Nitrogen Fertilization of Cotton Based on Inorganic Nitrogen Analysis of the Soil

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ABSTRACT

Cotton is produced on widely differing soils under irrigated or rainfed conditions in South Africa. Under these circumstances seed cotton yields can vary greatly and so do their nitrogen demands. This model was the culmination of nitrogen field trials carried out over three seasons at four locations scattered over South Africa. In these trials, six levels of nitrogen were applied, with four replications at each site. Pre-plant soil samples were taken at 0-300mm, 300-600mm and 600-900mm. These samples were analysed immediately for inorganic nitrogen. For assessment of the amount of nitrogen that can be mineralised, these samples were incubated at 15/26EC over a 14-week period. Petiole samples were taken for analysis at one and three weeks after the appearance of the first flower. The higher the initial nitrogen plus mineralised complement in the soil, the lower the percentage of nitrogen utilized by the cotton crop. A utilization factor of 66.7% seems to be a good average. The same results were obtained with applied nitrogen, where a utilization factor of 80% seems to be a good average. The nitrogen required to achieve a certain target cotton yield is taken as the point of departure in this model. Subtract from this 66.7% of the total inorganic N-content of the top 900mm soil plus the amount of nitrogen mineralised during the growth period. This leaves the amount of nitrogen to be applied for production of the target yield. The Nitrogen content of the irrigation water should be taken into account but it was negligibly low during these trials. Working with a utilization factor of 80% for the applied nitrogen, the actual amount can be calculated. Tests of the calculated nitrogen requirement against actual yields achieved in this and other trials gave a very good correlation of r^2 = 0.977 between calculated and actual nitrogen needs.

Introduction

Cotton requires large amounts of nitrogen, particularly under irrigation. Increased seed cotton yields with increased nitrogen applications are due to more and larger leaves, prolonged flower bud production, and more and larger fruit. However, an N response curve reaches a point where lint yield is maximised, and in some environments a reduction in yield or fiber quality can occur with if excessive N. Components of these reductions include delayed maturity, reduced ginning percentage, greater incidence of disease, and greater attractiveness to insect pests (Constable and Rochester, 1988; Hearn, 1975; Constable and Hearn, 1981)

Cotton is produced on widely differing soils under irrigated or rainfed conditions in South Africa. Under these circumstances it can be expected that seed cotton yields will vary greatly and so will the nitrogen demands. To accommodate these extremes in a single fertilizer guide, the quantity of nitrogen needed to obtain a specified target yield must be taken into account. Such a fertilizer guide will be of great value for economic cotton production and nitrogen fertilization.

Materials and methods

The amounts of nitrogen required by the cotton plant to produce a specified seed cotton yield are given in Table 1 (Halevy, 1989).

The first step is to establish a realistic target yield. This is set by taking the availability of irrigation water, climatic conditions and agricultural practices into consideration. Long-term production figures can be a valuable aid. Once the target yield is set, the N needed to produce it can be derived from Table 1.

For the calculation of the amount of N-fertilization needed certain parameters are required.

Amount of N needed for a target yield A

Residual inorganic N in profile (top 900mm) B
(Utilization of 66.7%)

Mineralisation of organic N (top 900mm) C
(Utilization of 66.7%)

Nitrogen applied with 400mm irrigation water D
(Utilization of 80%)

Shortfall of nitrogen.................A - (B+C+D) = E

Amount of N applied (utilization 80%)

$$\frac{E \times 100}{80}$$

The results of different fertilizer trials conducted on three locations over three seasons were used. Pre-plant inorganic soil nitrogen was determined on each site for depths of 0-300mm, 300-600mm and 600-900mm. Mineralisation was determined under controlled conditions, using samples from each site and depth. Inorganic nitrogen was extracted with 0.05M K_2SO_4 (Steenkamp and Boshoff, 1987). The samples were incubated at night at 15°C for 11 hours by day at 26°C for 13 hours. Inorganic nitrogen was extracted at weeks 0, 1, 3, 5, 8, 11 and 14.

Results

Experience shows that during the winter when temperatures are low and soils are dry, very little, if any, mineralisation takes place. Therefore, time does not have much influence the on inorganic nitrogen in soil samples taken in August-September before the first spring rains.

The utilization factor of 66.7% was derived from results of different N-fertilizer trials. Trials run over 14 years in which Soya beans and babala were rotated first with tobacco and then with cotton are of particular interest. N was applied at 0, 50, 100 and 150 kg/ha to each treatment. By using a utilization factor of 80% for applied nitrogen, the actual contribution of soil nitrogen to the production of a specified seed cotton yield could be calculated. With these data available, a utilization factor was calculated and the data are presented in Table 2.

These data reveal that the utilization of residual inorganic nitrogen varies from 42 - 94%. Cotton under irrigation is rarely fertilized with less than 50 kg N/ha. Ignoring the zero treatment in calculating the utilization factor, the mean of the other treatments was 65%.

Mineralisation

The amount of nitrogen mineralised differs between locations. The nitrification for each location was similar and strongly associated with the texture of the particular soil. Most of the research in this paper was at Vaalharts, Rietrivier, Loskop and Rustenburg. Mineralisation data from some locations are given in Table 3.

