USING DRAINAGE LYSIMETERS TO EVALUATE IRRIGATION AND NITROGEN INTERACTIONS IN COTTON PRODUCTION

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Abstract

Although the cost for water is one of the largest expenditures in a grower's budget in Arizona, many growers in the state still over irrigate their fields to assure that there will be no yield losses. Although these over irrigations usually do not cause any negative effects to the crop, they can cause the loss of available nitrogen to the plant and the potential for nitrate contamination of groundwater resources. To assess what impact over irrigation may have on cotton yields and the potential for groundwater contamination, a drainage lysimeter study was initiated at the Maricopa Agricultural Center, Maricopa, Arizona. Drainage lysimeters are large steel boxes with the top open filled with soil and placed underground in the experimental field. Crops are grown directly above the lysimeters and the water that moves through the soil profile is collected at the bottom of the lysimeter and analyzed. In this study, three lysimeters were installed. The lysimeters were 80" wide (two row widths), five feet long, and six feet deep. They were placed 18 inches below the soil surface and filled with soil as to best represent the soil in its natural condition. The data presented in this paper are from two years of an ongoing experiment. Throughout the growing season, water samples were taken from the lysimeters in the field. Nitrogen applications were made according to field conditions and weekly petiole sampling. Irrigations were made according to field conditions and using the AZSCHED irrigation scheduling program. Treatment one was irrigated according to the schedule recommended by AZSCHED. The amount applied was equal to the total crop water use since the last irrigation. In treatment two, the timing was the same as treatment one, but the amount of irrigation water applied was 1.25 times more. Treatment three was also irrigated at the same time but with 1.5 times more water. Yield samples were taken at the end of each season and showed no significant differences between treatments, with yields averaging about 1100 lb/acre of lint in 1995 and 940 lb/acre of lint in 1996. The drainage amounts ranged from 9.5" in treatment three to 2.5 inches in treatment one. The corresponding nitrate-N losses were 35.7 lb/acre for treatment three and 21.3 lb/acre for treatment. Monitoring continued during the winter to assess the impact of winter rainfall. In the last two years, there has been no significant winter rainfall.

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Introduction

Although many cotton growers are aware of the relationship between irrigation water applied and yield, very few know how their irrigations effects nitrate losses out of the rootzone. In most cases, growers know that too little water can reduce crop yield while too much water could can excessive vegetative growth and a reduction in yield. However, little is known of the fate of nitrogen due to excessive drainage caused by over irrigation. This paper discusses an ongoing project to study the interaction between irrigation strategy and the loss of nitrate below the rootzone in cotton production.

Materials and Method

In Spring of 1994, three large, stainless steel drainage lysimeters were constructed and placed into the ground at the Maricopa Agricultural Center, Maricopa, AZ. The drainage lysimeters were large steel boxes with the top open. The installation was similar to that described by Martin et al., 1994. The lysimeters used in this study were 80" wide (two row widths), five feet long and six feet deep. In the site where the lysimeters were to be placed, the soil was removed, layer by layer, and separated into individual piles. Once all of the soil was removed, the lysimeters were set in place, approximately 18 inches below the soil surface and filled with soil, again layer by layer, as to best represent the soil in its natural condition.

The lysimeters were placed approximately 75 ft. from the head end of the field. A collection bucket was placed in each lysimeter and tubing was connected to allow for a pump to be used to drain the lysimeter when the collection bucket became full. The sampling was done weekly though a sample was not always present because no drainage had occurred. The leachate was measured and samples were taken and analyzed for nitrate-N content.

Irrigation timing and amount of water applied were determined using neutron probe measurements, field observations and a computerized irrigation scheduling program called AZSCHED (Fox, et al., 1999). The maximum allowable deficit (MAD) of soil water in the rootzone was set to 50%. Once the 50% MAD target was reached, the amount of water applied was determined by the amount needed to refill the soil profile in the rootzone to 100%. Thus, at the time of irrigation, the amount of water applied was equal to the total crop water use (ETC) since the last irrigation, plus any system inefficiency. In this study, Treatment 1 was irrigated at a level of 1.0 * ETC. Treatment 2 was slightly over irrigated and the amount applied was 1.25 * ETC. Treatment 3 was heavily irrigated and the amount applied was 1.5 * ETC. Each treatment was replicated four times with one plot in each treatment containing a drainage lysimeter. The nitrogen applications were made based on University of Arizona recommendations using preseason soil sampling and weekly in-season petiole sampling (Doerge and Des Rosiers, 1992). The plots were dry planted and watered up (April 10, 1995; April 19, 1996).

Results and Discussions

Irrigation/Rainfall

The total amount of water applied to each treatment for 1995 is shown in Table 1. Water applied to each treatment remained the same until layby (July 19). Before this time, approximately four inches of water was applied to each treatment when irrigation was called for. This was done because four inches was the minimum amount of water that could be applied and still effectively cover the entire plot. In many cases, the target amount was less than four inches but four inches were still applied.

In 1996, less water was applied. Again, early season irrigations remained the same for all three treatments until the end of June, when different amounts could be applied without affecting irrigation efficiency.

