Summary of Nitrogen Management Experiments in Irrigated Cotton

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Abstract

A series of nitrogen management experiments have been conducted over the past 11 years around the state to develop and refine fertilizer nitrogen (N) recommendations for irrigated desert cotton production. Stability analysis was used to summarize the data and to determine which of the four treatment regimes is most stable over a range of environments. Results indicate that the feedback treatment (treatment 3) was the most stable treatment for both Upland and Pima cottons and provided the best probability for a higher yield under high yielding environments. The untreated control treatment (treatment 1) was the least stable over a wide range of environments. These results further validate the 'feedback' approach to management of fertilizer N.

Introduction

Second only to water, nitrogen (N) is the most limiting factor in desert cotton (Gossypium spp.) production systems. The addition of fertilizer N is necessary to achieve an optimum yield. The quantity necessary for optimum yield and economic return varies depending upon crop conditions, availability of soil N, and other sources of N addition such as irrigation water. Research conducted to determine N requirements for cotton have revealed that approximately 60-70 lbs. N is required to produce one bale (approximately 480 lbs.) of lint (Silvertooth and Unruh, 1992; Mullins and Burmester, 1990). Using this value as a base for determining crop needs is a good place to begin. Other sources of available N must also be considered. Residual soil N can often provide for a significant source of early season N for crop uptake. A representative soil sample will help in determining the contribution of soil N to the overall need of the crop. Irrigation water is also a potential source of significant N that should be considered. A water sample analyzed for NO_3^--N can provide an estimate of the amount of N being contributed to the crop via irrigation water. All of these other sources can be subtracted from the estimate of 60-70 lbs. of N needed to produce a bale of lint. This remainder needs to be supplied as fertilizer N.

These recommendations have been developed through years of research into N management and crop response to fertilizer N applications. Other tools of crop monitoring have proven successful in determining the N requirements of the crop. The demand for N of the crop as measured by the fruit retention (FR) and also the vigor of the crop measured by a height (in.) to node ratio (HNR) provide good indicators of the growth and development of the crop and thereby its response to and need for additional N. Also, petiole NO_3^--N levels also provide a good indication of the present N status of the crop.

All of the aforementioned tools that can be utilized in managing the N needs of a crop have been developed, in large part, from a series of fertilizer N management studies that have been conducted at three locations in Arizona over the past 11 years. These locations include University of Arizona Agricultural Centers at Maricopa, Marana, and Safford. These studies have addressed not only rates of fertilizer N being applied but also the optimum timing of application. One of the ultimate goals of these experiments was to develop a 'feedback' approach to managing fertilizer N in order to achieve a production system that is both agronomically and economically, as well as environmentally efficient.

A 'feedback' approach to managing fertilizer N in a cotton production system involves the integrated use of all the aforementioned tools. The series of N management experiments conducted around the state included a 'feedback' approach treatment compared to two other treatments plus an untreated control.

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The objective of this present article is to summarize the last 11 years of N management data using a statistical approach termed stability analysis. One of the challenges in the assessment and analysis of long-term studies such as these is to provide a measure of the effect of environment over time. Assessing environment by treatment interaction with the use of conventional analysis of variance becomes difficult as site-years increase and also due to the multiple factors influencing environment by treatment interaction (Raun et al., 1993). Yates and Cochran (1938) first proposed stability analysis for the interpretation of genotype by environment interaction. Their methodology held for the linear regression of variety yield on experimental "mean yield" in order to observe varietal stability across varying environments (Finlay and Wilkinson, 1963; Eberhart and Russell, 1966). More recently, stability analysis has been adapted for use in comparing agronomic treatments across differing environments consisting of the linear regression of treatment mean yield on the environmental mean (Raun et al., 1993; Boman et al., 1995; Unruh and Silvertooth, 1997).

The data obtained from the over 30 site-years of data will be summarized in the using stability analysis to determine which of the four N management treatment regimes provides for the most stable and efficient approach to N management

Materials and Methods

The details of each individual experiment can be found in individual yearly publications (Silvertooth et al., 1990; Silvertooth et al., 1991; Silvertooth et al., 1992; Silvertooth et al., 1993; Silvertooth et al., 1994; Silvertooth et al., 1995; Silvertooth and Norton, 1996; Silvertooth and Norton, 1997; Silvertooth and Norton, 1998; Silvertooth and Norton, 1999, and Silvertooth and Norton, 2000). A listing of the sites and species of cotton planted are located in Table 1. The general construct of each of the N management experiments is outlined in Table 2. Each of the experiments was either randomized complete block designs or split-plots within a randomized complete block design.

