

Nitrogen Management Experiments For Upland and Pima Cotton, 1991

J. C. Silvertooth, L. J. Clark, J. E. Malcuit, E. W. Carpenter, T. A. Doerge, and J.E. Watson

Abstract

Two field experiments were conducted in Arizona in 1991 at two locations (Maricopa and Safford). The purposes of the experiments were to validate and refine nitrogen (N) fertilization recommendations for both Upland and Pima cotton. The experiments each utilized N management tools such as pre-season soil tests for NO_3^- -N, in-season plant tissue testing (petioles) for N fertility status, and crop monitoring to ascertain crop fruiting patterns and crop N needs. Results at both locations revealed a strong relationship between the crop fruit retention levels and N needs for the crop. This pattern was further reflected in final yield analysis as a response to the N fertilization regimes used.

Introduction

The management of fertilizer nitrogen (N) is a very important component of any cotton (*Gossypium spp.*) production program in Arizona. Water, and N are normally the most limiting inputs to successful cotton production in most desert soils. It is important for farmers to use fertilizer N efficiently to maintain optimum return in yield for the amount of fertilizer N provided. Also, from an environmental standpoint, it is important to manage fertilizer N so that downward movement of NO_3^- -N in the soil profile, can be minimized.

For cotton production systems in the desert Southwest, there are several N management tools available to manage fertilizer N inputs efficiently in terms of economic, agronomic, and environmental concerns. These tools include: residual soil NO_3^- -N levels from pre-season soil samples, inputs of NO_3^- -N through irrigation water, petiole samples taken in-season for NO_3^- -N analysis, consideration of fruit load and growth pattern of the crop in terms of N needs, and the use of split applications of fertilizer N through the course of the season (Silvertooth and Doerge, 1990).

Recommendations from University of Arizona Cooperative Extension personnel concerning N management in cotton usually include these aforementioned tools. Growers are usually discouraged from making fertilizer N applications based purely on conjecture or guesswork. Therefore, two field experiments were conducted in 1991 as an extension of 1989 and 1990 experiments (Silvertooth et al., 1990 and Silvertooth et al., 1991b) to develop better guidelines for recommendations concerning the integration of N management tools to improve overall efficiency for the grower.

Materials and Methods

Field experiments were conducted in 1991 at the University of Arizona Maricopa Agricultural Center (MAC), and Safford Agricultural Center (SAC) with the following objectives: 1) to compare several fertilizer N management strategies for cotton in terms of N fertility status of the crop, and yield; and 2) develop refinements in the fertilizer N recommendations associated with in-season N fertility assessments using cotton petiole analysis and fruit load development.

Maricopa

Both Upland (*G. hirsutum* L., var. DPL 90) and American Pima (*G. barbadense* L., var. Pima S-6) were planted on a Casa Grande sandy loam on 19 April. The experimental structure was a split plot within a randomized complete block design with three replications. Whole plots were cotton varieties (DPL 90 and Pima S-6), with subplots being N treatments (Table 1). Subplots were eight, 40 inch rows wide and extended the full length of the irrigation run (800 ft.). All pest control and irrigation management practices being carried out on an as-needed basis. Preseason soil test results are shown in Table 2.

Basic plant measurements were carried out within each plot on a regular 14 day basis for the entire season. These measurements included plant heights, number of mainstem nodes per plant, flower numbers per 150 ft.² areas, and the number of nodes above the top white bloom and the terminal (NAWB). Petioles were also sampled on a routine basis throughout the season and analyzed for NO₃⁻-N. Plant mapping was performed on each distinct treatment (variety by N treatment) at five dates during the course of the season. Results from the plant mapping provide information concerning the percent total fruit retention (sum of positions one and two on each fruiting branch) for each treatment and a record of the general vegetative/reproductive balance maintained by the various treatments over time, as shown in Fig. 1 and 2. Actual fertilizer N applications are outlined in Table 3. Yield estimates were obtained by harvesting the entire center four rows of each plot with a mechanical picker.

Safford

The experimental design utilized at Safford was very similar to that described for Maricopa (Table 1) and included both DPL 90 and Pima S-6 planted 10 April on a Grabe clay loam soil. The N treatments utilized at Safford are shown in Table 4.

