RELATIONSHIPS BETWEEN COTTON LINT YIELD, FIBER QUALITY, AND SOIL APPARENT ELECTRICAL CONDUCTIVITY

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Abstract

A two year research (2006 and 2007) was conducted to quantify the relationships between lint yield, fiber quality and soil apparent electrical conductivity (ECa) in four cotton fields in Texas. Soil ECa surveys were implemented with an electromagnetic induction sensor (EM38DD). Cotton lint yield was determined by weighing hand harvested cotton samples from known-size sampling locations (4 m^2) in 2006, and a cotton yield monitor in 2007. Simple linear and quadratic regressions were applied to explore the relationships between these variables. Lint yield consistently showed quadratic relationships with soil ECa (adjusted R^2 ranging from 0.10 to 0.63), with highest yield at the mid ECa range. In three of the four fields, micronaire was significantly correlated with soil ECa (adjusted R^2 ranging from 0.25 to 0.38). However, the different micronaire-ECa relationships indicated distinct cotton responses to varying growing conditions in each field. Fiber length and strength were correlated with ECa for two fields in 2006 (adjusted R^2 of 0.49 and 0.45 for length, and 0.26 and 0.68 for strength), but not for the other two fields in 2007. Because soil ECa is highly correlated with soil textures and water hold capability in these fields, these relationships reflected the importance of soil texture and water content to cotton growth. It is concluded that soil ECa maps could be a useful tool to develop site specific management strategies for both lint yield and fiber quality in cotton production.

Introduction

Successful application of precision agriculture relies heavily on farmers' ability to (1) capture the within-field variability of relevant field factors (such as topography, soil nutrients, available water, pest occurrence, etc) quickly and cost-effectively, and (2) understand the cause-effect relationships between crop performances (such as yields) and these important field factors. Soil apparent electrical conductivity (ECa) survey has been proposed as an effective method for capturing in-field variation of soils; and soil ECa has been found correlated with many soil properties (such as clay content, available water, etc) and crop yield (Corwin and Lesch, 2005; Lund et al., 2000; Kitchen et al., 2003). For cotton producers, their profitability is determined by not only lint yield but also fiber quality. In addition to lint yield, numerous studies have studied the spatial variation of different fiber quality parameters, and related them to various field factors such as soil properties (Elms et al., 2001; Ping et al., 2004; Ge et al., 2008). The objective of this study is to quantify the relationships between both cotton lint yield and fiber quality and soil ECa.

Materials and Methods

The field study was conducted in four cotton fields at Texas A&M University's research farm near College Station, Texas over two years. The fields in 2006 were identified as IMPACT-D1, and IMPACT-I3; and in 2007 IMPACT-I1 and Riverside field. Dominant soil types in these fields including a Belk Clay, a Ships Clay, a Weswood Silty Loam, and a Weswood Silty Clay Loam. Cotton variety DPL 455 BG/RR was planted in these fields. Important field factors including field size, water regime, seeding rate, row space, plant date, and defoliation date for each field are summarized in table 1. All other field management practices including field preparation, fertilization, and chemical applications (herbicides and pesticides, growth regulators, and defoliants) followed the recommendations made by the Texas AgriLife Extension Service. Weather data were available from the USDA-ARS Minilab Weather Station located at the IMPACT field laboratory and monthly precipitation during each growth season (from Apr. to Sep.) is given in figure 1.

The soil ECa surveys were implemented with an EM38DD sensor along with a survey grade GPS and a data logger.

For cotton yield and fiber quality determination, sampling sites were laid out in each field by means of either grid sampling or stratified random sampling. Lint yield was determined by weighing hand harvested cotton from ~4 m^2 area at each sampling site in 2006. In 2007, lint yield was determined by a cotton yield monitor after proper calibration and data cleaning. Around 1.0 lb of seed cotton was also hand harvested from each sampling site, ginned with a laboratory scale saw gin, and analyzed with the High Volume Instrument for fiber quality parameters (micronaire, length, and strength).

Regression analysis was applied to quantify the relationships between lint yield and soil ECa and the HVI fiber quality parameters and ECa. Simple linear models were first attempted and then quadratic models (by adding a quadratic term in regression) were attempted. In the cases where both linear and quadratic models were significant for a variable, ANOVA was implemented to test the reduced model (linear) against the full model (quadratic). The full model was selected only when the partial F-statistic (additional mean sum of squares accounted for by the quadratic term divided by the residual mean sum of squares) was significant at the 0.05 level.

Table 1. Selected agronomic factors in the study fields.

