The Effects of the Nitrogen Fertilizer Rates on the Uptake and Yield of Cotton on Calcareous Soil

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ABSTRACT

Excessive nitrogen fertilizer rates in Upland cotton (Gossypium hirsutum L.) produces high levels of nitrates in calcareous soils. The experiments were conducted in the Experimental Station of Vardates in central Greece, during the seasons 1992 and 1993. The objectives were to examine the effects of variable nitrogen rates on the nitrogen uptake and the yield of cotton in calcareous soils. The experiments were conducted in complete, randomized blocks, using the nitrogen rates of 0, 60, 90, 120, 150, and 180 kg.ha^{-1}, while phosphorus and potassium were kept constant at 80 kg.ha^{-1}. The dry matter content (grams per plant) and nitrogen uptake, as well as the concentration of NO_3^- (ppm) in soil depth of 0-30 cm, differed for the applied nitrogen rates and stages of plant growth. Cotton plants appeared to have a higher dry matter content and nitrogen uptake at the 'blooming' stage while the lowest value of concentration of NO_3^- (ppm) in soil appeared at the 'squares' stage. The yield of seed cotton of 4400 - 4500 kg.ha^{-1} was not significantly affected by the high nitrogen rates of 120 - 180 kg.ha^{-1}, ($r^2 = 0.4$). The yield of seed cotton (4733 kg. ha^{-1}) and the dry matter content (100 g.plant^{-1}), were positively affected by the rates of 60 kg N. ha^{-1}, 80 kg P_2O_5. ha^{-1} and 80 kg K_2O. ha^{-1} ($r^2 = 0.75$).

Introduction

The needs of cotton growth in N-P-K nutrients were studied under different soil conditions in many experiments conducted by various authors (Christidis, 1955; Podimatas, 1979; Maretis, 1981; Evageliou, 1985; Simonis, 1985; Mitsios *et al.*, 1993). The results of the application of various nutrient rates to cotton cultivated on calcareous soils and their effects on the growth and yield have been published in the last ten years (Panos, 1969; Maretis, 1981; Simonis, 1985; Sharplay, 1987; Mitsios *et al.*, 1993). High concentration of nitrates in soil and underground water were created by high N fertilizer rates on cultivated plants over an extended period.

The objectives of this work are a) to optimize nitrogen use on cotton crops (cv. Sindos - 80) in calcareous soils under the climatic and soil conditions of central Greece (Vardates); and b) to evaluate the relation between nitrogen fertilizer rates and dry matter, nitrogen uptake and the concentration of nitrates in soil depth of 0 - 30 cm.

Materials and Methods

Soil

The experiments were conducted on the Experimental Station of Vardates in central Greece. The soil type was classified as calcareous (Table 1). The 42 trials had seven treatments in complete, randomized blocks with six replicates and three row plots of 11 m (33 m^2). Nitrogen was applied at 0, 60, 90, 120, 150 and 180 kg N.ha^{-1}, while the P_2O_5 and K_2O were kept constant at 80 kg.ha^{-1} .

Prior to seeding, mixtures with 75% of the total nitrogen and the total amount of phosphorous and potassium were applied. The rest of the nitrogen was applied during the 'squares' stage. Nitrogen was applied as:

- ammonium sulphate (21% N)
- ammonium nitrate (33.4% N)

All fertilizers were incorporated to 15 cm.

Soil analysis

Soil samples were taken at each stage of growth. Exchangeable K^+ was determined by 1M CH_4COONH_4 (pH=7), and the concentration of nitrates in soil was measured in 2M KCl extraction with a spectrophotometer (Jackson, 1970). The content of $CaCO_3$ (%) was calculated by the Bernard method, and organic matter (%) by the Walkley & Black method.

Plant analysis

Two plants at each stage of growth were taken and analyzed by the double-dry ashing method (550^0C). Total nitrogen (%) was determined by the Kjeldhal method (Jackson, 1970).

Results and Discussion

The experiments indicate that the value of the dry matter content was highest at the 'blooming' stage for all nitrogen fertilizer rates. However, 60 N kg. ha^{-1} produced the highest dry matter content compared to other rates (Figure 1).

In all treatments the mean values of the nitrogen uptake by cotton plants during the "blooming" stage was independent of the nitrogen fertilizer rates (LSD, p=5%) (Table 2).