Basic plant measurements were carried out within each plot on an approximately 14 day basis for the entire season. These measurements included plant heights, number of mainstem nodes per plant, flower numbers per 50 ft.² areas, and the NAWB. Yield estimates were obtained by harvesting the entire center four rows of each plot with a mechanical picker, similar to that described at MAC.

Surface soil samples were collected preseason at Maricopa and Safford, to which routine soil analyses were performed. Routine soil test results are shown in Table 2. Soil samples were also collected by one foot depth increments, to a depth of two feet on 28 March and 2 April at Maricopa (Table 5) and Safford (Table 6), respectively.

Results

Maricopa

Fruit retention levels developed from the plant mapping data are shown in Fig. 1 and 2 for both the DPL 90 and the Pima S-6, respectively. Petiole NO₃⁻-N concentrations observed for each treatment are illustrated in Fig. 3 and 4 for both DPL 90 and Pima S-6, respectively. Residual soil NO₃⁻-N from each treatment area preseason are listed in Table 5, to a depth of two feet. Heavy fruiting patterns were experienced throughout the season for both the Upland (DPL 90) and Pima (S-6) crops (Fig. 1 and 2). The development of a substantial boll load is indicative of a strong N sink and a high N demand. Fruit retention levels and NO₃⁻-N concentration patterns in petioles led to the 22 July application of fertilizer N to treatments 3 and 4 (Table 3). The response to this application of N can be seen by the resultant increases in petiole NO₃⁻-N levels in early August, followed by a sharp decline in the late season (DPL 90 only), apparently due to the continued development of a boll load as evidenced by the fruit retention levels.

The DPL 90 check plots (treatment 1) experienced an apparent premature cut-out near 1 August (2200, 86/55 °F heat units after planting (HUAP)), possibly due to N deficiency. Visual symptoms of N deficiency became

apparent in check plots for both DPL 90 and Pima S-6 near 1 August. Petiole levels for treatment 1 showed a distinct increase in early August, which is often a characteristic response following cut-out or a substantial loss in fruit retention, and in this case there was no loss in fruit retention. Treatment 2 in the Pima S-6 plots also experienced an increase in petiole NO_3^- -N concentrations in early August which apparently was not associated with a concomitant fruit loss pattern.

The DPL 90 plots for treatment 3 progressed towards cut-out near 15 August (2500 HUAP), which is very much in line with a full season Upland variety supporting a strong boll load, as this crop was. The final irrigation was applied on 11 September in an effort to provide adequate soil moisture to accomplish full development of bolls set by cut-out. Defoliant was applied on 10 October to all plots.

Plots were mechanically harvested on 8 November. Yield data for both the DPL 90, and Pima S-6 are shown in Table 7. Significant differences were detected among the N treatments for the DPL 90 with the check treatment (1) yielding less than any of the other three treatments. Treatments two, three, and four were not different in a statistical sense. However, it is interesting to note that treatment 3 (1X feedback) required only 58 lbs. N/acre, utilized a split application with only two applications and provided for optimum yield potential. Similar to the 1990 results (Silvertooth et al., 1991), there was no benefit in terms of yield from the 2X feedback treatment (4) which had a total of 116 lbs. N/acre applied over two applications. There was no apparent advantage recognized from the pre-season N application made with treatment 2 based upon the in-season petiole analyses, fruit retention information, or yield. This information provides a strong statement of support for the Best Management Guidelines for N fertilization of cotton, which advocates the use of petiole testing and plant monitoring in-season, and split applications of fertilizer N based upon plant needs. There is little justification of pre-season fertilizer N applications based upon these studies.

The yield data for the N treatments with the Pima S-6 are also shown in Table 7. However, no statistical differences were declared based upon the analysis of variance, which did reveal a coefficient of variation (CV) of only 6.9% but a non-significant F value (OSL = 0.0867). The general trends revealed an interesting pattern very similar to that previously described for the DPL 90. In the case of the Pima S-6, even though the check treatment was not statistically different ($P \leq 0.05$) from other treatments an average yield depression of 136 lbs. lint/acre compared to the other three N treatments was recorded. The distinct suppression in yield is certainly noteworthy at least, if not statistically significant.