Field	Size (ha)	Water Regime	Seeding Rate (ha^{-1})	Row Space (m)	Plant Date	Defoliation Date
2006-IMPACT-D1	11	Dryland	128 000	0.76	Apr. 04th	Aug. 1st
2006-IMPACT-I3	20	Irrigated	123 500	0.76	Apr. 04th	Aug. 1st
2007-IMPACT-I1	25	Irrigated	123 500	0.76	Apr. 10th	Sep. 20th
2007-Riverside	12	Dryland	98 800	1.02	Apr. 23rd	Sep. 20th

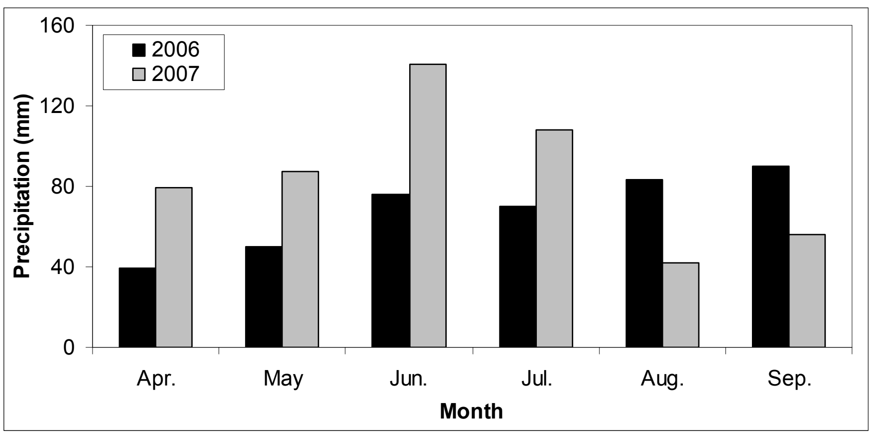

Figure 1. Monthly precipitation during the growing seasons of 2006 and 2007.

Results and Discussion

Table 2 gives the descriptive statistics (mean, standard deviation, and CV) of lint yield and HVI fiber quality parameters in the study fields. The average lint yield in 2007-Riverside was much higher than 2006-IMPACT-I3, partly due to the ample amount of rainfall in 2007. The low average lint yield in 2007-IMPACT-I1 could be attributed to waterlogging in some areas of the field. Ample precipitation also resulted in higher average micronaire and fiber strength in 2007 than 2006. Comparing to fiber quality, lint yield had the highest level of spatial variation in all fields, with CV ranging from 16% to 27%. For three HVI fiber quality parameters, micronaire consistently showed higher spatial variation than fiber length and strength. These findings are in agreement with other studies in the literature (Elms et al., 2001; Johnson et al., 2002; Ping et al., 2004). Comparing to lint yield, cotton fiber quality is largely determined by its genetic traits and therefore can be modified by field factors to a less degree than lint yield (Bradow and Davidonis, 2000; Johnson et al., 2002). Micronaire, which relates to fiber maturity (or fiber wall thickening) within a cotton variety (the same fiber fineness or fiber cross section diameter), are more prone to be modified by the growing environment than other intrinsic fiber quality parameters such as length and strength.

Table 2. Descriptive statistics of lint yield and fiber quality parameters in the study fields.§

Study Field	Statistics	Lint Yield (kg ha^{-1})	Micronaire	Length (mm)	Strength (g tex^{-1})
2006-IMPACT-D1	Mean	N/A	3.60	28.17	28.10
	STD	N/A	0.31	1.53	1.36
	CV (%)	N/A	8.5	5.4	4.8
2006-IMPACT-I3	Mean	1200	3.76	29.79	28.68
	STD	272	0.44	1.14	1.91
	CV (%)	23	12	3.8	6.7
2007-IMPACT-I1	Mean	1103	3.99	29.34	29.49
	STD	302	0.27	0.67	1.29
	CV (%)	27	6.7	2.3	4.4
2007-Riverside	Mean	1890	4.65	28.89	29.62
	STD	305	0.24	0.68	1.33
	CV (%)	16	5.1	2.3	4.5

§ The lint yield information in the 2006-IMPACT-D1 field was not available.

The relationships between lint yield and soil ECa are summarized in table 3. For all three fields (the yield information was not available in 2006-IMPACT-D1), lint yield was significantly correlated with soil ECa, with adjusted R^2 ranging from 0.10 to 0.63. Lint yield consistently exhibited quadratic relationships with soil ECa, with highest yield achieved at the mid range of ECa. These are in agreement with some early studies that documented the same relationships between crop yield and ECa (Lund et al., 2000; Kitchen et al., 2003). They further proposed that such a yield-ECa relationship where yield peaks at the mid-ECa range was due to an optimal balance of soil ECa and hydraulic conductivity.

Table 3. Relationship between cotton lint yield and soil ECa in the study fields.§

Study Field	Relationship	Adjusted R^2	*F*-statistic (significance level)
2006-IMPACT-D1	N/A	N/A	N/A
2006-IMPACT-I3	$Y = -0.34\,X^2 + 54.01\,X - 632.9$	0.62	10.13 ($p < 0.01$)
2007-IMPACT-I1	$Y = -0.35\,X^2 + 35.82\,X - 432.1$	0.63	12 420 ($p < 0.001$)
2007-Riverside	$Y = -0.567\,X^2 + 107.6\,X - 3115$	0.10	390 ($p < 0.001$)

§ Lint yield in 2006-IMPACT-I3 was determined from hand harvest samples; and in 2007-IMPACT-I1 and 2007-Riverside was determined from cotton yield monitor data. Lint yield data in 2006-IMPACT-D1 was not available. Y is lint yield (in kg ha^{-1}) and X is ECa (in mS s^{-1}).