Regressing the treatment mean against the environmental mean, which is the overall mean for each site-year, provided the stability analysis. The elevation of the resulting regression equation indicates the stability of the treatment. Stability analysis was performed for each treatment and species.

Results and Conclusions

The stability analysis procedure resulted in eight separate regression equations. Each of the overall regression models were significant with observed significant levels (OSL) of <0.0001. The slope of each of the individual equations was also significant with OSL of <0.0001. Other regression results for each of the treatments are outlined in Tables 3 and 4 for Upland and Pima cotton respectively.

Figures 1 and 2 plot the individual data points and regression equation lines for each of the four treatments for both Upland and Pima cotton respectively. Stability analysis for the Upland cotton yield indicates that the most stable treatment is the feedback approach, treatment 3. Treatment 1 (untreated control) separated out as the least stable treatment across environments (Figure 1). Similar trends were also observed for the Pima yield treatments. They were however much more pronounced (Figure 2). Treatment 3 again proved to be the most stable treatment across environments and provided the greatest probability for a higher yield under high yielding environments. The untreated control, treatment 1, was the least stable.

Accumulated yield response patterns for Upland cotton at Maricopa (Figure 3), Marana (Figure 4), the combined Upland data for Maricopa and Marana (Figure 5), and Pima cotton at Maricopa (Figure 6) reveal several interesting points. A very broad pattern of lint yield response as a function of N rate was experienced in each case. General yield maximums were realized with a total rate of approximately 150 lbs. N/acre. A wide range of lint yields was experienced with the check plots (0 N applied). Positive yield responses were realized in cases (site-years) where the yield potential was high, which was indicated by high fruit retention levels, as shown in previous publications describing this project (Silvertooth et al., 1990; Silvertooth et al., 1991; Silvertooth et al., 1992; Silvertooth et al., 1993; Silvertooth et al., 1994; Silvertooth et al., 1995; Silvertooth and Norton, 1996; Silvertooth and Norton, 1997; Silvertooth and Norton, 1998; Silvertooth and Norton, 1999, and Silvertooth and Norton, 2000)

These results further validate a feedback approach to fertilizer N management utilizing crop monitoring to schedule fertilizer N applications.

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Table 1. Location and species information for each of the location, 1989 – 2000.

Year	Location	Species	Elevation (m)	Soil Series
1989	Maricopa	Upland	366	Casa Grande Sandy Loam
1990	Maricopa	Upland	366	Casa Grande Sandy Loam
1990	Maricopa	Pima	366	Casa Grande Sandy Loam
1991	Maricopa	Upland	366	Casa Grande Sandy Loam
1991	Maricopa	Pima	366	Casa Grande Sandy Loam
1992	Maricopa	Upland	366	Casa Grande Sandy Loam
1992	Maricopa	Pima	366	Casa Grande Sandy Loam
1993	Maricopa	Upland	366	Casa Grande Sandy Loam
1993	Maricopa	Pima	366	Casa Grande Sandy Loam
1994	Maricopa	Upland	366	Casa Grande Sandy Loam
1994	Maricopa	Pima	366	Casa Grande Sandy Loam
1994	Marana	Upland	594	Pima Clay Loam
1995	Maricopa	Upland	366	Casa Grande Sandy Loam
1995	Maricopa	Pima	366	Casa Grande Sandy Loam
1995	Marana	Upland	594	Pima Clay Loam
1996	Maricopa	Upland	366	Casa Grande Sandy Loam
1996	Maricopa	Pima	366	Casa Grande Sandy Loam
1996	Marana	Upland	594	Pima Clay Loam
1997	Maricopa	Upland	366	Casa Grande Sandy Loam
1997	Maricopa	Pima	366	Casa Grande Sandy Loam
1997	Marana	Upland	594	Pima Clay Loam
1998	Maricopa	Upland	366	Casa Grande Sandy Loam
1998	Marana	Upland	594	Pima Clay Loam
1999	Maricopa	Upland	366	Casa Grande Sandy Loam
1999	Marana	Upland	594	Pima Clay Loam
2000	Maricopa	Upland	366	Casa Grande Sandy Loam
2000	Marana	Upland	594	Pima Clay Loam

Table 2. General treatment outline for N management experiments, 1989 – 2000.

Treatment	Protocol
1	Check (no fertilizer N)
2	Standard: Preplant and Sidedress
3	Feedback approach from soil and petiole NO_3^--N analysis
4	2X rate from soil and petiole NO_3^--N analysis

Table 3. Regression analysis results for stability analysis procedure of treatment yield mean as a function of environmental mean for Upland, 1989 – 2000.

