Effect of fertilizer form on cotton production under the alkaline clayey soil of Sudan Gezira

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ABSTRACT

The vertisols of the Gezira Scheme, Sudan, are characterized by high clay content low total nitrogen, organic matter and available phosphorous, high pH and poor physical properties. Cotton production depends on application of nitrogenous fertilizer at a rate of 86 kg N/ha in form of urea. Cotton yield depression and lack of response to urea were observed in Gezira. In a completely randomized block design experiments, other forms of fertilizers including Nitrophoska (NPK 18:18:5), ammonium sulphate nitrate (ASN 26% N + 14% S) and ammonium sulphate (AS 21 % N + 24 % S) were tested for cotton yield promotion in Gezira in comparison with the standard fertilization practice (urea). The seed cotton yield and nitrogen utilization efficiency (NUE) were higher for the tested fertilizers in comparison with the standard fertilization practice. This is mainly due to readily available form of nitrogen in the tested fertilizers for the crop uptake together with their content of more than one nutrient element necessary for the crop growth. The results obtained cast doubt about the efficiency of urea as a source of nitrogen for cotton production under the Gezira soil conditions.

Introduction

Cotton is one of the major cash crops in the Sudan and is the main rotation crop in Gezira Scheme. The total area of the Gezira Scheme is about 850000 ha out of which about 170000 ha are grown with cotton in a five course rotation *viz.*, cotton, wheat, groundnut, sorghum and fallow. Two types of cottons are grown in Gezira, which include medium staple cotton variety, Barac (67) and long staple cotton variety Barakat (90). Sowing of medium staple cotton starts on the first of July and continues until the end of the month, while that of long staple cotton extends from mid-July to mid-August. Nitrogen is the only nutrient applied for cotton production in Gezira. The recommended dose is 2N equivalent to (86 kg N/ha) in form of urea applied 6-8 weeks after sowing followed by green ridging and watering.

The Gezira soils belong to the central clay plain of the Sudan. They are classified as vertisols and characterized by high clay content, low nitrogen, organic matter and available phosphorus, with high pH and poor physical properties (Table 1).

Cotton production in the Gezira Scheme showed progressive decrease in average yield of seed cotton (Table 2) and farmers became reluctant to grow cotton, as it is a long season crop with low returns. A number of factors can be suspected for cotton yield depression and among these are soil fertility and fertilization. A fertile soil is that capable of providing the crop with 13 nutrient elements necessary for growth and development (Tandon, 1992). The most important of these nutrients is the nitrogen, which is absorbed from the soil under field conditions in the ionic form of NO_3^- and to a lesser extent as NH_4^+. Previous work has shown that cotton can respond well to nitrogenous fertilizers with readily available ionic form of nitrogen (Ali *et al.*, 1992). Results of analysis of xylem sap of cotton plant fertilized with urea indicated that NO_3^- was the main form of nitrogen translocated from the root to the shoot (Elshiekh, 1984). Urea nitrogen is in the amide form (-NH_2) and as such is useless to cotton plant unless transformed into a form suitable for the crop uptake. These transformation reactions of urea include a hydrolytic step brought about by the enzyme urease and two oxidative steps brought about by *Nitrosomonas* and *Nitrobacter*. These steps can be summarized as follows:

Urea urease > NH_4^+ *Nitrosomonas* > NO_2^- *Nitrobacter* > NO_3^-

Any factor adversely affecting this chain of urea transformation in the soil will ultimately reduce its efficiency as a source of nitrogen for crop growth.

For sustainable production the fertility of the soil should be maintained and this is either by incorporating the crop residues into the soil or application of suitable fertilizers that can replenish the nutrients that are removed by the different crops. The cropping pattern adopted in the Gezira Scheme, i.e. five course rotation is very extractive to the soil. This is because crop residues are never incorporated into the soil and usually taken for animal feeding or burned as the case with cotton to reduce disease carry over. In addition to this only a single nutrient fertilizer is being used for cotton production (urea) and other nutrients are completely ignored. Such practices can seriously affect soil fertility with concomitant crop yield depression.

