Effects of Organic and Inorganic Nitrogen Fertilizer Applications on Cotton Yield, Quality and Soil Properties in Gezira, Sudan

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ABSTRACT

A factorial field trial investigating the effects of farm yard-manure (FYM) and urea application on cotton yield, quality and soil properties was conducted on a Vertisolic soil, low in organic matter, using cultivar Acala 93-H, for 3 consecutive seasons (1995-98) at the Gezira Research Station in Sudan. The FYM was given at 3 levels (0, 10, and 20 t/ha), while urea was at the rates (0, 21.5, 43.0, 64.5 and 86.0 kg N/ha). Both FYM and urea application significantly increased cotton fiber yield. Application of 20t FYM+43 kg N/ha gave the optimum cotton fiber yield (908 kg/ha) and outyielded the standard control (86 kg N/ha) by 10.1%. Urea and FYM application had no significant effects on most of the fiber properties. FYM reduced bulk density, and increased the hydraulic conductivity, total nitrogen and organic carbon of the top 30 cm of soil. The proposed practice (20t FYM+43kg N urea/ha) has definitely reduced the cost of inorganic nitrogen fertilizer and improved the soil conditions.

Introduction

The Gezira Scheme of the Sudan is one of the largest agricultural schemes in the world (925K ha). Cotton, the major cash crop of the Sudan, is grown with wheat, groundnuts and sorghum in a five-course rotation (cotton-wheat-groundnuts-sorghum-fallow). The soil of the Gezira Scheme is a heavy, cracking clay belonging to the Vertisol order. The mean pH of this soil is 8.2 and it is poor in organic matter and, as such, it has inadequate supplies of some essential nutrients particularly nitrogen. The physical properties of this soil (e.g. hydraulic conductivity, permeability) are low while the bulk density is rather high. The cropping system adopted in the Gezira Scheme does not allow for the build up of high levels of organic matter as all crop residues are either removed or burned.

Earlier research workers in Sudan had realized this problem of the low level of the organic matter of the Gezira soil. Greene and Bailey (1930-40) conducted a series of experiments whereby they tested cotton seed cake or meal, animal dung and ammonium sulphate. Their results showed that the organic fertilizer resulted in higher seed cotton yields than the inorganic fertilizer. Other organic fertilizers such as green manure, cover crops, compost and FYM were evaluated as fertilizers (Rai 1966; Musa and Fuwzi 1969; Mukhtar 1988/89; Ibrahim 1995).

In India, manures versus inorganic fertilizers were tested on Vertisolic soils. The result of these experiments showed that manure application increased crop yields, organic carbon, organic nitrogen, pore space, hydraulic conductivity, aggregate stability and available water and it decreased the bulk density and pH of the these soils. (Shinde and Ghosph, 1971; Biswas and Khosla, 1971).

The objectives of this study were to determine the effects of FYM and urea on : (1) the yield and quality of cotton fiber. (2) soil properties.

Material and Methods

This experiment was conducted at the experimental farm of the Gezira Research Station. The soil of the research farm represents most of the Gezira Scheme soils and is classified as fine smectitic, isohyper-thermic, chromic haplusterts (USDA, 1996). Some of the physical and chemical properties of this soil are: total sand 18% ; Silt 25%; Clay 57%; pH 8.2; ESP 8.5; EC 1.0 dS/m; CEC 54 m.e./100g soil; Total N 320 ppm; organic carbon 0.295%; Sodium bicarbonate extractable P 3 ppm.

There were two major treatments namely, (A) Farm yard manure, (FYM) application and (B) Urea (46% N) application. The manure used in this experiment was collected from the dairy of the Gezira Research Station where cattle are being kept. The manure contains N =1.5%; total P = 0.5%, carbon = 18% and C/N = 12. It was air-dried under the shade and then crushed into small pieces. There were 3 FYM treatments; M_0 = Zero t FYM /ha ; M_1 = 10 t FYM and M_2 = 20 t FYM/ha. Urea was given at 5 rates; N_0 = Zero kg N ; N_1= 21.5 kg N ; N_2= 43.0 kg N; N_3= 64.5 kg N and N_4= 86.0 kg N/ha.

A factorial experiment with the following 15 combinations was used:

M_0N_0; M_0N_1; M_0N_2; M_0N_3; M_0N_4; M_1N_0; M_1N_1; M_1N_2; M_1N_3; M_1N_4; M_2N_0; M_2N_1; M_2N_2; M_2N_3; M_2N_4.