Treatment	Intercept	S.E. of Estimate	Slope	S.E. of Estimate	C.V. (%)	R^2
1 – Check	36.6	81.9	0.92	0.07	11.3	0.7438
2 – Scheduled	18.2	42.3	0.99	0.04	5.5	0.9275
3 – Feedback	-31.5	27.7	1.06	0.02	3.5	0.9712
4 – 2x Feedback	-27.5	43.2	1.03	0.04	5.4	0.9313

Table 4. Regression analysis results for stability analysis procedure of treatment yield mean as a function of environmental mean for Pima, 1990 – 2000.

Treatment	Intercept	S.E. of Estimate	Slope	S.E. of Estimate	C.V. (%)	R^2
1 – Check	129.9	134.7	0.77	0.15	12.9	0.5791
2 – Scheduled	-1.2	35.1	1.03	0.04	3.0	0.9736
3 – Feedback	-92.4	59.0	1.17	0.06	4.8	0.9438
4 – 2x Feedback	12.7	88.4	0.98	0.10	7.8	0.8368

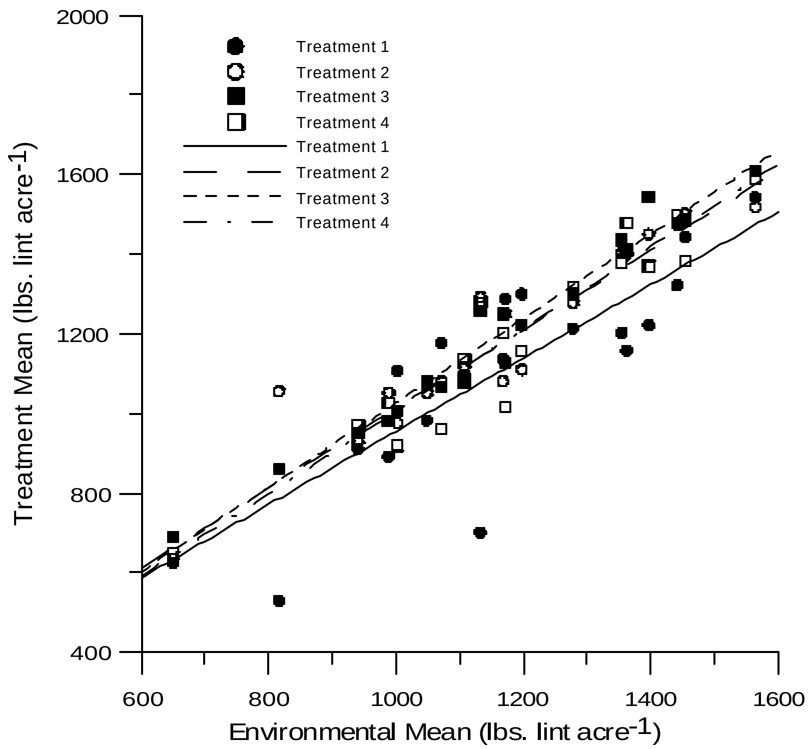

Figure 1. Treatment mean as a function of the environmental mean indicating the stability of each treatment, Upland cotton, 1989 – 2000.

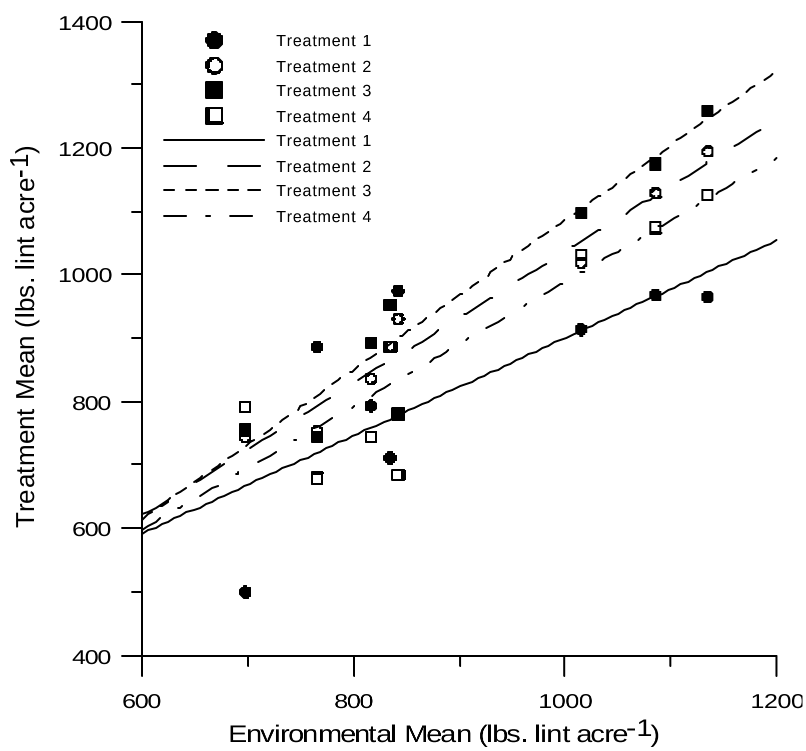

Figure 2. Treatment mean as a function of the environmental mean indicating the stability of each treatment, Pima cotton, 1990 – 2000.

