Factors Affecting Yield Variability in Irrigated Cotton

J. Ping and C. J. Green
Texas Tech University
Lubbock, TX

Abstract

Precision agriculture provides an opportunity to increase production efficiency. However, successful application of precision agriculture management practices will depend on the understanding of spatial variability of yield and factors that influence yield variability. The objectives of this study were to evaluate spatial variability of cotton yield, yield components, and soil parameters and their relationships in irrigated cotton fields. This research was conducted on two irrigated cotton fields near Lubbock, Texas. Soil was sampled on 2.5 acres grid system. Cotton lint yields and yield components were determined on a 0.001-acre area near each soil sampling point. The variation of soil and cotton parameters was processed with classical statistics and geostatistics. Lint yield averaged 796 lb/a and had a CV of 0.18 in Field 1. Lint yield averaged 996 lb/a and had a CV of 0.15 in Field 2. Cotton lint yield was positively correlated to boll number, boll per plant, and lint per boll in both fields. Except potassium saturation in Field 1, there were no strong correlations between lint yield and soil nutrients in the 0 – 6" layer since most nutrients were above their critical values in both fields.

Introduction

The development of geographic information systems (GIS), global positioning systems (GPS), remote sensing, yield monitor equipment, and variable rate technology provide effective tools for precision agriculture. The successful application of precision agriculture management practices will depend on the understanding of spatial variability of yield and factors that influence yield variability.

Crop yield is affected by many factors (Sudduth et al, 1996). Previous studies have shown that cotton lint yield, fiber quality, and some soil properties are spatially correlated (Johnson et al., 1999). Elms et al. (1998) reported relatively high variability in lint yield, soil nitrate, and zinc contents, and lower variability in fiber length, strength, soil texture, pH, potassium, and copper. Furthermore, sand and clay distribution can affect yield pattern (Ping and Green, 1999). Understanding relationships between yield and soil spatial variability across different weather patterns could explain changes in spatial variability of yield and related parameters over time. The objective of this study was to evaluate spatial variability of cotton yield, yield components, and soil parameters and their relationships in irrigated cotton fields.

Reprinted from the *Proceedings of the Beltwide Cotton Conference*
Volume 2:1404-1407 (2000)
National Cotton Council, Memphis TN

Materials and Methods

This research was conducted on two irrigated cotton fields near Lubbock, Texas during 1999. Field 1 contained three soil types-Acuff loam (Fine-loamy, mixed, thermic Aridic Paleustalfs), Amarillo fine sandy loam (Fine-loamy, mixed, thermic Aridic Paleustalfs) and Olton clay loam (Fine-loamy, mixed, thermic Aridic Paleustolls). Field 2 contained only Amarillo fine sandy loam (Fine-loamy, mixed, thermic Aridic Paleustalfs). Both fields had center pivot LEPA systems.

PayMaster-200 was planted on May 13 1999 at approximately 63000 plants/acre in Field 1. Row spacing was 32 inches. This field was fertilized with 90 lb of nitrogen and 45 lb of phosphorous per acre. Six and half inches of irrigation were applied from July 6 through August 20 1999.

DPL-2379 was planted on May 12 1999 at approximately 70000 plants/acre in Field 2. Row spacing was 31.5 inches. This field was fertilized with 85 lb of nitrogen, 40 lb of phosphorous, 12 lb of sulfur, and 2 lb of zinc per acre. Seven inches of irrigation were applied June 20 through August 27 1999.

A grid system of 2.5 acres (330 by 330 feet) was the basic unit for soil sampling. Cross points were taken at the center from four neighboring regular points (Figure 1 and 2). Sampling positions were georeferenced by means of DGPS. On June 2 and July 5, soil samples were collected by compositing three samples within the center of each grid at depths of 0 - 6", 6 - 12", 12 - 24". The soil water content, nitrogen, phosphorous, organic matter, zinc, copper, iron, manganese, texture, and pH were determined by using standard soil testing methods. Yield and yield component data were collected by hand on a 0.001 acre area (43.6 square feet) from 2 rows of cotton near the soil sampling points for each grid. Other than sample collection, all activities were conducted by the producers according to their normal management practices.

The variation of soil and cotton parameters was processed with classical statistics and geostatistics. Correlation analyses were done by determining Pearson correlation coefficients between variables (SAS, 1990). Spatial variability maps were developed by using Arc Info®, ArcView®. The latitude and longitude degrees in Geographic Reference System from GPS were converted to coordinate system in the unit of meter with the projection of the Universal Transverse Mercator (UTM). Measured data positioning with the coordinate system were input to GS_{TM}^{+} GeoStatistics to determine their spatial variations. The isotropic variogram model with the lowest reduced sums of squares (RSS) was used for kriging

(Goovaerts, 1997). Kriged estimates served as the basic data in Arcview for mapping their variability.