Over the two-year period, very little rainfall occurred (Fig. 1). During the 1995 growing season, only 1.25 inches of rainfall occurred. During the winter, a total of 3.33 inches of rain had fallen. In 1996 growing season, only 1.19 inches of rain was recorded.

The Nitrogen Applications

Nitrogen applications were made based on preseason soil sampling and in-season petiole sampling. In 1995, preseason soil tests showed a deficient level of soil nitrogen and 40 lb/acre of N were applied. Another application of 50 lb/acre of N was made to the field on June 18 and a final application of 50 lb/acre of N was made July 18. All of the plots showed the same relative petiole concentrations and there were little or no differences between treatments.

In 1996, a preseason soil test showed no N deficit. Nitrogen was applied on May 23 at a rate of 60 lb N /acre. On June 23, another application of 75 lb/acre of N was made. A final application of 30 lb N/acre was made on July 20.

The Yield

Yield data for 1995 were collected on November 22, 1995 (Table 1). There was no significant difference in yield between the treatments. Treatment 1 had the highest yield and treatments 2 and 3 had virtually the same yield. Further analysis also showed no differences in seed yield.

In 1996, harvest was on November 21, 1996 (Table 2). Again, there were no significant differences in the yields between the treatments. Treatment 3 was the highest yielding treatment with 980 lb/acre of lint and treatment 1 and 2 followed closely behind. The reduction of yield from 1995 to 1996 was primarily due to a lygus infestation which caused many bolls not to open fully.

Water Drainage

The lysimeters began to drain almost immediately after the first irrigation in 1995. However, the lysimeter in treatment 2 did not continue to drain and there was no water recovered beyond the first irrigation. Based on data gathered from the other two lysimeters, treatment 2 was estimated. The seasonal drainage data are shown in Table 1 and presented in graphic form in Fig. 2. As seen in Fig. 2, the lysimeters drained at approximately the same rate until about July 19 (layby). This makes sense since the amount of water applied prior to July 19 was the same for all treatments. Also, we can see from the graph that lysimeter 1 (treatment 1) had almost no drainage after layby. This was because after layby, the target amount could be obtained and treatment 1 did not receive any excess irrigation water. Lysimeter 3 had the most irrigation water applied and the most drainage, while lysimeter one received the least amount of water and had the lowest total drainage.

Over the winter of 1995-96, lysimeter 2 was reinstalled. Although it did have some drainage initially, this drainage was not recorded since it was mainly due to the refilling of the lysimeter. During the 1996 season (Table 2-Fig. 2), there was no drainage from any lysimeter for the first part of the season. This primarily due to the low soil water content at the beginning of the season and the lag time associated with drainage lysimeters. Once drainage did begin occurring, around the first of July, the lysimeters drained according to the irrigation application amounts, with lysimeter 1 draining the least and lysimeter 3 draining the most.

Nitrate Losses

The total amount of nitrogen recovered in the drainage water for 1995 is shown in Table 1 and Fig. 3. The nitrate-N losses follow the drainage water closely. This would be expected since nitrates move with water quite easily. As with the drainage water, lysimeter 3 loss the most nitrate-N (33 lb/ac) and lysimeter one lost the least (20 lb/ac).

In 1996, this trend continued, but at a much lower rate (Table 2 - Fig. 3). Only 2.7 lb/acre more of nitrate-N leached from lysimeter 3 and than 1.3 lb/acre from lysimeter 1.

Summary

The lysimeter followed the expected patterns. However, it was thought that the excessive water may produce excessive vegetation in treatment 3. The expected excess growth caused by the water may have been offset by the additional loss of nitrogen, though this cannot be determined form these data. It was hoped that these lysimeters could also be used to evaluate the effect of winter rains on nitrate movement. However, there have been no significant winter rains during the past two years.

The relatively high nitrate leaching that occurred during the first part of 1995 was probably due to the initial mixing of the soil to load the lysimeters. In 1996, the losses were quite low, indicating that there is not too much leaching occurring in-season. However, with so little rainfall, it is difficult to determine what how much nitrogen was left in the soil. Further testing we be needed to better understand the movement of nitrates in this arid environment.

References

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Table 1. Data for the three treatments in the lysimeter study at Maricopa Agricultural Center, Maricopa, AZ, 1995.

Trmt	Total Water Applied (in.)	Nitrogen Applied (lb/acre)	Yield* (lb/acre)	Water Drained (in.)	Nitrate-N Leached (lb/acre)
One	49	140	1095a	1.8	20.0
Two	55	140	1070a	3.0**	26.5*
Three	60	140	1169a	4.2	33.0

**Means followed by the same letter are not significantly different ($P \leq 0.05$) according to the S-N-K test.
** Lysimeter 2 values are estimated.

Table 2. Data for the three treatments in the lysimeter study at Maricopa Agricultural Center, Maricopa, AZ, 1996.