A number of research experiments dealing with cotton nutrition were carried out at the Gezira Research Station and on farm. The results reported for these experiments did not indicate any fertilization practices that can effectively promote crop yield in Gezira. This work was reviewed by Ibrahim (1998) and one of the suggestions was to test different forms of fertilizers. The results of such tests are reported here

Experimental procedure

Researcher managed experiments were carried out at the Gezira Research Station Farm for seasons 2000/01 and 2001/02 to test the efficiency of three fertilizers for cotton yield promotion in comparison with the standard fertilization practice (2N urea). The tested fertilizers included the following:

1. Nitrophoska (NPK) 18% N (7.5% NO_3^--N + 10.5% NH_4^+-N): 18% P_2O_5 : 5 % K_20 with 3% S and 1.5% Mg plus trace elements making a total of 11 nutrient elements.
2. Ammonium sulphate nitrate (ASN): 26%N (9% NO_3^--N + 17% NH_4^+-N) + 14% S
3. Ammonium sulphate (AS) 21% NH_4^+-N + 24% S.

These fertilizers are manufactured by BASF Company-Germany and supplied by Danasidco Company-Sudan. The first season included 14 treatments (Table 3) replicated four times in a completely randomized block design experiments. In the second season the split application of fertilizers treatments were excluded and 1N urea treatment was introduced making a total of nine treatments replicated four times in a completely randomized block design experiments. Fertilization was either split application, i.e. first dose at sowing and the second dose applied six weeks after sowing or a single dose applied six weeks after sowing followed by green ridging and watering. Other cultural practices were as recommended for the Gezira Scheme. Seed cotton yield data were recorded and whole plant samples were analyzed for N and P uptake (Ali *et al*., 1992)

Results and Discussion

After about 22 weeks of growth composite samples of whole plant including all replicates for the two cotton varieties were taken from the second season experiments and the dry matter was recorded. The samples were then prepared for N and P determinations. The results are presented in Tables 4 and 5 for the medium and long staple cotton, respectively. The results were expressed on per area basis rather than concentration. This is meaningful in reflecting the actual uptake of N and P and eliminates artifacts arising from concentration caused by stunted plant growth or dilution caused by vigorous plant growth.

As seen in Table 4 for the medium staple cotton, the highest dry matter production was observed for the treatment receiving 2N NPK followed by 2N ASN treatment. There are no significant differences between the other treatments, which are all significantly different from the 0N treatment. The pattern of nitrogen uptake is almost similar to that of the dry matter production. This is in line with the earlier report that cotton can respond to nitrogenous fertilizers with readily available ionic form of nitrogen (Ali *et al*., 1992). Phosphorous uptake is highest for the treatment receiving 2N NPK followed by 2N of either ASN or AS. For NPK, P is one of its constituents, while for ASN and AS their SO_4^- component might have induced local reduction in soil pH resulting in release of unavailable soil P. Also the tested fertilizers NPK, ASN and AS contain some of the nitrogen or all of it in the NH_4^+ form. It was reported that during NH_4^+ nutrition, the pH at the root surface is decreased (Haynes and Goh, 1978). The presence of NH_4^+ in the tested fertilizers might have caused a local pH reduction, resulting in the mobilization of unavailable soil P for crop uptake.

Nitrogen recovery percentage was calculated by subtracting the total nitrogen of the ON treatment from that of the other treatments and then expressing the remainder as a percentage of the nitrogen applied (43 kg N in the case of 1N and 86 kg N in the case of 2N treatments). This parameter is useful in reflecting the efficiency of the fertilizer in supplying the crop with its nitrogen requirement. Generally, irrespective of the nitrogen dose, the NPK treatments scored the highest nitrogen recovery followed by ASN and AS while urea treatments showed the least recovery. This is expected; because the nitrogen content of the fertilizers under test is in readily available form for the crop uptake, i.e. NH_4^+ or a combination of NH_4^+ and NO_3^- while that of urea is in the amide form (-NH_2) which requires the well known transformation reactions to take place in the soil. The product of urea hydrolysis by the enzyme urease is ammonium carbonate which is rather unstable molecule especially under alkaline conditions and can easily volatilizes as NH_3 and CO_2. The physical and chemical properties of the Gezira soil are not favoring the quantitative transformation of urea nitrogen into a form suitable for the crop uptake and losses through NH_3 volatilization are common (Musa, 1968; Ali *et al*., 1992) hence low nitrogen recovery by the crop. The patterns of dry matter production, N and P uptake and nitrogen recovery for long staple cotton are similar to those of medium staple cotton (Table 5).