The FYM was incorporated into the soil by a disc harrow prior to sowing. Cotton, variety Acala 93-H, was sown in experimental plots, each of on area of 5.6 x 4 (22.4 m2). The cotton was sown at a spacing of 80 cm between ridges and 50 cm between hills with 5 seeds per hill during the first week of August. The crop was thinned to 2-3 plants per hill at 6 weeks, after which urea was applied, followed by re-ridging to incorporate the fertilizer. The trial was cultivated three times and irrigated every 14 days. Cotton picking commenced in late November and was completed by February after three picks. After picking, soil samples were taken from the top 30 cm of each experimental plot for total-nitrogen, organic carbon and hydraulic conductivity determinations. Soil bulk density of the top 30 cm was determined in situ by the core method.

Fiber tests included seed index, lint index, fiber length (mm) (HVI 2.5 % span length), and HVI fiber bundle strengths and micronaire values.

Results and Discussion

The results of this experiment are reported in Tables 1 - 7. Manure and urea application significantly increased fiber cotton yield in all the seasons (1995-1998) (Table 1). There was a significant interaction between manure and urea application in 1996-97. Treatment M_2N_3 (20t FYM + 64.5 kg N/ha) attained the highest fiber yield and outyielded the standard practice, M_0N_2 (86.0 kg N/ha) by 62% in season (1995-96). In season 1996-97, treatment M_1N_4 (10 FYM + 86 kg N/ha) attained the highest fiber yield and outyielded the standard practice by 12% (Table 1). The cotton yields in this season (1996-97) were lower than in the other two seasons because the cotton plants suffered from continuous water logging for 4 weeks. Season 1997-98 gave the highest cotton yields compared with the other two seasons (1995-96 and 96-97). Treatment M2N4 (20t FYM + 86 kg N/ha) attained the highest fiber yield (Table 1). When the results of the 3 seasons were subjected to combined analysis, it was found that there were no significant differences between the following high yielding treatments: M_2N_3, M_2N_4, M_1N_4, and M_2N_2 which outyielded the standard practice by 15.3, 14.3, 11.3, and 10.1% respectively (Table 2). In this context, treatments M_2N_2 (20t FYM + 43 kg N/ha) is taken as optimum for practical use because of the lower quantity of urea compared with other treatments attaining the highest cotton fiber yields.

The leaf petiole NO_3-N of the 4th leaf, from the top, which was taken just before the application of urea (40 days from sowing) was: Control (No FYM) = 11000 ppm; M_1 (10t FYM/ha) = 19000 ppm. M_2 (20t FYM/ha) = 23000 ppm. The manure-treated plants had very high leaf petioles NO_3-N levels, indicating a better nitrogen nutrition at six weeks than the control plants.

Farmyard manure and urea application had no significant effects on the cotton fiber characteristics. However, the manure application increased fiber bundle strength (Table 3).

Application of FYM and urea significantly increased the total-nitrogen content of the top 30 cm of the soil in the two seasons (1995-96 and 96-97) (Table 4). There was a significant interaction between the manure and urea in season 1995-96 (Table 4). On the other hand, manure application significantly increased the organic carbon of the top 30 cm of soil in both seasons, while urea significantly increased the organic carbon in season 1997-98 (Table 5). Manure application significantly decreased the bulk density and increased the hydraulic conductivity of the top 30 cm (Tables 6 and 7). Although the decrease in bulk density between the two levels of manure application (M_1 and M_2) was not large, the difference in the increase in hydraulic conductivity due to FYM between the two levels was large and highly significant.

Root penetration, aeration, soil-plant-water relationships and crop nutrition have probably improved greatly, particularly with the highest level of manure (20t/ha), due to the improvement brought about by FYM in the physical and chemical soil properties and the nutrients provided by the manure. This has provided a better environment, resulting in better crop growth and higher cotton yields. It is worthy of note that the animal population of the Gezira Scheme is around 1.75 million cattle, sheep and goats. These are more or less in equal proportions. There are also a substantial number of donkeys and few camels. This animal population can provide a great deal of manure.

In conclusion, this study demonstrates clearly the benefits of the addition of FYM in improving the physical, chemical and nutrient status of the Vertisolic soil of the Gezira Scheme, resulting in higher cotton yield. This is in addition to the savings made in the fertilizer quantities used with all its merits (i.e. economical, environmental).