Trmt	Total Water Applied (in.)	Nitrogen Applied (lb/acre)	Yield* (lb/acre)	Water Drained (in.)	Nitrate-N Leached (lb/acre)
One	42	165	950a	0.68	1.3
Two	48	165	900a	3.0	2.1
Three	55	165	980a	5.3	2.7

* Means followed by the same letter are not significantly different ($P \leq 0.05$) according to the S-N-K test.

Table 3. Data for the three treatments in the lysimeter study at Maricopa Agricultural Center, Maricopa, AZ, 1995-1996.

Trmt	Total Water Applied (in.)	Nitrogen Applied (lb/acre)	Yield* avg. (lb/acre)	Total Water Drained (in.)	Total Nitrate-N Leached (lb/acre)
One	91	305	1023a	2.5	21.3
Two	103	305	985a	6.0	28.5
Three	115	305	1075a	9.5	35.7

* Means followed by the same letter are not significantly different ($P \leq 0.05$) according to the S-N-K test.

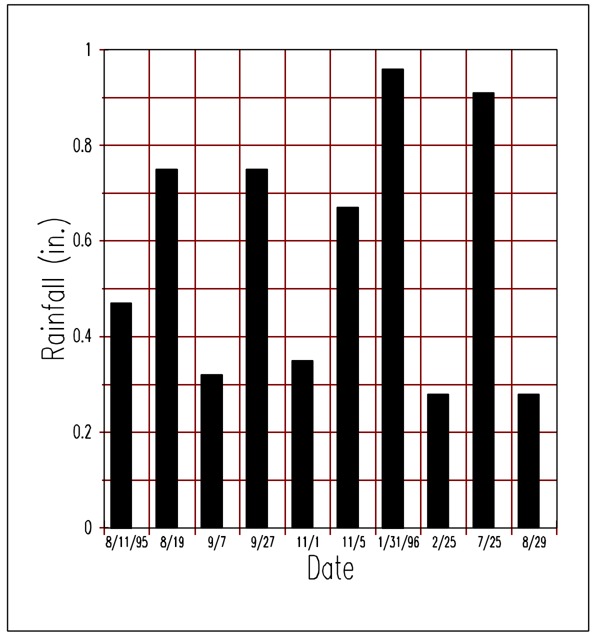

Figure 1. Rainfall amount for 1995-96, Maricopa Agricultural Center, Maricopa, AZ.

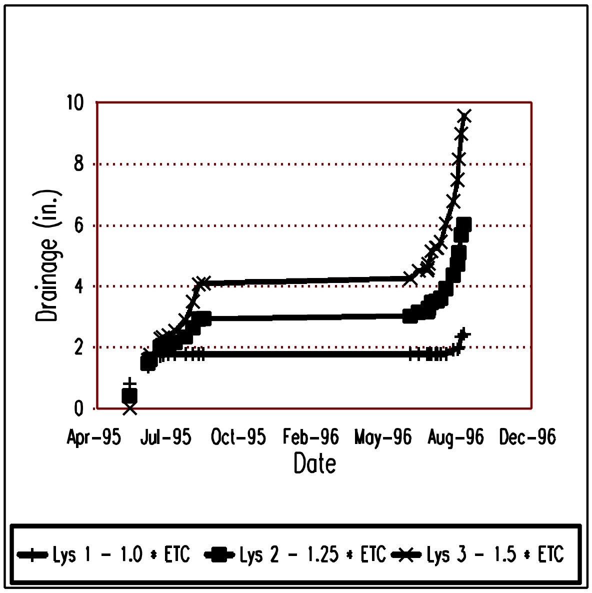

Figure 2. Cumulative drainage from the three drainage lysimeters under upland cotton production at the Maricopa Agricultural Center, Maricopa, AZ, 1995-96.

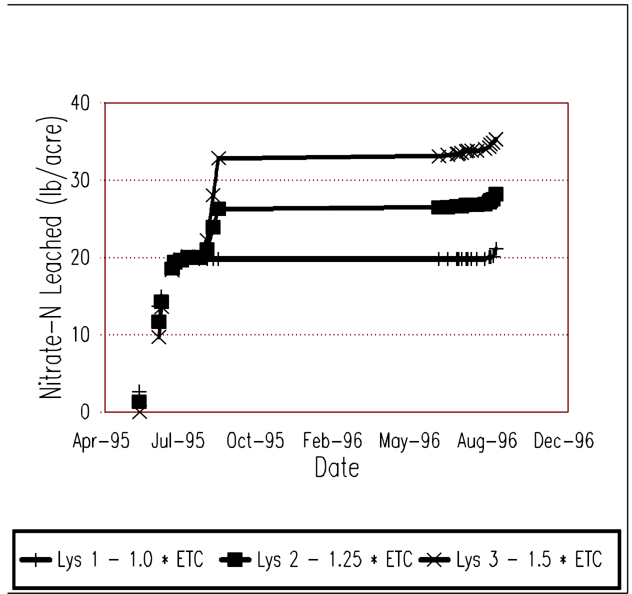

Figure 3. Cumulative Nitrate-N losses from the three drainage lysimeters under upland cotton production at the Maricopa Agricultural Center, Maricopa, AZ, 1995-96.