The relationships between micronaire and soil ECa are given in table 4. As mentioned early, micronaire (again, reflecting fiber maturity in the same variety) is more prone to be influenced by agronomic and environmental factors in the fields. In 2006-IMPACT-D1, micronaire showed a quadratic relationship with soil ECa. Both high and low soil ECa resulted in high micronaire values and mid ECa resulted in low micronaire. Because of the scarcity of rainfall in 2006 from Apr. to Jul., cotton plants in the low ECa zone (light soil with very little plant available water) experienced severe water drought throughout the growing season. This resulted in small plant framework (due to stunted vegetative growth) and boll retention only at the inner and lower fruit sites (due to excessive square and boll abscission). This greatly reduced the plant water requirements at the late season to bring the remaining bolls into full maturation. This helps to explain the negative relationship between micronaire and ECa at the lower ECa range.

It is interesting that an inverted quadratic relationship between micronaire and soil ECa was shown in 2007-Riverside. Due to the ample amount of rainfall in the early season of 2007 (May to Jul.), cotton in the high ECa regions developed larger vegetative framework and maintain a higher portion of bolls at outer and higher fruit sites than that in the low and mid ECa regions. Toward the end of season (Aug. and Sep.) when cotton was going through boll maturation and fiber wall thickening, inadequate rainfall and therefore plant available water was able to carry only bolls at lower and inner fruit sites to full maturation. A substantial portion of bolls at higher and outer fruit sites either failed to open or were far less mature, lowering the overall micronaire value at the high ECa region. This helps to explain the negative relationship between micronaire and ECa at higher ECa range under ample soil moisture conditions.

Table 4. Relationship between cotton fiber quality and soil ECa in the study fields.§

Study Field	Relationship	Adjusted R^2	F-statistic (significance level)
	Micronaire		
2006-IMPACT-D1	$Y = 0.00067\,X^2 - 0.091\,X + 6.59$	0.32	16.46 ($p < 0.001$)
2006-IMPACT-I3	No relationship		
2007-IMPACT-I1	$Y = 0.0085\,X + 3.42$	0.38	10.02 ($p < 0.01$)
2007-Riverside	$Y = -0.00082\,X^2 + 0.148\,X - 1.93$	0.25	8.71 ($p < 0.001$)
	Length (mm)		
2006-IMPACT-D1	$Y = 0.078\,X + 22.66$	0.49	63.05 ($p < 0.001$)
2006-IMPACT-I3	$Y = 0.027\,X + 27.94$	0.45	10.03 ($p < 0.05$)
2007-IMPACT-I1	No relationship		
2007-Riverside	No relationship		
	Strength (g tex^{-1})		
2006-IMPACT-D1	$Y = 0.051\,X + 24.48$	0.26	23.98 ($p < 0.001$)
2006-IMPACT-I3	$Y = -0.0021\,X^2 + 0.34\,X + 16.59$	0.68	12.64 ($p < 0.01$)
2007-IMPACT-I1	No relationship		
2007-Riverside	No relationship		

§ Y is fiber quality parameters (micronaire, length, and strength) and X is ECa.

The relationships between fiber length and strength and soil ECa are also given in table 4. For both fiber quality parameters, significant relationships were observed in 2006 but not in 2007. The literature points out that the soil-crop relationships are most evident when soil properties under investigation are true crop growth limiting factors. Because of the limited amount of rainfall in the early season of 2006 (especially in the boll enlargement or fiber elongation stage), soil moisture content (and thus soil textures and ECa) became a critical limiting factor for fiber elongation, which manifested the positive relationship between fiber length and ECa. On the other hand, ample rainfall in 2007 made soil moisture content (thus soil textures and ECa) a much less limiting factor for fiber elongation. Therefore the relationships between the two appeared to be random.

Summary

A two-year field study was conducted to quantify the relationship between cotton lint yield and fiber quality and soil ECa. The major conclusions can be drawn from this study are as follows.

- Lint yield and fiber quality parameters showed various degrees of spatial variation: lint yield > micronaire > fiber length and strength.
- ECa explained 10% to 67% of the variation in lint yield. The relationship between the two was consistently quadratic, with medium ECa indicating highest lint yield.
- Micronaire had significant relationships with ECa in three of the four fields. However, the relationships were not consistent. These reflected cotton's varying physiological responses to different growing environments.
- Significant relationships were found in 2006 between fiber length and ECa and fiber strength and ECa. In 2007, no significant relationship was observed between these variables. This might be caused by the ample rainfall in 2007 that made plant available water a less limiting factor for length and strength than in 2006.

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