Another interesting feature that is apparent from the data obtained over the course of this past season and also from the 1990 season (Silvertooth et al., 1991b) is the N supplying power of the check plots which have received no fertilizer N for two seasons, yet have the capacity of supporting 2.4 and 1.9 bales/acre yields from the DPL 90 and the Pima S-6, respectively in 1991. All check plots expressed substantial visual deficiency symptoms (overall plant chlorosis, beginning first with lower, older portions of the plants and covering the entire plants in most cases by late-season) from early August throughout the remainder of the season. The residual NO_3^- -N available to all N treatment plots at MAC in 1991 averaged about 61 lbs. N/acre for DPL 90, in the top two feet of the soil profile pre-season (Table 5). No real differences could be seen with soil NO_3^- -N among any treatments pre-season as a function of 1990 N fertilization. In the Pima plots there was a slight trend towards higher residual soil NO_3^- -N in the top two feet in the higher N treatments, particularly as compared to treatment 1 (check).

This information indicates an area of research that is in need of further study concerning the N mineralization/immobilization transformations and the dynamics associated with mineralizable soil-N inherent in such soils of the Sonoran Desert. To better understand the N supplying power of agricultural soils of this region and the management implications associated with production systems such as cotton and N fertilization details such as these, there is a need for more specific research and experimentation.

Safford

Fruit retention data for the DPL 90 and the Pima S-6 at Safford are shown in Fig. 5 and 6. The early season fruit retention levels were low, relative to baseline figures (Silvertooth et al. 1991a) for both DPL 90 and Pima

S-6. However, general plant measurements did not indicate an excessive vegetative tendency for any N treatment. The fruit retention patterns did not necessarily recover to levels indicative of optimum yield potentials, as experienced in 1990 (Silvertooth et al., 1991b), but they did show an improvement mid-season. Petiole concentrations of NO_3^- -N are outlined in Fig. 7 (DPL 90) and Fig. 8 (Pima S-6). Both figures describe patterns of petiole NO_3^- -N which are not indicative of a situation in which the N sink has been substantially eliminated. Based upon petiole information obtained, the crop appeared to maintain a strong N demand throughout the season and N fertilization on 23 July (Table 3) was in line with general petiole guidelines. Based upon the late season increase in petiole NO_3^- -N concentrations, an increase in the N fertility status in response to the 23 July fertilizer N applications can be seen. The conversion of this increase in N fertility status is not apparently translated into improved fruit retention or yield (Table 8). However, N treatment 2, which received 46 lbs. N/acre on 23 July increased in fruit retention and petiole NO_3^- -N as compared to the other N treatments. The late season increases in petiole NO_3^- -N are observed for the check plots in the DPL 90 and Pima S-6, but not to the extent as that shown for the higher N rates. Therefore, based upon these observations, there is an argument for the possibility that all N treatments progressed into a N deficiency mid-season. The application of the N fertilizer to treatments 2, 3, and 4 on 23 July was in order, but possibly late on the order of 14-20 days. This possibility also points out the importance of timeliness when delaying fertilizer N inputs based on crop needs and tissue testing programs. Some degree of anticipation will always be required, but cases such as these indicate the potential penalty from hesitation. In this case, the difference of making the in-season N application one irrigation cycle earlier (approximately 2 weeks) may have made a difference and been more timely.