Tables 6, 7, 8 and 9 show the seed cotton yield, nitrogen utilization efficiency (NUE) and the rank of the treatments according to seed cotton yield. The NUE is an important agronomic parameter in reflecting the efficiency of the fertilizer as a nitrogen source for crop production. It is calculated by subtracting the seed cotton yield of the ON treatment from that of the other treatments and the remainder is then divided by the amount of N applied. For the medium staple cotton (Table 6), the highest seed cotton yield was observed for the treatment receiving 2N NPK either splitted or applied as a single dose followed by 2N ASN. 1N treatments of NPK, ASN and AS are not significantly different from the standard treatment (2N urea) according to Duncan multiple range test. Split application of 2N AS gave yield higher than that of 2N AS applied as a single dose. This indicates the sensitivity of the crop to NH_4^+ nutrition when in high concentration. For the long staple cotton (Table 7), the highest seed cotton yield was shown by the treatments receiving 2N of ASN and NPK applied as a single or split dose. The lowest yields were observed for the treatments receiving the fertilizer AS. Since the nitrogen of AS is exclusively in the NH_4^+ form, this negative effect can be ascribed to volatilization losses and / or toxicity (Findenegg, 1987). The N.U.E values for the fertilizers NPK, ASN and AS are higher when compared to the standard fertilization practice (2N urea).

Tables 8 and 9 present the second season yield

data, NUE and treatments rank for the medium and long staple cottons, respectively. Split fertilizer application treatments were omitted, as their results were not significantly different from those of single dose application according to Duncan multiple range test. The results presented are almost confirming the first season results.

From the results obtained during this work, it can be concluded that cotton production under Sudan Gezira and other similar conditions can be improved when fertilizers with readily available form of nitrogen and containing more than one nutrient element necessary for growth are applied to the crop. Also long staple cotton is rather sensitive to high levels of NH_4^+ .For this reason split application of fertilizers containing nitrogen exclusively in the NH_4^+ form is recommended.

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Table 1. *Some chemical and physical properties of the Gezira soil.*

Character	Quantity
Clay %	55-65
Bulk density dry soil (kg/dm^3)	1.2-1.6
Wetting front (cm)	23
Infiltration rate (IR) cm/hr	1.7
CEC (cmol/kg soil)	54
ECe (dS/m) 0-30 cm	0.9
30-120 cm	3.2
ESP (0-30 cm)	6
PH	8.5
O.C. (%)	0.2-0.4
N (%)	0.15-0.3
Total P (ppm)	400-700
Available P (ppm)	4
$CaC0_3$ (%)	3.7

Table 2. *Average seed cotton yield (kg/ha) in Gezira Scheme for season 99/91 to 2001/02 (medium staple cotton).*

Season	Average yield (kg/ha)
90/91	1230
91/92	1870
92/93	1400
93/94	1270
94/95	1300
95/96	1370
96/97	1300
97/98	1470
98/99	1470
99/2000	770
2000/2001	1430
2001/02	1800

Table 3. *Treatments of the 2000/01season and time of fertilizer application.*

No.	Treatment	Time of application
1	ON	-
2	2N urea	6 weeks after sowing
3	1N NPK	6weeks after sowing
4	1N ASN	6weeks after sowing
5	1N AS	6 weeks after sowing
6	2N NPK	6 weeks after sowing
7	2N ASN	6 weeks after sowing
8	2N AS	6 weeks after sowing
9	1N NPK+1N NPK	1st dose at sowing + 2nd dose 6 weeks after sowing
10	1N NPK+1N ASN	1st dose at sowing +2nd dose 6 weeks after sowing
11	1N NPK+1N AS	1st dose at sowing + 2nd dose 6 weeks after sowing
12	1N urea + 1N urea	1st dose at sowing+ 2nd dose 6 weeks after sowing
13	1N ASN+1N ASN	1st dose after sowing + 2nd dose 6 weeks after sowing
14	1N AS+ 1N AS	1st dose after sowing+ 2nd dose 6 weeks after sowing

Table 4. *Dry matter production, N and P uptake (kg/ha) and N-recovery (%) for Barac(67)B during the 2001/02 season.*

No.	Treatment	D.M	N	$P_2 0_5$	N-recovery
1	ON	7110	131	17	0
2	1N urea	9007	153	22	50
3	1N NPK	11212	177	32	100
4	1N ASN	9248	172	23	95
5	1N AS	8152	163	26	74
6	2N urea	9771	188	22	66
7	2N NPK	15676	217	42	100
8	2N ASN	13038	215	37	98
9	2N AS	12976	204	37	84
Mean		10688	180	29	-
SD±		2579	29	9	-

