COTTON YIELD VARIABILITY AND CORRELATIONS BETWEEN YIELD, PREVIOUS YIELD, AND SOIL PROPERTIES

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Abstract

Precision agriculture technologies are providing an opportunity to manage fields as separate units instead of one management unit. These technologies are valuable because soil and crop parameters often vary spatially and temporally within a field. However, relatively little spatial and temporal variability data are available for cotton. This experiment was conducted to study variability of an irrigated cotton field. At 57 points (0.23 acre grid size) within a field, cotton yield and quality parameters and soil properties were determined. Yield was more variable than were other plant parameters, but was correlated to yield in the previous season. The number of fruiting sites per plant and fiber length were also correlated to their values in the previous season. Nitrate and zinc had the highest spatial variability of the soil parameters measured, and the soil parameters with the lowest variability were sand percentage, organic matter percentage, pH, potassium, and copper. Preliminary correlation analyses for relationships between soil and plant parameters showed relatively few significant relationships.

Introduction

Typically, variations occur within a field even though climate, cultural practices and timing of irrigation (if any) are uniform (Warrick and Gardner,1983). Previous work from this laboratory has shown 4-fold variability in yield of irrigated cotton (Elms et al, 1997). Precision agriculture techniques give producers the ability to assess and potentially manage these variations. Variability can occur in both time and space (Lark and Stafford, 1996). Spatial variability has received relatively more attention than has temporal variability. To effectively manage variability in production fields, a measure of the temporal variability in crop production is desirable.

Objectives

The objectives of this study were to evaluate spatial and temporal variability of cotton parameters within an irrigated cotton field. The cotton parameters evaluated were cotton yield, production of fruiting sites, fruit retention, length, strength, and micronaire. These parameters were also correlated to soil test parameters.

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Material and Methods

This study was conducted at the Erskine Research Farm at Lubbock, TX. The 13 acre field was irrigated by a center pivot LEPA system. The soils at this site included Amarillo fine sandy loam and Acuff fine sandy loam.
Cotton (HS-26) was planted at an approximate seeding rate of 65,000 seeds/acre. Fertilizer was applied at a uniform rate over the entire field: 120 pounds of nitrogen per acre, 26 pounds of phosphorus per acre, and 0.5 pounds of zinc per acre. The site received approximately 19 inches of rain between January 1 and October 31, 1997. Approximately 8 inches of irrigation was applied during the growing season.

A grid system was established on 100-foot intervals; each grid cell was approximately 0.23 acres in area. (Figure 1). A total of 70 grid points were established; 57 of the points were located inside the irrigated portion of the field, and 13 of the points were located outside of the irrigated portion of the field (Figure1). The center pivot irrigation system is denoted by the circular outline in Figure 1. Due to physical limitations, the top portion of the field was not irrigated. The sampling locations were at the center of each grid cell. Only samples taken from within the irrigated region of the field were discussed in this paper.

Soil samples were taken at the center of each grid cell on January 12, 1997. Within each grid cell, nine samples were collected from 0 to 6 inches and from 6-12 inches. At each depth, the 9 samples were composited, and a subsample was analyzed by a commercial soil testing laboratory. The soil samples were analyzed for texture, organic matter, nitrate-nitrogen, phosphorous (Bray P-1 and Olsen bicarbonate), potassium, calcium, pH, cation exchange capacity, zinc, manganese, iron, and copper. For the purpose of this paper, soil data were averaged over depth.

Yield data were collected at each grid point by harvesting all bolls within an area of 52 inches by 3 rows; a harvested area was centered onto each grid point. The harvested bolls were ginned in a plot gin. A sub-sample of lint from each yield sample was sent to the International Textile Center in Lubbock, TX for determination of length, strength, and micronaire.

Eight plants were collected immediately adjacent to the harvest area for determination of production of fruiting sites and fruit retention (Landivar and Benedict, 1996).

To evaluate temporal changes in values of plant parameters from 1996 to 1997, percentage change was calculated. The percentage change in value of a given plant parameter was calculated by subtracting the value for 1996 from the value from 1997; this difference was then expressed as a percentage of the value for 1996. A positive percentage change denotes an increase in the value in 1997, and a negative percentage change denotes a decrease in the value in 1997.

To reduce to potential differences due to usage of different gins in 1996 (Elms et al., 1997) and 1997, relative yields were used to compare yield data from 1996 and 1997. Relative yields were calculated by dividing yield at each grid point by the highest yield observed in a given year.