The lint yield results shown in Table 8 did not reveal statistically significant differences among N treatments at Safford for either DPL 90 or Pima S-6 in 1991. This fact is particularly interesting in relation to this particular experiment in that the integrity of these plots have been maintained since 1989. Therefore, the checkplots (N treatment one) have not received any fertilizer N for three consecutive cotton seasons over 1989, 1990, and 1991 (Silvertooth et al., 1990 and Silvertooth et al., 1991b). A very slight trend indicating higher levels of residual NO_3^- -N (Table 6) with high rates of fertilizer N can be seen. Residual levels of NO_3^- -N in 1991 ranged from 73 to nearly 120 lbs. N/acre. Checkplots had 73 to 94 lbs. NO_3^- -N/acre, in the top two feet of the soil profile. The source of this residual NO_3^- -N is likely from the soils inherent mineralization capacity and irrigation water inputs. Irrigation water provided by a groundwater well provided 2.1 acre feet of the irrigation water provided to this crop. Analyses of this water revealed an average concentration of 4.75 ppm NO_3^- -N. Therefore, approximately 27 lbs. NO_3^- -N/acre were provided in roughly 3 lb. NO_3^- -N/acre increments over the season through the irrigation system. Total N uptake estimates on the check plots indicate a total of 149 lbs. N/acre and 104 lbs. N/acre taken up by the Upland and Pima plots, respectively. Assuming complete availability of the residual soil NO_3^- -N levels in the top two feet and the NO_3^- -N contributions from the irrigation water, we find 119 and 100 lbs. NO_3^- -N available to the Upland and Pima check plots. This estimate is based on a very general accounting of available N in this soil-plant system and a series of assumptions concerning availability of various N inputs. Nevertheless, the lack of a yield response to any of the N treatments by DPL 90 or Pima S-6 at this location illustrates the necessity of monitoring both crop and soil conditions in an effort to maintain efficient use of N and other crop production inputs, and also the importance of timeliness in management responses.

Summary

The 1991 experiments at Maricopa and Safford demonstrate the value and utility of incorporating various N and crop management tools into cotton production systems of Arizona. The dynamic nature of the cotton crop (Upland and Pima) is such that the management of inputs such as fertilizer N are critical in attaining optimum efficiency with these inputs agronomically, economically, or environmentally. The difficulty in predicting crop N needs for any given season in advance, in combination with the residual soil NO_3^- -N levels commonly experienced for these experiments, indicate the need to exercise extreme caution in pursuit of any preseason N fertilization. In-season crop monitoring techniques for fruit load development and N fertility status compliment each other for managing N inputs for better efficiency, but must be used in a timely manner.

These experiments also reveal the intriguing aspects of soil N mineralization capacities in Sonoran Desert soils, which are often considered as having virtually negligible N supplying potentials. Monitoring of NO_3^- -N inputs through irrigation water also represents an important component in crop management that can be very important, such as shown at Safford.

The use of crop management tools such as petiole NO_3^- -N analyses in-season, can provide a benefit to decisions such as timing, form, and rate of N fertilization when used in conjunction with good crop monitoring practices. Petiole samples taken regularly at close intervals (approximately every two weeks), and in combination with regular trips through the field for crop inspection (or plant mapping) serve as a more complete approach for the management of fertilizer N applications.

References

- Silvertooth, J. C., L. J. Clark, E. W. Carpenter, J. E. Malcuit, P. T. Else, and T. A. Doerge. 1990. Nitrogen management in irrigated cotton. Cotton, A College of Agriculture Report. University of Arizona. Series P-81:169-174.
- Silvertooth, J. C. and T. A. Doerge. 1990 Nitrogen management in Arizona cotton production. Report 9024. The University of Arizona, College of Agriculture. Tucson, AZ.
- Silvertooth, J. C., P. W. Brown, and J.E. Malcuit. 1991a. Basic crop development patterns. Cotton, A College of Agriculture Report. University of Arizona. Series P-87:43-49.
- Silvertooth, J. C., L. J. Clark, J. E. Malcuit, E. W. Carpenter, T. A. Doerge, and J. E. Watson. 1991b. Nitrogen management experiments for Upland and Pima Cotton, 1990. Cotton, A College of Agriculture Report. University of Arizona. Series P-87:209-221.

Table 1. Nitrogen fertilization treatments used at the Maricopa and Safford Agricultural Centers, 1991.

<u>N Treatments No.</u>	<u>Fertilizer N Management</u>
1	Check (No fertilizer N)
2	Standard: Preplant & Side dress
3	Feedback approach from soil and petiole NO ₃ ⁻ -N analysis, 1X rate.
4	2X rate from soil and petiole NO ₃ ⁻ -N feedback

Table 2. Preseason soil test results for each N treatment at Maricopa and Safford, AZ, 1991.