Result and Discussion

Cotton Lint Yields in 1999

Lint yield averaged 796 lb/a and had a CV of 0.18 in Field 1 (Figure 3). Lint yield decreased by 58 lb/a compared to the average yield in the same field in 1998 (Ping and Green, 1999). However, the CV was quite similar to 0.19 observed in 1998. The yield decrease in Field 1 could be partly due to the hail damage in early June, which caused the delay of cotton development for about two weeks.

Lint yield averaged 996 lb/a and had a CV of 0.15 in Field 2 (Figure 4). Yield increased by 33 lb/a compared to the average yield in this field in 1998. The CV decreased by 0.05 compared to that in 1998 (Ping and Green, 1999). The increase in yield and decrease in CV in this field may be associated with a more favorable growing season (i.e. less water stress) in 1999.

Yield Spatial Variability in 1999

To facilitate graphing, lint yield was grouped into quartiles (Figure 5). The lowest yield groups were located at northwest and southeast regions. The latter was also one of lowest yield regions in 1998; whereas the northwest region was the highest in 1998 (Ping and Green, 1999). The northeast region had a higher yield and higher yield variability in 1999. The northwest region was the lowest region in terms of elevation. As a result, water collected in this region in June 1999 after approximately 3.3" inches of rainfall fell within 5 days. Therefore, nitrate leaching or denitrification was possible. Soil samples collected in early July indicated that nitrate was less than 10 ppm. The low yield in this region may be partly attributed to temporary excessive water or low nitrate concentrations. The second highest yield region in 1998 was the highest yield region in 1999. However, the overall yields in 1998 were not significantly correlated with those in 1999 in Field 1. It seems that higher rainfall, water redistribution by elevation difference, and potential nitrate loss contributed to the difference in yield spatial variability between the two years.

In the Field 2, highest yielding regions were located near the middle, northeast, and west edge of the field (Figure 6). There were three low yield zones in east, southeast, and northwest regions. Previous non-agricultural land management activities in these areas appeared to have resulted in soil conditions that were unfavorable for lint production. However, the overall yield variability was similar in 1998 and 1999 (Ping and Green, 1999). Lint yield in 1999 was positively correlated with lint yield in 1998 (0.53 ***).

Effect of Yield Components on Yield

Lint yields were highly correlated to boll number in both fields. Lint yield was positively correlated to cotton population in Field 1 but was not significantly correlated to cotton population in Field 2 (Table 1). Yield was positively correlated to boll number per plant and lint per boll in the two fields. This suggests that development of individual plants was an important factor influencing final lint yield.

Effect of Some Soil Parameters on Yield

Summary statistics for soil parameters (0 – 6") measured in this study are shown in Tables 2 and 3. In general, soil fertility levels were high. Except for potassium saturation in the Field 1, there were no significant overall correlations between soil fertility parameters in the 0 – 6" layer and lint yield based on the point data in 1999. Soil fertility would not be expected to strongly influence yield variability since fertility levels generally were adequate for cotton production.

Soil nitrate averaged 23 ppm and had a high CV of 0.85 in Field 1. With the yield goal of 2 bales/a, soil nitrate in this field was in the medium soil test range (Gass, 1989). However, soil nitrate was less than 10 ppm (very low) in the northwest region due to possible leaching in June 1999 (Figure 7). Low nitrate could have reduced yield in this region. Soil nitrate was above 45 ppm in the southeast region. Variable rate application of nitrogen may be an appropriate management technique for next season. Other nutrients measured in this study were at or above critical levels. Lint yield, however, was related to potassium saturation. Soil nutrient levels measured in this study were at or above critical levels in Field 2.

Summary

Our results showed that spatial variability of cotton lint yield varied with different weather patterns. Cotton lint yield was positively correlated to boll number, boll per plant, and lint per boll in both fields. Except potassium saturation in Field 1, there were no strong correlations between lint yield and soil nutrients since most nutrients were above their critical values in both fields. However, low nitrate concentrations were associated with the low yielding regions in one of the fields. Lint yield in 1999 was correlated with lint yield in 1998 in one of the fields.

Acknowledgement

Funding for this project was provided by Cotton Incorporated and by the International Cotton Research Center.

References

Elms, M. K., C. J. Green, and D. R. Upchurch. 1998. Cotton yield variability and correlations between yield, previous yield, and soil properties. Proceedings – Beltwide Cotton Production Research Conferences. pp 630 - 636.

Gass, 1989. Soil, plant, and water testing laboratory. Texas Agricultural Extention Service, Texas A&M University, College Station, TX.

Goovaerts, Pierre. 1997. Geostatistics for natural resources evaluation. Oxford University Press, New York, NY.