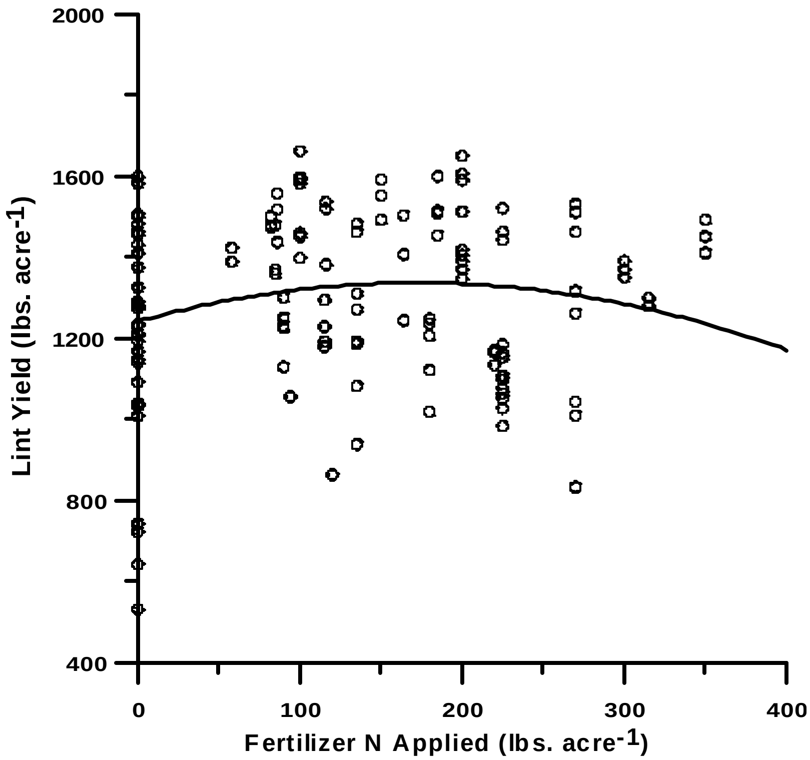

Figure 3. N Response Curve – Upland, Maricopa, AZ, 1989-2000.

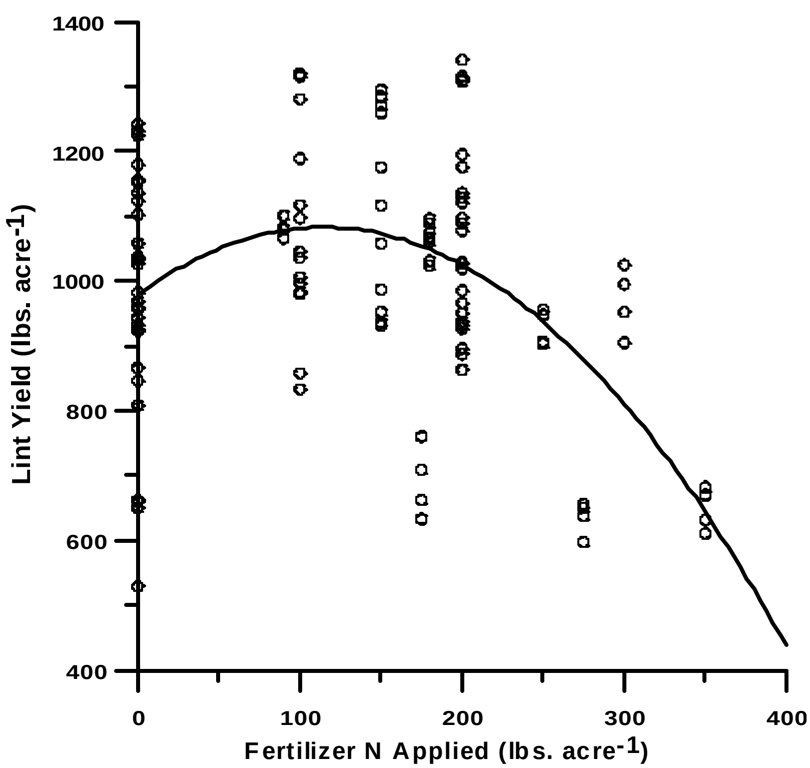

Figure 4. N Responsive Curve – Marana, AZ, 1994-2000.