Treatment	Ca*	Mg	Na	K	Zn**	NO ₃ -N***	P†	pH (1:1 H ₂ O)	EC ds/m	ESP§ -%
----- ppm -----										
<u>Maricopa</u>										
1	4780	300	208	384	0.9	16	10.0	8.2	2.1	3.2
2	5000	310	210	393	1.0	17	10.0	8.2	2.0	3.1
3	4370	294	189	381	1.0	16	9.6	8.2	1.9	3.1
4	4580	310	199	410	0.9	18	11.0	8.2	2.0	3.2
<u>Safford</u>										
1	6630	613	857	666	1.6	17	10.0	8.1	4.3	8.5
2	6230	670	910	754	1.9	16	8.1	8.2	3.5	9.3
3	5810	600	977	680	1.5	16	6.8	8.3	3.5	10.6
4	6000	615	940	720	1.4	18	6.6	8.2	3.5	10.0

* Exchangeable cations using neutral molar ammonium acetate.
 ** DTPA extractable Zn.
 *** NO₃-N using specific ion electrode.
 † NaHCO₃ extractable P
 § Computed - exchangeable sodium percentage.

Table 3. Fertilizer N applications for each N management treatment, MAC, 1991.*

<u>Date</u>	<u>Form</u>	<u>Method**</u>	<u>Treatment Number</u>			
			<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>
			-----lbs N/acre-----			
17 April	Am. Sulphate (21-0-0)	SD	0	50	0	0
19 June	Urea (46-0-0)	SD	0	35	35	70
22 July	Urea (46-0-0)	SD	0	0	23	46
		TOTAL	0	85	58	116

** SD = sidedress

Table 4. Fertilizer N applications for each treatment, SAC, 1991.

<u>Date</u>	<u>Form</u>	<u>Method*</u>	<u>Treatment Number</u>			
			<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>
			-----lbs N/acre-----			
4 April	Urea (46-0-0)	SD	0	42	0	0
23 July	Urea (46-0-0)	SD	0	46	21	42
		TOTAL		88	21	42

* SD = sidedress

Table 5. Preseason soil NO₃--N mean concentrations for two, one foot depth increments for each N treatment at Maricopa, AZ, 28 March, 1991.

Treatment	Depth	NO ₃ --N		
		-ppm-	-lbs./acre-	Total (lbs./acre)*
<hr/>				
DPL 90				
1	1	10.3	41.2	
1	2	4.0	16.0	57.2
2	1	11.5	46.0	
2	1	3.9	15.6	61.6
3	1	11.3	45.2	
3	2	4.1	16.4	61.6
4	1	10.7	42.8	
4	2	5.1	20.4	63.2
<hr/>				
Pima S-6				
1	1	8.2	32.8	
1	2	3.5	14.0	46.8
2	1	12.0	48.0	
2	2	4.7	18.8	66.8
3	1	11.9	47.6	
3	2	5.0	20.0	67.6
4	1	13.7	54.8	
4	2	5.4	21.6	76.4

* Sum of depth one and two, for each N treatment.

Table 6. Preseason soil NO₃--N mean concentrations for two, one foot depth increments for each N treatment at Safford, AZ, 2 April, 1991.

Treatment	Depth -feet-	NO ₃ --N		
		ppm	lbs./acre	Total (lbs/acre)*
<u>DPL 90</u>				
1	1	18.0	72.0	
1	2	5.1	20.4	92.4
2	1	22.0	88.0	
2	2	4.2	16.8	104.8
3	1	16.8	67.2	
3	2	3.3	13.2	80.4
4	1	25.0	100.0	
4	2	4.6	18.4	118.4
<u>Pima S-6</u>				
1	1	15.2	60.8	
1	2	3.0	12.0	72.8
2	1	19.2	76.8	
2	2	4.2	16.8	93.6
3	1	18.0	72.0	
3	2	5.1	20.4	92.4
4	1	24.0	96.0	
4	2	3.6	14.4	110.4

* Sum of depths one and two, for each N treatment.

Table 7. Lint yield means for each N management treatment, Maricopa, AZ, 1991.

