lower in no-till plants. Leaf temperature (LT) and canopy temperature (CT) means from no-till leaves were numerically lower than conventionally-grown leaves. There were no leaf color attribute differences between leaves from either tillage system. In *Hibiscus esculentus*, okra, this approach was able to detect stress differences between leaves from mulched and unmulched plants (Makus et al., 1994).

Mean soil temperatures under conventional and no-till systems were 34.0 and 32.7 °C, respectively, at the time of sampling. A tillage X depth interaction ($P<0.07$) indicated that surface temperatures were 4.5 °C greater in conventionally managed soils compared to no-till soils, but similar at other depths. During the second sampling period, no-till soils contained slightly more water at the 25 cm depth ($P<0.14$).

Sampling Period

As the season progressed, plant water levels declined. Plant water content and leaf water attributes indicated that plants were operating under greater water stress. During the second sampling week there was increased cloud cover and somewhat lower air temperatures (data not shown). Virtually all these measurements are effected by meteorological conditions and rapid changes in cloud cover during measurements can substantially contribute to increases in experimental error. Differences in leaf color attributes between sampling weeks were probably influenced by the changes in sampling the fourth leaf vs the third leaf, leaf N status (not measured), and higher incidence of insect pressure on the cosmetic appearance of leaves over time.

Soil temperatures, particularly nearest the surface, were higher during the second sampling date (Fig. 1). Soil moisture was similar at the 25 and 50 cm depth, and highest at the 100 cm depth during the first sampling week. A sampling date X irrigation interaction (not shown) occurred for the 25 cm depth, indicating that moisture differences between irrigated and non-irrigated locations were greatest during the second sampling week. Net radiometric measurements were not significant for any main effect or interaction (data not shown).

Linear Correlations

Canopy temperature, CT, was correlated with all leaf stress responses (Table 4). Minolta 'L' values were correlated with all leaf parameters except RWC. Minolta SPAD readings were weakly correlated to LWP and CT. Leaf chlorophyll content, LC, was correlated to leaf stress responses (except RWC), CT, and 'L' values. Porometry measurements and LWP were well correlated, but RWC was correlated only to 'a' (greenness), hue angle and weakly related to CT.

Summary

In a production year characterized by high temperatures and little rainfall, irrigated cotton plants out-performed dry land-grown cotton in both lint yield and reduced plant stress. Yields from no-till and conventionally-grown cotton plants were similar, but no-till grown plants were physiologically less stressed for moisture; and soil surface temperatures in no-till fields were lower. Non-destructive leaf reflectance 'L' values were moderately correlated with leaf water stress measurements.

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Table 1. Performance of conventional and no-till cotton plants grown at two dry land and three irrigated locations.

Main effects[z]	Plant Dry wt. (g/plant)	Plant water content (%)	Leaf no	Leaf area (cm^2)	LAI	Boll no.	Bloom no.	Square no.	Plant stand (10^4/ha)	Lint yield (kg/ha)
Irrigation:										
No	17	70	10.2	61.1	---	3.0	0.3	2.5	36	227
Yes	38	77	14.8	79.2	---	6.5	1.0	4.5	28	544
	0.17[Y]	0.18	**[X]	**	-	NS	0.11		0.08	*
Tillage:										
Conventional	30	74	13.2	70.8	1.8	4.9	0.8	3.7	34	348
No-till	29	75	12.7	73.2	2.1	5.3	0.7	3.8	29	422
	NS	NS	0.16	NS	0.06	NS	NS	NS	NS	NS
Weeks of:										
8 Jun	20	78	12.3	78.9	1.6	4.0	1.0	6.0	---	---
29 Jun	34	71	13.6	65.1	2.4	6.2	0.6	1.4	---	---
	0.06	*	0.06	0.11	**	0.10	NS	*	-	-

[Z] No interactions were significant.
[Y] Probability of > 'F' value.
[X] NS, *, ** = Not significant and significant at P<0.05 or P<0.01, respectively.

Table 2. Plant stress responses of leaves of dry land and irrigated conventionally and no-till grown cotton.[z]

Main effects	RWC	LWP	TR	CD	DR	LT	CT
	Leaf water stress responses						
Irrigation:							
No	71.7	-22.5	8.8	0.55	2.61	35.6	37.8
Yes	71.9	-18.9	12.0	1.22	0.90	33.0	33.2
	NS[Y]	NS	.10[W]	*	.14	.11	.10
Tillage:							
Conventional	70.6	-21.2	9.6	0.83	1.99	34.2	35.8
No-till	73.0	-19.5	11.9	1.08	1.18	33.9	34.3
	*	*	*	.06	*	NS	NS
Sampling week:							
8 Jun	70.4	-18.2	12.2	1.06	1.35	34.1	34.5
29 Jun	73.1	-22.5	9.3	0.86	1.82	34.0	34.7
	.06	*	**	NS	*	NS	NS

[Z] Abbreviations: RWC= Relative water content (%); LWP= leaf water potential (- bars); TR= transpiration ($\mu g/cm^2/s$); CD= stomatal conductance (cm/s); DR= diffusive resistance (s/cm); LT= leaf temperature (°C); CT= canopy temperature (°C).
[Y] NS, *, ** = Not significant, or significant at P<0.05 and P<0.01, respectively.
[W] Probability > 'F' value.