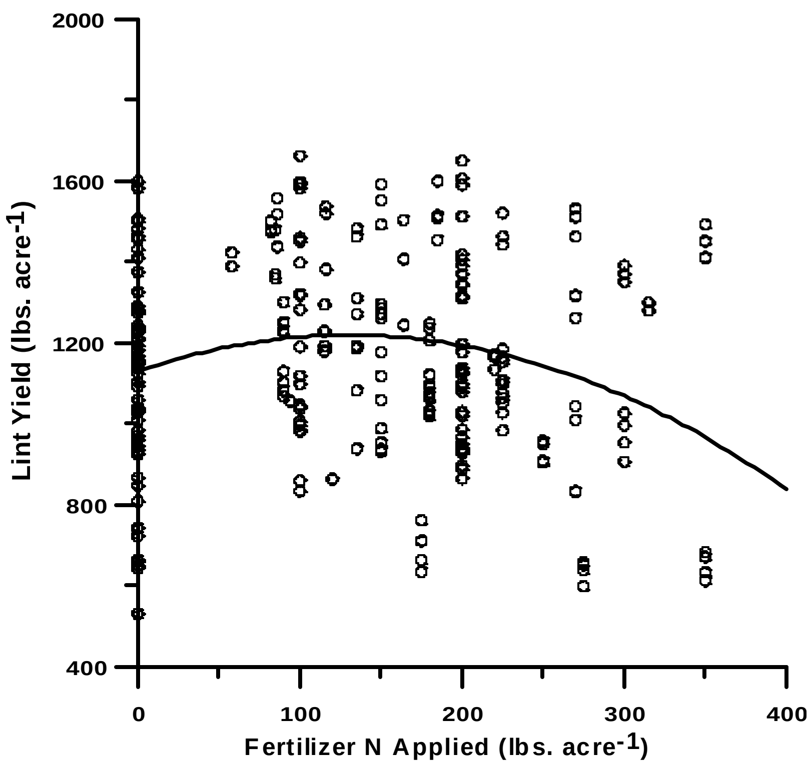

Figure 5. N Response Curve – Upland, Maricopa and Marana, AZ, 1989-2000.

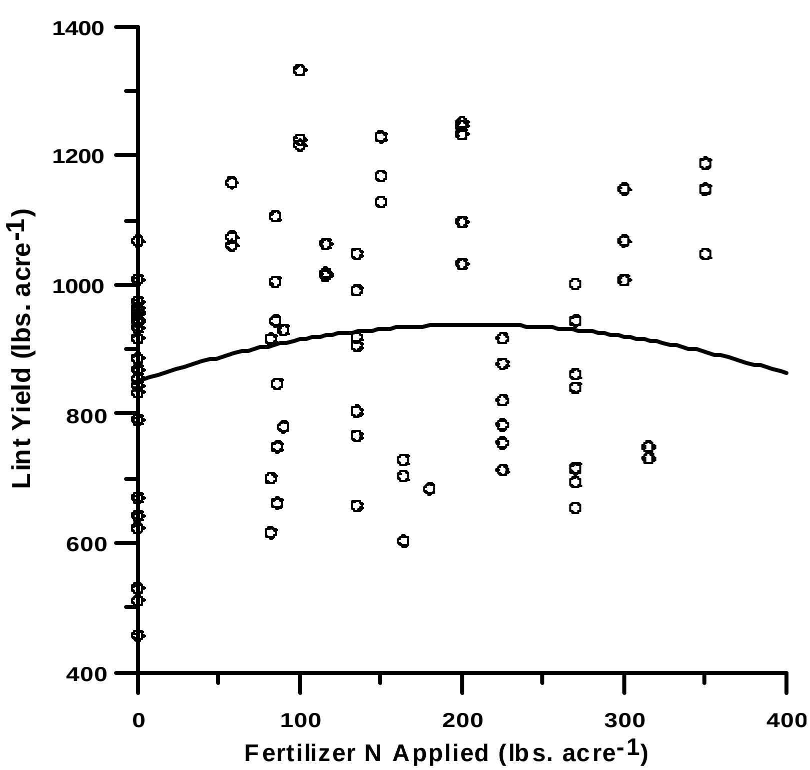

Figure 6. N Response Curve – Pima, Maricopa, AZ, 1987-1989.