<u>Treatment</u>	<u>Yield</u>	
	<u>DPL 90</u>	<u>Pima S-6</u>
	-----lbs. lint/acre-----	
1	1158 b*	914
2	1402 a	1019
3	1411 a	1098
4	1479 a	1032
LSD 0.05	95	NS
OSL †	0.0008	0.0867
CV (%) §	3.5	6.7

* Means followed by the same letter are not significantly different ($P \leq 0.05$) according to pairwise comparisons using a Fisher's LSD.
 † OSL = observed significance level.
 § CV = Coefficient of variation.

Table 8. Lint yield means for each N management treatment at Safford, AZ, 1991.

<u>Treatment</u>	<u>Yield</u>	
	<u>DPL 90</u>	<u>Pima S-6</u>
	-----lbs. lint/acre-----	
1	1302	911
2	1318	709
3	1310	934
4	1225	843
LSD 0.05	NS	NS
OSL †	0.6680	0.0739
CV (%) §	9.2	13.4

* Means followed by the same letter are not significantly different ($P \leq 0.05$) according to pairwise comparisons using a Fisher's LSD.
 † OSL = observed significance level
 § CV = Coefficient of variation

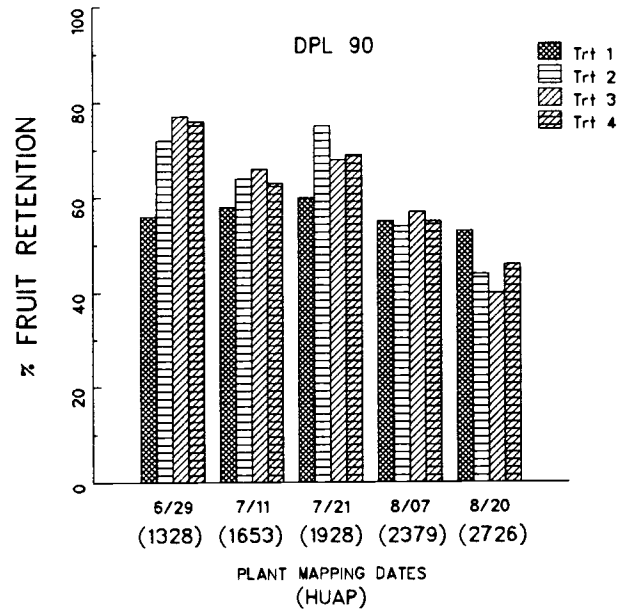


Fig. 1. Fruit retention levels, DPL 90, Maricopa Nitrogen Management, 1991.

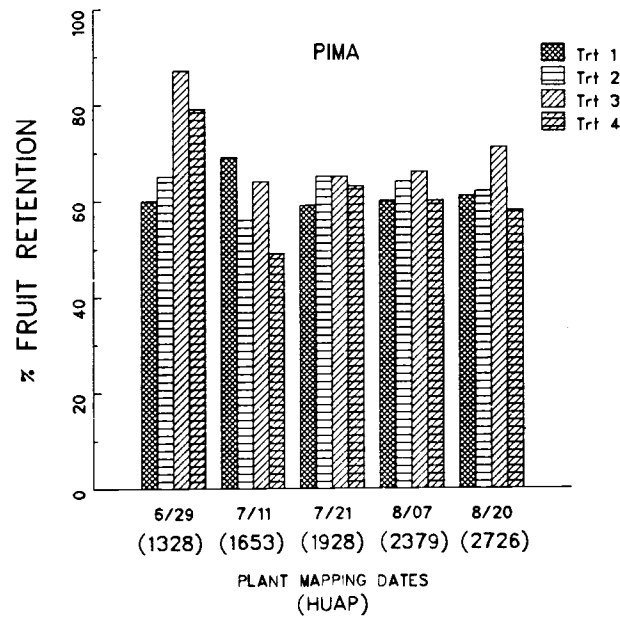


Fig. 2. Fruit retention levels, Pima S-6, Maricopa Nitrogen Management, 1991.