Johnson, R. M., J. M. Bradow, P. J. Bauer, and E. J. Sadler. 1999. Spatial variability of cotton fiber yield and quality in relatin to soil variability. *In* Robert, Rust, and Larson (eds). Precision agriculture. Proceedings of the 4th international conference. Minneapolis, Minnesota. pp. 487 – 497.

Ping, J. and C. J. Green. 1999. Spatial analysis of agronomic properties in two production cotton fields in West Texas. Proceedings – Beltwide Cotton Production Research Conferences. pp. 1286-1290.

SAS, 1990. SAS procedure guide, 3rd Edition. SAS Institute inc., Cary, NC.

Sudduth, K. A., S. T. Drummond, S. T. Birrell, and N. R. Kitchen. 1996. Analysis of spatial factors influencing crop yield. p129-139. *In* Robert, Rust, and Larson (eds). Precision agriculture. Proceedings of the 3rd international conference. Minneapolis, Minnesota.

Table 1. Correlation coefficients between yield and some parameters in 1999

Parameters	Field 1	Field 2
Boll number	0.96***	0.85***
Population	0.56***	NS
Boll PP†	0.56***	0.33*
Lint per boll	0.42**	0.42**
K Sat.	0.31*	NS

†- Boll number per plant.

Table 2. Summary of soil parameters (0 – 6” depth) in Field 1

Parameters	Mean	CV	Min	Max
OM, %	0.52	0.28	0.2	0.8
Nitrate, ppm	23.2	0.85	5.7	83.8
Bray P, ppm	23.8	0.31	10.6	47.8
K, ppm	388	0.18	271	599
Ca, ppm	1771	0.3	981	2799
Mg, ppm	550	0.19	290	852
Zn, ppm	0.43	0.36	0.2	0.8
Mn, ppm	8.23	0.33	3.1	14.5
Fe, ppm	3.35	0.39	1.5	7.8
Cu, ppm	0.89	0.32	0.4	1.6
pH	7.9	0.03	7.4	8.3
CEC, meq/100g	14.4	9.7	21.1	0.22
K Sat., %	7.1	0.17	4.5	10.2
Mg Sat., %	32.1	0.18	17	41.4
Ca Sat., %	60.4	0.11	49.8	76.4
Sand, %	69.4	0.12	55.1	86.1
Clay, %	17.7	0.24	10.1	28.9

Table 3. Summary of soil parameters (0 – 6” depth) in Field 2

Parameters	Mean	CV	Min	Max
OM, %	0.82	0.22	0.6	1.5
Nitrate, ppm	41.5	0.32	20.6	91.8
Bray P, ppm	60.0	0.38	22.7	128.8
K, ppm	666	0.15	447	856
Ca, ppm	2559	0.19	1801	3621
Mg, ppm	764	0.13	629	963
Zn, ppm	2.0	0.26	1.1	3.0
Mn, ppm	10.0	0.17	6.8	14.1
Fe, ppm	4.4	0.16	3.4	5.9
Cu, ppm	1.0	0.19	0.7	1.5
pH	8.2	0.02	7.8	8.4
CEC, meq/100g	20.8	0.11	16.2	24.9
K Sat., %	8.3	0.19	5.3	10.9
Mg Sat., %	30.5	0.15	21.5	40.2
Ca Sat., %	60.9	0.1	50.4	72.6
Sand, %	60.3	0.07	50.4	68.2
Clay, %	22.5	0.1	18.2	27.2