The maximum yield of seed cotton of 4733 kg. ha^{-1} was obtained for the fertilizer rate of 60 N - 80P_2O_5 - 80K_2O kg.ha^{-1}. In all other treatments the yield of seed cotton was not significantly altered (LSD, Duncan test, p=5%) (Table 3).

The yield of seed cotton was positively correlated with the total nitrogen uptake and dry matter content at the 'blooming' stage (Tables 2 and 3).

The concentration of NO_3^- in the top 30 cm soil in 1992 and 1993 during the 'squaring' stage was lowest (32.2 to 40.0 ppm) compared to the concentration at other growth stages ('seeding', '5-leaves', 'squares', 'blooming' and 'maturing') (Figures 2 - 6). The lowest values were not affected by the nitrogen fertilizer rates. Excessive use of nitrogen fertilizer produced high levels of NO_3^- in the top 30 cm of soil (Figures 2 – 6).

The relationship between the nitrogen uptake, the concentration of nitrates in top 30 cm of soil and the seed cotton yield, is given by a regression analysis, using the expression:

$Y = 1280.6 + 621.1\ X_1 + 10.1\ X_2$ ($R_2 = 0.75$), where:

- X_1, total nitrogen uptake (g. $plant^{-1}$)
- X_2, concentration of NO_3^- (ppm)
- Y, yield of seed cotton (kg.ha^{-1})

Conclusions

The following: conclusions were drawn:

The yield of seed cotton was positively correlated with the nitrogen uptake and dry matter content at the 'blooming' stage.

The maximum seedcotton yield of 4733 kg. ha^{-1} was achieved with fertilizer rate of 60N - 80P_2O_5 - 80K_2O kg.ha^{-1}. The seed cotton yield was not significantly different in the other treatments.

The excessive use of nitrogen fertilizer in the experiments produced high levels of NO_3^- in the top 30 cm of soil.

The concentration of NO_3^- in the top 30 cm of soil during the 'squaring' stage had the lowest impact compared to other stages. This was not affected by nitrogen fertilizer rates.

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Table 1. Properties of the soil.

Depth (cm)	clay (%)	silt (%)	sand (%)	E C mmhos. cm^{-1}	pH	CaCO3 (%)	O M (%)	NH4+ (ppm)	NO3- (ppm)	Exch . K meq/100 g
0 – 30	57	39	3	< 3	7.9	5.8	1.9	9.4	63.3	0.24
30 – 60	54	38	8	< 3	8.1	7.2	1.1	9.8	87.8	0.28

Table 2. Effects of nitrogen fertilizer rates on dry matter, nitrogen uptake and the concentration of nitrates in soil depth 0-30 cm at 'blooming'.

Treatments N - P_2O_5 - K_2O_1	Dry matter content (%)	Nitrogen uptake (g . $plant^{-1}$)	NO_3 Conc.- (ppm) in soil depth 0 - 30 cm
0 - 0 - 0	59.90	3.20	46.60
0 - 80 - 80	66.20	3.00	32.70
60 - 80 - 80	99.40	4.20	88.60
90 - 80 - 80	85.20	3.80	61.90
120. - 80 - 80	92.80	4.70	46.00
150 - 80 - 80	94.30	3.90	49.20
180 - 80 - 80	89.90	4.20	49.70

1 Fertilizer rates in kg. ha^{-1}

Table 3. Effects of nitrogen fertilizer rates on the yield of seed cotton.

Treatments	Yield of Seedcotton				
N - P_2O_5 - K_2O 1	(kg.ha^{-1})	1992 (%)	(kg.ha^{-1})	1993 (%)	Mean
0 - 0 - 0	3344		3112	-	3228
0 - 80 - 80	3587	100.0	3767	100.0	3677
60 - 80 - 80	4583 *	127.7	4884 *	129.6	4733
90 - 80 - 80	4360 ns	121.5	4732 ns	125.5	4545
120. - 80 - 80	4293 ns	119.6	4703 ns	124.8	4498
150 - 80 - 80	4154 ns	115.8	4740 ns	125.8	4447
180 - 80 - 80	4159 ns	115.9	4634 ns	123.0	4396

1 Fertilizer rates in kg. ha^{-1}

Figure 1. Effect of nitrogen fertilizer rates on dry matter in cotton plants (mean values for the years 1992 and 1993).