Statistical analyses were performed by using the appropriate procedure from SAS statistical package (SAS Institute, Inc., 1989). Spatial variability maps were developed by using bi-cubic spline interpolation to a 10= pixel; this was accomplished with Spyglass Transform software (Fortner Research LLC, Sterling VA).

Results

Summary statistics for soil parameters measured in this study are shown in Table 1. Soil parameters with the highest variability (highest coefficient of variation, CV) include nitrate and zinc. Soil parameters with the lowest variability include sand percentage, organic matter percentage, pH, potassium, and copper.

Lint yield ranged from 242 pounds/acre to 1101 pounds/acre (Figure 2). Lint yield was highly variable as indicated by a CV of 20% (Figure 2). The spatial variability of lint yield is shown in Figure 3. The lower yields are clearly shown in the points following outside of the irrigated region. Percentage change in lint yield for each grid cell in the irrigated part of the field from 1996 to 1997 is shown in Table 2 and Figure 4. Lint yield in 1997 was significantly correlated with lint yield in 1996 (Figure 4). This suggests that within the field studied and the time scale studied here, yield relationships are generally conserved in time.

The correlations between soil properties measured in this study and lint yield are shown in Table 3. Yield was positively correlated with calcium concentration, cation exchange capacity, and pH. Yield was negatively correlated with nitrate concentration. This observation could be explained by greater nitrogen uptake (lower nitrogen remaining in the soil) at the higher yielding areas.

The number of fruiting sites per plant ranged from 15 to 37 (Figure 5). The number of fruiting sites per plant was highly variable as indicated by a high CV of 20%. The spatial variability of the number of fruiting sites per plant is shown in Figure 6. Percentage change in number of fruiting sites per plant for each grid cell in the irrigated part of the field from 1996 to 1997 is shown in Table 2 and Figure 7. Number of fruiting sites per plant in 1997 was significantly correlated with number of fruiting sites per plant in 1996 (Figure 7).

The correlations between soil properties measured in this study and number of fruiting sites are shown in Table 3. The average number of fruiting sites was positively correlated with calcium concentration, cation exchange capacity, and zinc concentration. The average number of fruiting sites was negatively correlated with iron and copper concentrations.

Fruit retention ranged from 15.2% to 33.3% (Figure 8). Percentage fruit retention was highly variable as indicated by a high CV of 19.3%. The spatial variability of percentage fruit retention is shown in Figure 9. Percentage change in fruit retention for each grid cell in the irrigated part of the field from 1996 to 1997 is shown in Table 2 and Figure 10. Percentage fruit retention in 1997 was not significantly correlated with percentage fruit retention in 1996 (Figure 10).

The correlations between soil properties measured in this study and percentage fruit retention are shown in Table 3. Percentage fruit retention was not significantly correlated with any soil property measured in this study.

Fiber length ranged from 1.01 to 1.16 inches (Figure 11). Fiber length had low variability as indicated by a low CV of 2.3%. The spatial variability of fiber length is shown in Figure 12. Percentage change in fiber length for each grid cell in the irrigated part of the field from 1996 to 1997 is shown in Table 2 and Figure 13. Fiber length in 1997 was significantly correlated with fiber length in 1996 (Figure 13).

The correlations between soil properties measured in this study and fiber length are shown in Table 3. Fiber length was negatively correlated with Bray P-1 phosphorous concentration.

Fiber strength ranged from 27.9 to 35.3 gm/tex (Figure 14). Fiber strength had low variability as indicated by a low CV of 3.9%. The spatial variability of fiber strength is shown in Figure 15. Percentage change in fiber strength for each grid cell in the irrigated part of the field from 1996 to 1997 is shown in Table 2 and Figure 16. Fiber strength in 1997 was not significantly correlated with fiber strength in 1996 (Figure 16).

The correlations between soil properties measured in this study and fiber strength are shown in Table 3. Fiber strength was not significantly correlated with any soil property measured in this study.

Micronaire ranged from 3.9 to 5.1 (Figure 17). Micronaire had low variability as indicated by a low CV of 4.5%. The spatial variability of micronaire is shown in Figure 18. Percentage change in micronaire for each grid cell in the irrigated part of the field from 1996 to 1997 is shown in Table 2 and Figure 19. Micronaire in 1997 was not significantly correlated with micronaire in 1996 (Figure 19).