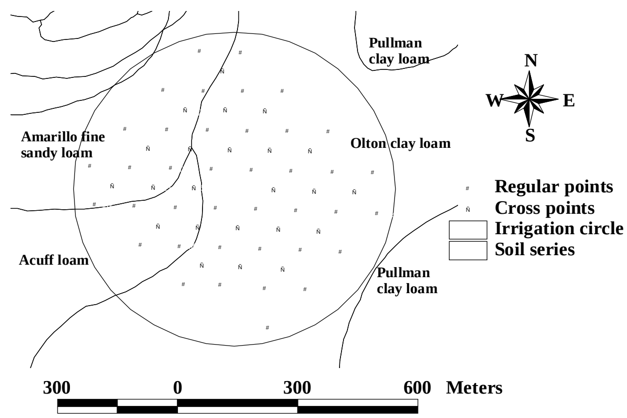

Figure 1. Sampling positions in Field 1

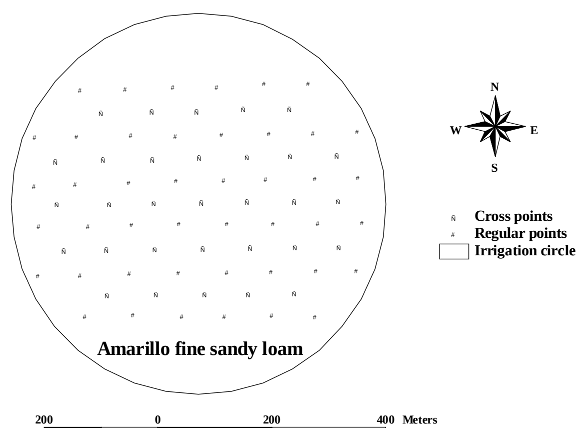

Figure 2. Sampling positions in Field 2

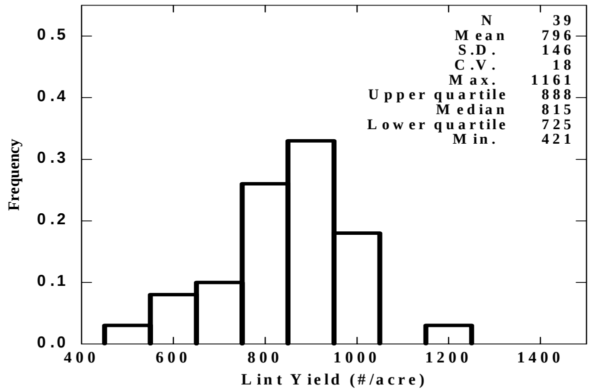

Figure 3. Frequency distribution and summary statistics for lint yield in Field 1

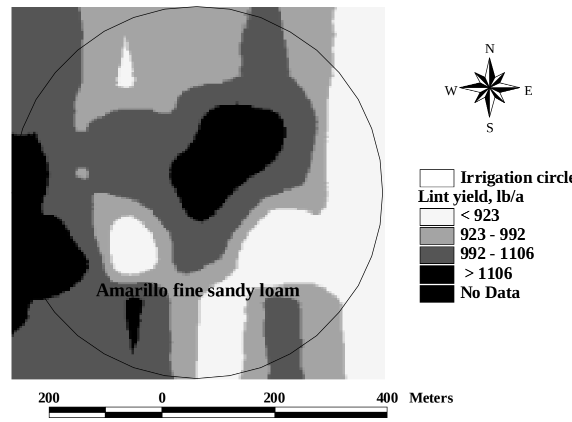

Figure 6. Spatial variability of lint yield in Field 2

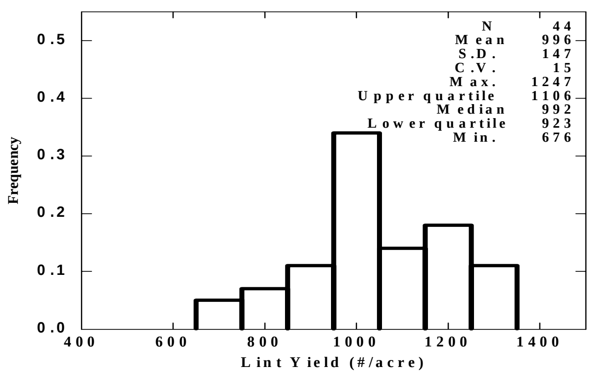

Figure 4. Frequency distribution and summary statistics for lint yield in Field 2

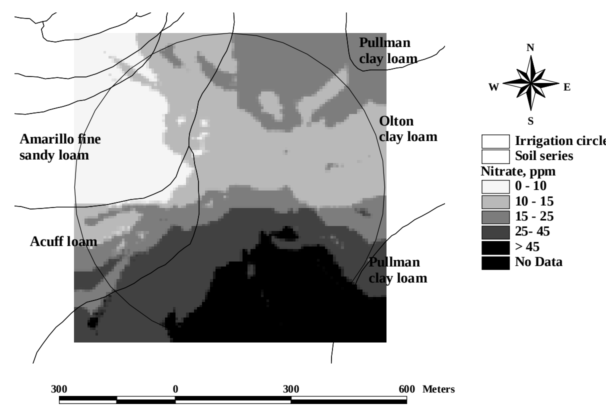

Figure 7. Spatial variability of soil nitrate (0 – 6”) in Field 1

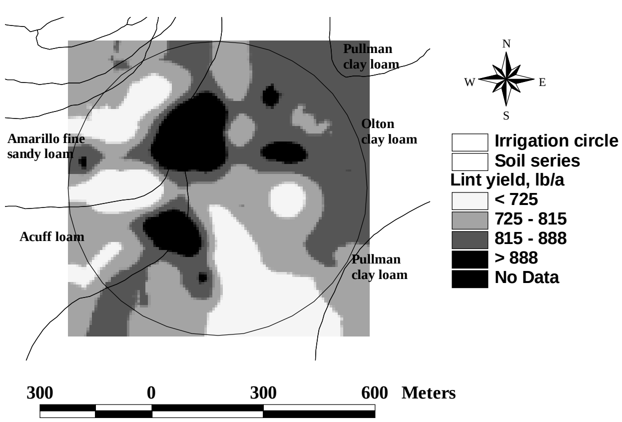

Figure 5. Spatial variability of lint yield in Field 1