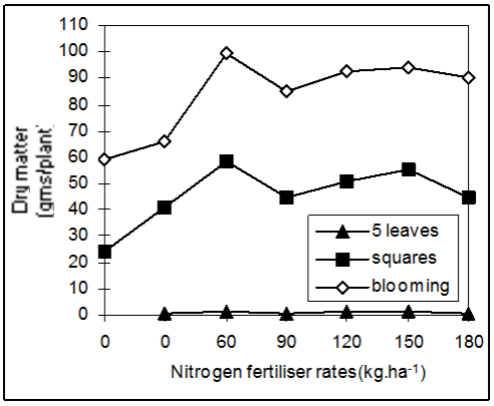

Figure 2. Effect of nitrogen fertilizer rates on the concentration of NO3- (ppm) in top 30 cm of soil at 'seeding' stage: 1992 and 1993.

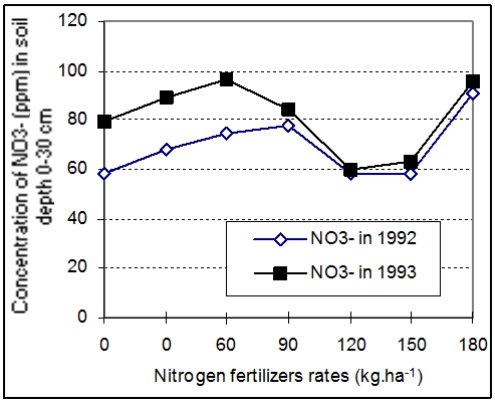

Figure 3. Effect of nitrogen fertilizer rates on the concentration of NO3- (ppm) in top 30 cm of soil at '5 leaves' stage: 1992 and 1993.

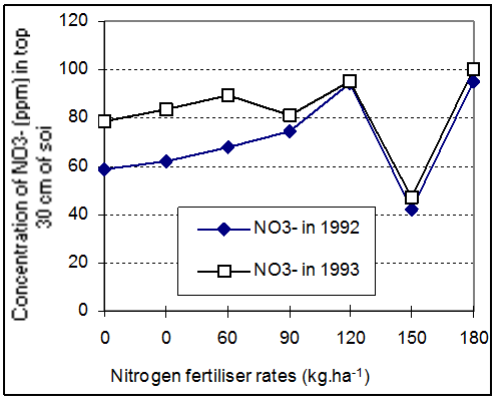

Figure 4. Effect of nitrogen fertilizer rates on the concentration of NO3- (ppm) in top 30 cm of soil cm at 'sqares' stage: 1992 and 1993.

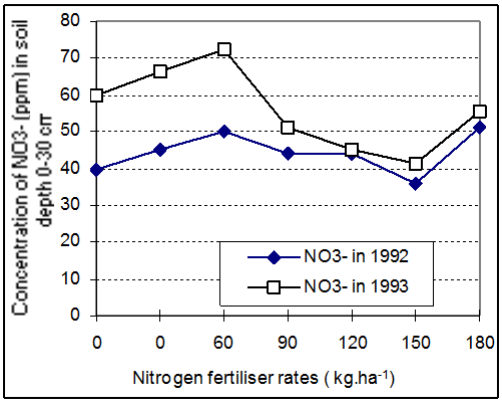

Figure 5. Effect of nitrogen fertilizer rates on the concentration of NO3- (ppm) in the soil depth 0-30 cm at 'bloom' stage: 1992 and 1993.

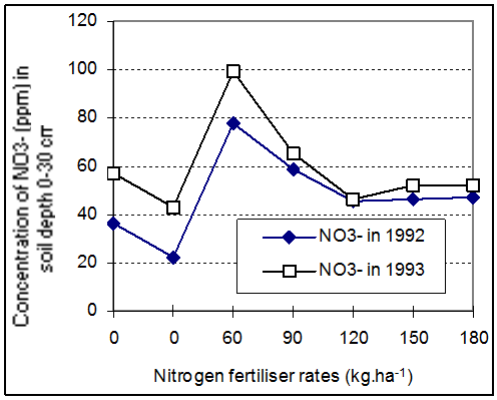

Figure 6. Effect of nitrogen fertilizer rates on the concentration of NO3- (ppm) in the top 30 cm of soil at 'mature' stage: 1992 and 1993.