The correlations between soil properties measured in this study and micronaire are shown in Table 3. Micronaire was positively correlated to soil pH.

Summary

The cotton parameters measured in this study varied within the 13 acre field. The plant parameter with the highest spatial variability was yield, and the plant parameters with the lowest spatial variability were length and strength. The soil parameters with the highest spatial variability were nitrate and zinc, and the soil paramters with the lowest variability were sand percentage, organic matter percentage, pH, potassium, and copper. Preliminary correlation analyses for temporal relationships showed that yield, number of fruiting sites per plant, and fiber length values in 1997 were significantly correlated to their respective values in 1996. Preliminary correlation analyses for relationships between soil and plant parameters showed relatively few significant relationships.

More rigorous statistical analyses are being conducted to further establish relationships between spatial and temporal relationships of soil and plant parameters.

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Table 1. Summary statistics for soil parameters measured in this study

Sand (%)	72	65	76	2.2	3
Silt (%)	12	8	19	2.9	24.2
Clay (%)	16	9	21	2.7	16.8
Organic matter	1	0.9	1.2	0.1	7.1
Nitrate-N (ppm)	18	6	51	9.8	54.4
Bray P-1	41	25	69	9.5	23.2
Olsen bicarbonate	5	3	8	1.1	23.3
Potassium (ppm)	349	289	439	34.1	9.8
Calcium (ppm)	986	660	2105	257	26.1
Soil pH	8	7.6	8.4	0.2	2.3
Cation exchange	12.5	10.8	18.3	1.3	10.5
Zinc (ppm)	0.8	0.4	2.2	0.4	50.9
Manganese (ppm)	13.6	9.5	21	2.3	16.7
Iron (ppm)	7.4	4	11	1.5	19.9
Copper (ppm)	0.8	0.7	0.9	0	6.2

[1]Standard deviation
[2]Coefficient of variation

Table 2. Summary of percent change from 1996 to 1997 of selected plant parameters.*

Plant parameter	Average	Minimum	Maximum	S.D.[1]	C.V.[2]
Yield[3]	9.2	-44.7	108	27.2	297
Fruiting sites	-6.2	-41.6	51.9	22.9	367
Fruit retention(%)	-17.8	-58.0	68.9	24.1	136
Length	0.5	-8.6	10.5	3.8	738
Strength	5.7	-6.6	16.8	5.4	95
Micronaire	-6.5	-25.0	25.6	11.4	176

*1996 data can be found in Elms et al., 1997
[1]Standard deviation
[2]Coefficient of variation, number in table is absolute value of actual value.
[3]Relative yield calculation as described in text.

Table 3. Pearson correlation coefficients for plant and soil parameters[1]

Plant Parameter	Nitrate-N	Phosphorous[2]	Calcium	CEC	pH	Zinc	Iron	Copper
Yield	-0.40**	Ns	0.28*	0.26*	0.32*	ns	ns	ns
Fruiting sites	ns	ns	0.27*	0.26*	ns	0.31*	-0.34*	0.87***
Fruit retention(%)	ns	ns	ns	ns	ns	ns	ns	ns
Length	ns	-0.28*	ns	ns	ns	ns	ns	ns
Strength	ns	ns	ns	ns	ns	ns	ns	ns
Micronaire	ns	ns	ns	ns	0.42***	ns	ns	ns

*,**,***Significant at the 0.05, 0.01, and 0.001 levels respectively.
[1]Soil parameters measured in this study but not included in this table were not significantly correlated with any plant parameter.
[2]Bray P-1 Phosphorous

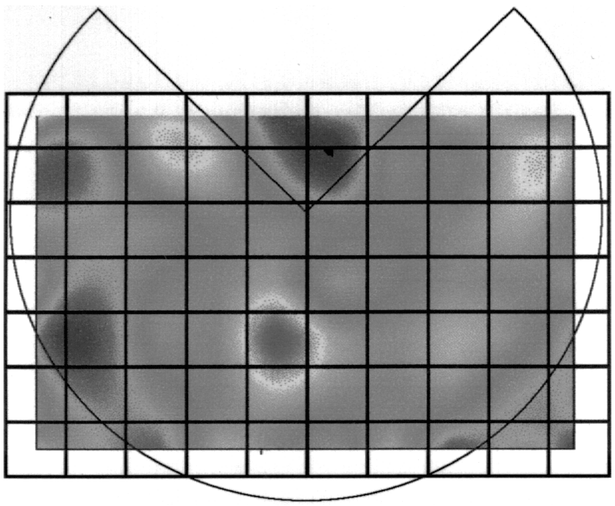


Figure 1. Map of field site showing grid system and outline of irrigation system.