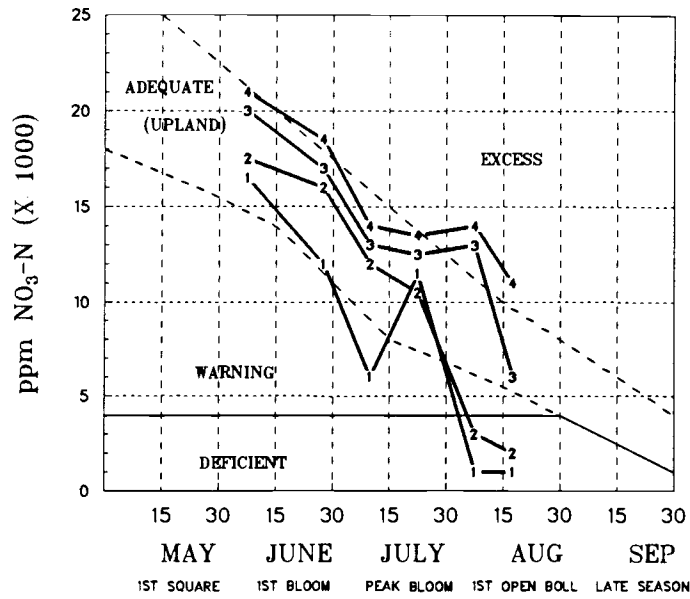


Fig. 3. NO₃-N Levels in Cotton Petioles, Maricopa (DPL 90), 1991.

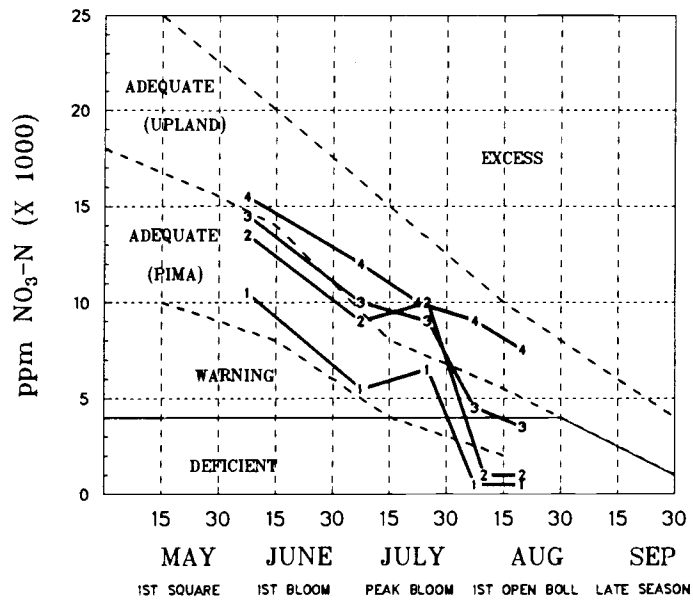


Fig. 4. NO₃-N levels in Cotton Petioles, Maricopa (Pima S-6), 1991.