Table 5. *Dry matter production, N and P uptake (kg/ha) and N-recovery (%) for Barakat season 2001/02.*

No.	Treatment	D.M	N	$P_2 0_5$	N-recovery
1	ON	114776	165	32	0
2	1N urea	14529	189	33	57
3	1N NPK	14271	203	39	90
4	1N ASN	14198	200	34	81
5	1N AS	13231	195	35	71
6	2N urea	15129	215	47	58
7	2N NPK	18652	246	59	95
8	2N ASN	19064	242	52	90
9	2N AS	15810	240	50	87
Mean		15151	211	42	-
SD±		2431	28	10	-

Table 6. *Effect of fertilizer form and nitrogen rate on seed cotton yield (kg/ha) and NUE (kg seed cotton/kg N) for Barac(67)B during the 2000/01 season.*

No.	Treatment	Yield*	N.U.E.	Rank
1	ON	2236 e	0	14
2	2N urea	2550 de	4	12
3	1N NPK	2902 cde	16	8
4	1N ASN	2667 cde	10	10
5	1N AS	2631 cde	9	11
6	2N NPK	3895 ab	19	2
7	2N ASN	3445 abc	14	3
8	2N AS	2438 de	2	13
9	IN NPK+1N NPK	4160 a	22	1
10	1N NPK+1N ASN	3250 abc	12	6
11	1N NPK+1N AS	3014 cde	9	7
12	1N urea+1N urea	2862 cde	7	9
13	1N ASN+1N ASN	3395 abc	14	5
14	1N AS+1N AS	3431 abc	14	4
C.V. (%)		14.2	-	-
S.E.		251	-	-

*Means within the column having the same letter are not significantly different.

Table 7. *Effect of fertilizer form and nitrogen rate on seed cotton yield (kg/ha) and NUE (kg seed cotton/kg N), Barakat season 2000/01.*

No.	Treatment	Yield*	N.U.E.	Rank
1	ON	926 g	0	13
2	2N urea	1367 defg	5	9
3	1N NPK	1750 bcdef	19	7
4	1N ASN	1250 efg	8	11
5	1N AS	1150 fg	5	12
6	2N NPK	1950 abcd	12	4
7	2N ASN	2550 a	19	1
8	2N AS	926 g	0	13
9	IN NPK+1N NPK	2250 ab	15	2
10	1N NPK+1N ASN	1950 abcd	12	4
11	1N NPK+1N AS	1876 bcde	11	6
12	1N urea+1N urea	1543 cdefg	7	8
13	1N ASN+1N ASN	20883 abc	14	3
14	1N AS+1N AS	1326 defg	5	10
C.V. (%)		21.4	-	-
S.E.		202	-	-

* Means within the same column having the same letters are not significantly different.

Table 8. *Effect of fertilizer form and nitrogen rate on seed cotton yield (kg/ha) and NUE (kg seed cotton/kg N) for Barac (67)B during the 2001/02 season.*

No.	Treatment	Yield*	N.U.E.	Rank
1	ON	1762 e	0	9
2	1N urea	2357 d	16	8
3	1N NPK	2876 bcd	28	4
4	1N ASN	2538 cd	20	7
5	1N AS	2664 bcd	23	6
6	2N urea	2700 bcd	12	5
7	2N NPK	3729 a	24	1
8	2N ASN	3214 ab	18	2
9	2N AS	3081 bc	16	3
C.V. (%)		14-4	-	-
S.E.		196	-	-

* Means within the same column having the same letters are not significantly different.

Table 9. *Effect of fertilizer form and nitrogen rate on seed cotton yield (kg/ha) and NUE (kg seed cotton/kg N), Barakat season 2001/02.*

No.	Treatment	Yield*	N.U.E.	Rank
1	ON	1236 d	0	9
2	1N urea	2088 c	20	7
3	1N NPK	2429 bc	28	3
4	1N ASN	2138 c	21	6
5	1N AS	2033 c	19	8
6	2N urea	2248 bc	12	5
7	2N NPK	3010 a	21	1
8	2N ASN	2555 ab	15	2
9	2N AS	2343 bc	13	4
C.V. (%)		11-3	-	-
S.E.		126	-	-

* Means within the same column having the same letters are not significantly different.