Figure 2. Normalized histogram and summary statistics for yield data obtained at 57 grid points within an irrigated field.

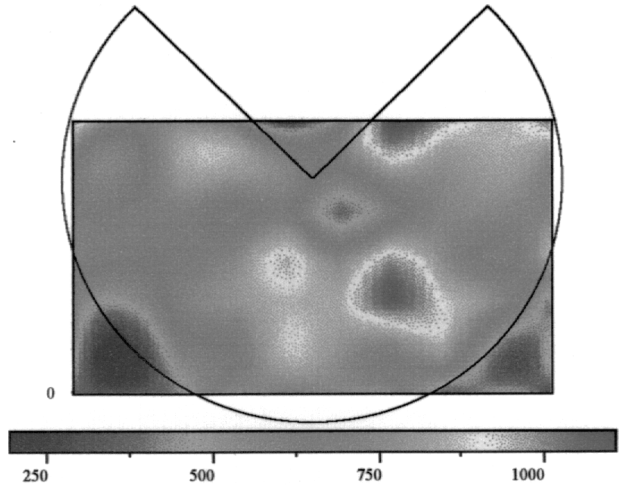
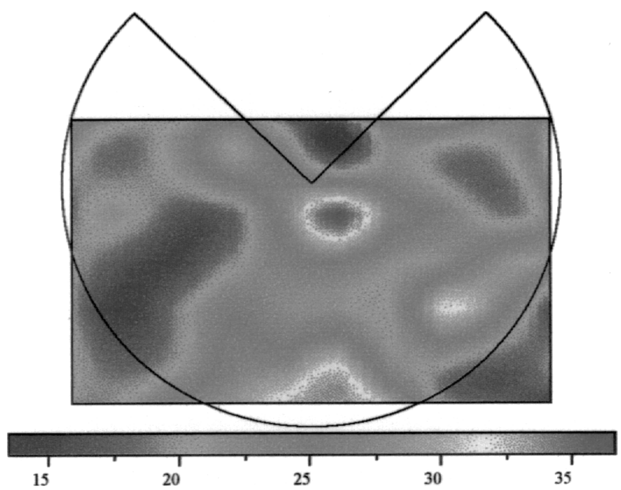


Figure 3. Spatial variability map for yield obtained at 70 grid points within a cotton field.

Figure 4. Change in relative yield and results of correlation for two growing seasons.

Figure 5. Normalized histogram and summary statistics for average number of fruiting sites per plant obtained at 57 grid points within an irrigated cotton field.

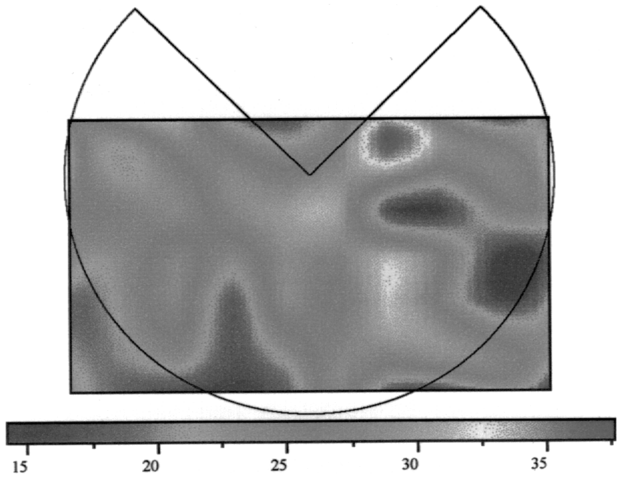


Fruiting sites (number/plant)

Figure 6. Spatial variability map for fruiting sites obtained at 70 grid points within a cotton field.

Figure 7. Change in number of fruiting sites and results of correlation analysis for two growing seasons.

Figure 8. Normalized histogram and summary statistics for fruit retention percentage obtained at 57 grid points within an irrigated cotton field.



Fruit retention (%)

Figure 9. Spatial variability for fruit retention percentage obtained at 70 grid points within a cotton field.

Figure 10. Change in fruit etention percentage and results of correlation analysis for two growing seasons.