The amounts of nitrogen mineralised correspond with data reported by Halevy (1985) and others. For the calculation of the fertilizer requirements, the data used are extrapolated from those given in Table 4.

Irrigation water

Irrigation water is an important contributor of nitrogen because of the large volumes of water applied per season. A seasonal application of 400mm corresponds to an amount of 4kg N/ha for each mg N/L of irrigation water.

Testing of model

Before a model can be accepted in practice, its reliability must be verified. Data from fertilizer trials at two locations indicate that maximum yields would be expected at N-levels of 129 and 91 kg N/ha for Vaalharts and Loskop, respectively (Table 5). In actual field trials, yields were maximised at 120 and 80 kg N/ha (Fig 1). Fertilizer trials on three locations show that maximum yields can be expected at 193, 79 and zero kg N/ha for Vaalharts, Loskop and Rustenburg, respectively (Table 6). In the field trials, maximum yields were obtained at 150, 75 and zero kg N/ha (Fig 2).

A regression between actual N-levels needed to obtain a specified target yield and predicted values was calculated, even though there were only had five points. A good correlation with $r^2 = 0.977$ was obtained (Figure 3). Further refinement are needed but the model, is already useful in calculating N requirements of cotton crops.

Conclusion

From these results, it is evident that:

1. Pre-plant inorganic soil N-content is useful in predicting N fertilizer needs for any cotton crop.
2. A good correlation was found between calculated N- requirements and actual figures obtained in the trials.

References

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Table 1. N required for cotton to produce a target yield (kg/ha).

Target Yield	N Required
1000	90
1500	140
2000	180
2500	215
3000	230
3500	240
4000	245
4500	250

Table 2. Utilization factor for inorganic soil N.

Nitrogen Applied Kg/ha	Soya bean Utilization %	Babala Utilization %
0	93	94
50	79	88
100	62	66
150	42	53

Table 3. Nitrogen mineralised by different soils at different locations (0 and 13 weeks).

Locality	Sample	Soil Depth			Total
		0 - 300	300 - 600	600 - 900	Kg/ha
Vaalhartz	Begin[1] mg/kg	4.5	3.8	6.2	
	End[2] mg/kg	9.0	8.8	10.8	
	Miner[3] mg/kg	4.5	5.0	4.6	
	Kg/ha	18	20	18.4	56.4
Loskop	Begin[1] mg/kg	18.6	8.4	5.3	
	End[2] mg/kg	28.6	19.2	15.8	
	Miner[3] mg/kg	10.0	10.8	10.5	
	Kg/ha	40.0	43.2	42.0	125.2
Rustenburg	Begin[1] mg/kg	12.0	8.0	6.0	
	End[2] mg/kg	28.0	20.0	17.0	
	Miner[3] mg/kg	16.0	12.0	11.0	
	Kg/ha	64.0	48.0	44.0	156.0

[1] Begin: Inorganic N-content at week 0; [2] End: Inorganic N-content at week 13
[3] Miner: N-mineralisation during incubation period

Table 4. Organic N mineralisation to 90 cm depth.

Soil Texture	Nitrogen Mineralisation kg/ha
Sand	60
Loam	120
Clay	160

Table 5. Calculated N-requirements on two locations.

Inorganic N	Depth mm	Vaalhartz mg/kg	Loskop mg/kg
	0 - 300	30	25
	300 - 600	8	9
	600 - 900	2	3
		Kg/ha	Kg/ha
		160	145
0.667		107	97
Mineralisation		60	120
0.667		40	80
Available		147	177
N Required		250	250
Shortfall		103	73
To Be Applied		129	91

Tables 6. Calculated N requirement at three locations in South Africa.

Inorganic N	Depth mm	Vaalhartz mg/kg	Loskop mg/kg	Rustenburg mg/kg
	300	7	14	30
	600	5	15	20
	900	9	11	15
		Kg/ha	Kg/ha	
		84	160	260
0.667		56	107	173
Mineralisation		60	120	160
0.667		40	80	120
Available		96	187	293
N Required		250	250	245
Shortfall		154	63	0
To Be Applied		193	79	0

Figure 1. Influence of N-amendments on seed-cotton yield.

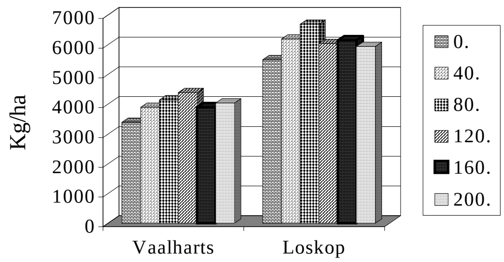

Figure 2. Influence of N-amendments upon seed-cotton yield.

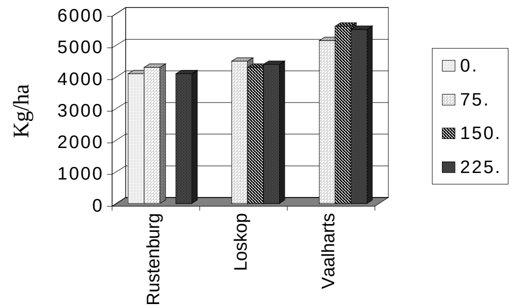

Figure 3. Linear regression of actual N-level applied against that predicted for a specified seed-cotton yield.