Table 3. Non-destructive light measurements of leaves of dry land and irrigated conventionally and no-till grown cotton.[z]

	Leaf color attributes						
Main effects	SPAD	L	a	b	Hue	Chroma	LC
Irrigation:							
No	43.4	40.4	13.3	16.3	.828	21.0	3.1
Yes	39.2	38.9	14.2	18.1	.790	23.1	4.7
	NS[Y]	NS	NS	NS	NS	NS	*
Tillage:							
Conventional	41.2	39.7	13.8	17.9	.768	22.6	5.3
No-till	40.5	39.1	14.1	17.1	.837	22.2	5.2
	NS	NS	NS	NS	.07[W]	NS	NS
Sampling week:							
8 Jun	41.4	38.3	12.0	14.8	.815	19.1	-
29 Jun	40.4	40.2	15.5	19.6	.793	25.0	-
	NS	**	**	**	NS	*	-

[Z] Abbreviations: SPAD= Minolta SPAD reading (relative value); L, a, b= color readings of lightness, greenness and yellowness, respectively; HUE angle= arc tan(b/a); Chroma= $(a^2+b^2)^{½}$; LC= leaf chlorophyll (mg/g dry wt).

[Y] NS, *, ** = Not significant, or significant at P<0.05 and P<0.01, respectively.

[W] Probability > 'F' value.

Table 4. Simple linear correlations between leaf water status and non-destructive leaf color attributes.[z]

	RWC	LWP	DR	CD	TR	LT	CT	SPAD	L	a	b	Hue	Chroma	LC
RWC	-	-	-	-	-	-	$-.35^{.09}$	-	-	-.46″	$-.70^{*}$	-	-	-
LWP		-	$-.66^{**}$	$.52^{**}$	$.70^{**}$	$-.52^{**}$	$-.52^{**}$	$-.38^{*}$	$-.76^{*}$	-	-	-	-	$.80^{**}$
DR			-	$-.79^{**}$	$-.79^{**}$	$.79^{**}$	$.62^{**}$	-	$.61^{**}$	-	-	-	-	$-.72^{*}$
CD				-	$.79^{**}$	$-.82^{**}$	$-.64^{**}$	-	$-.62^{**}$	-	-	-	-	$.87^{**}$
TR					-	$-.52^{**}$	$-.54^{**}$	-	$-.58^{**}$	-	-	-	-	$.72^{*}$
LT						-	$.64^{**}$	-	$.55^{**}$	-	-	-	-	$-.91^{**}$
CT							-	$.46^{*}$	-	-	-	-	-	$-.82^{**}$
SPAD								-	-	$.65^{**}$	$-.73^{**}$	-	$-.72^{*}$	-
L									-	-	$.43^{*}$	-	-	$.80^{**}$
a										-	$-.93^{**}$	-	$.97^{**}$	-
b											-	$.79^{**}$	$.99^{**}$	-
Hue												-	$.72^{**}$	-
Chroma													-	-
LC														-

Abbreviations: RWC= Relative water content (%); LWP= leaf water potential (- bars); TR= transpiration ($\mu g/cm^2/s$); CD= stomatal conductance (cm/s); DR= diffusive resistance (s/cm); LT= leaf temperature(°C); CT= canopy temperature (°C); SPAD= Minolta SPAD reading (relative value); L, a, b= color readings of lightness, greenness and yellowness, respectively; HUE angle= arc tan(b/a); Chroma= $(a^2+b^2)^{1/2}$; LC= leaf chlorophyll (mg/g dry wt).

Table 5. Effect of irrigation, tillage system and date on soil moisture (kg/m^3).

	Depth (cm)		
	25	50	100
Irrigation (I):			
No	1.62	4.43	5.28
Yes	2.66	4.54	4.54
	**[Z]	NS	NS
Tillage (T):			
Conventional	2.09	4.34	4.71
No-till	2.41	4.66	4.96
	0.14[Y]	NS	NS
Sampling week (W):			
8 Jun	2.20	4.50	4.97
29 Jun	2.30	4.50	4.69
	NS	NS	*
Interactions:			
I X T	NS	NS	NS
I x W	*	NS	NS
I x T x W	NS	NS	NS

[Z] NS, *, ** = Not significant, or significant at P<0.05 and P<0.01, respectively.

[Y] Probability > 'F' value.

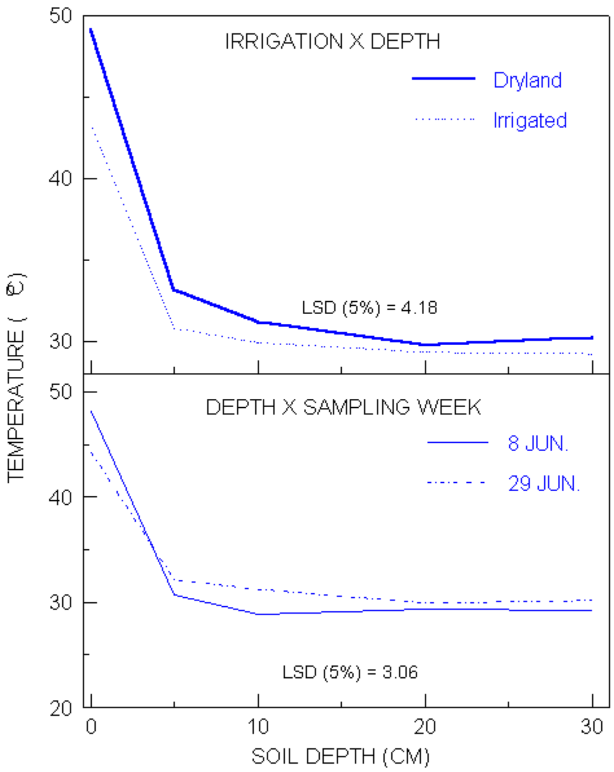

Figure 1. Effect of irrigation and season on soil temperature profile.