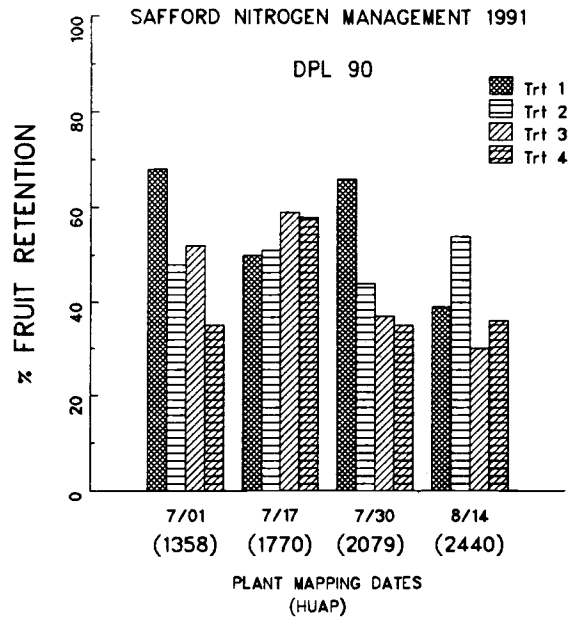


Figure 5. Fruit retention levels, DPL 90, Safford Nitrogen Management, 1991

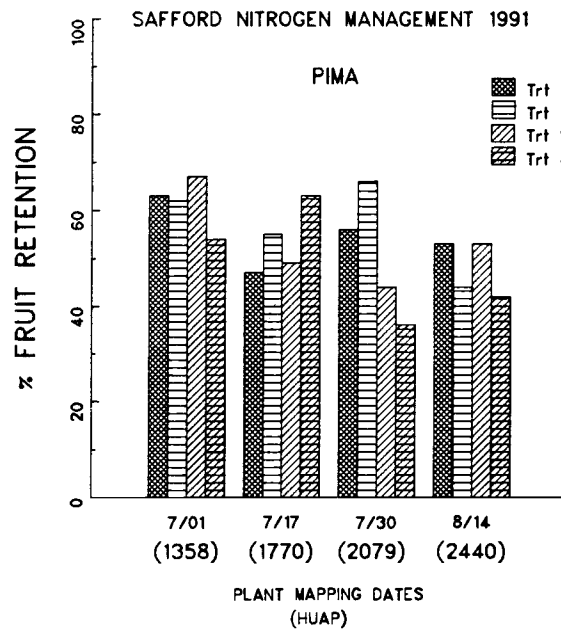


Fig. 6. Fruit retention levels, Pima S-6, Safford Nitrogen Management, 1991.

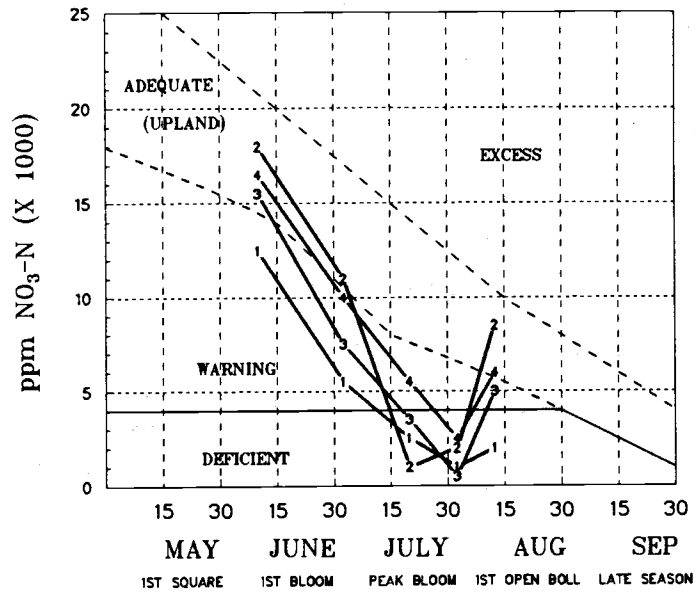


Fig. 7. NO₃-N Levels in Cotton Petioles, Safford (DPL 90), 1991.

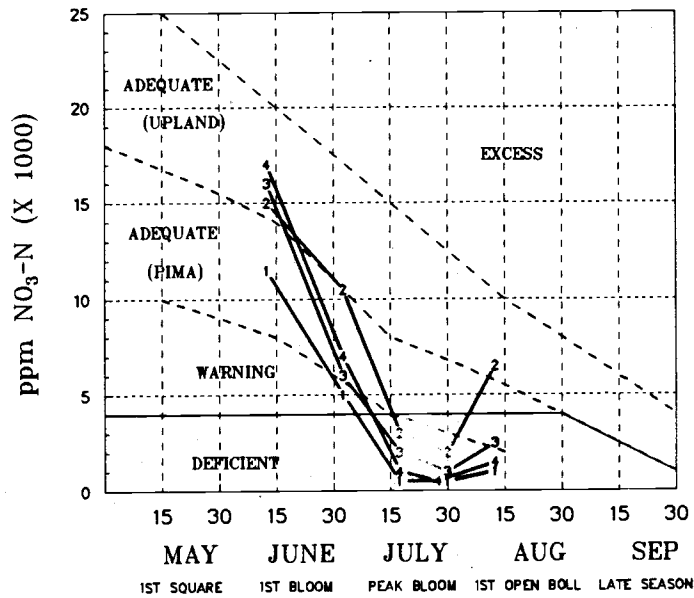


Fig. 8. NO₃-N Levels in Cotton Petioles, Safford (Pima S-6), 1991.