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Table 1. Effect of the FYM and urea application on the yield of cotton fiber (kg/ha). Seasons1995-96, 96-97 and 97-98.

Season 1995-96				
	M_0	M_1	M_2	Mean
N_0	551.7 E	756.0 BCD	759.3 BCD	689.0
N_1	590.0 E	735.7 CD	832.0 BC	719.2
N_2	643.0 DE	831.3 BC	814.0 BC	762.8
N_3	741.0 BCD	856.3 BC	1041.0 A	879.4
N_4	791.7 BC	880.3 BC	888.0 B	853.3
Mean	663.5	811.9	866.9	
S.E.± N = 22.63;	M = 5.36;	M x N = 43.91 n.s.		
Season 1996-97				
	M0	M1	M2	Mean
N0	524.7 H	599.0 G	668.0 DEF	597.2
N1	616.0 FG	644.0 EFG	703.3 DE	654.4
N2	694.3 DE	706.7 ABCD	723.3 ABCD	708.1
N3	709.3 BCDE	771.7 AB	696.7 DE	725.9
N4	768.3 ABC	775.3 A	716.7 ABCD	753.4
Mean	662.5	699.3	702.2	
S.E. ± N = 5.97;	M = 699.3;	M x N = 19.39		
Season 1997-98				
	M0	M1	M2	Mean
N0	600.7 D	917.3 BC	946.3 BC	821.4
N1	761.3 CD	951.7 BC	1077.0 AB	930.0
N2	905.3 BC	1084.3 AB	1185.0	AB1058.2
N3	938.0 BC	1037.0 AB	1113.0 AB	1029.0
N4	913.0 BC	1097.0 AB	1222.0 A	1077.3
Mean	803.7	1015.5	1108.7	
S.E. ± N = 21.38;	M = 24.48;	M x N = 62.94 n.s.		

Table 2 . Effect of FYM and urea application on the cotton fiber yield, (kg/ha) (combined analysis, average of 3 seasons, 95-96, 96-97,97-98).

	M_0	M_1	M_2	Mean
N_0	557.9 F (-32)[1]	757.3 D (-8.1)	791.3 CD (-4.0)	702.2
N_1	655.8 C (-20.4)	771.0 D (-6.5)	870.8 ABC (5.6)	765.9
N_2	747.6 D (-9.3)	874.1 ABC (6.0)	907.7 A (10.1)	843.1
N_3	796.3 CD (-3.4)	888.4 AB (7.8)	950.2 A (15.3)	878.3
N_4	824.3 BCD	917.7 A (11.3)	942.0 A (14.3)	894.7
Mean	716.38	841.7	892.4	

[1] % increase in fiber yield over standard practice, M_0N_2 (86 kg N/ha) is shown in the brackets

Table 3. Effect of FYM and urea application on fiber characteristic (1997/98).

Treatments	Seed index	Lint index	Fiber Length (mm)	Fiber Bundle Strength	Micronaire Value
M_0N_0	12.27	6.53	30.28	25.55	4.36
M_0N_1	12.31	6.30	29.81	25.43	4.10
M_0N_2	12.65	6.87	30.03	24.96	4.52
M_0N_3	12.63	6.44	30.42	25.74	4.52
M_0N_4	12.53	6.55	30.44	26.16	4.34
M_1N_0	12.17	6.46	30.57	26.21	4.20
M_1N_1	11.87	6.27	30.38	27.16	4.17
M_1N_2	12.13	6.71	30.07	27.16	4.24
M_1N_3	12.25	6.43	30.26	27.07	4.00
M_1N_4	11.89	6.05	30.07	27.49	4.11
M_2N_0	12.33	6.38	30.17	24.64	4.41
M_2N_1	12.57	6.36	29.76	26.04	4.08
M_2N_2	11.07	5.90	29.85	26.58	3.86
M_2N_3	12.13	6.50	30.06	26.02	4.29
M_2N_4	12.32	6.14	30.10	26.21	4.14

Table 4. Effect of the levels of FYM and urea application on the soil total nitrogen (ppm) of the 0-30 cm depth (season 1995-96 and 1997-98).

	Season 1995-96			
	M0	M_1	M_2	S.E. Mean (N= 3.10)
N_0	313	366	453	377
N_1	322	357	467	382
N_2	322	364	462	383
N_3	331	373	471	392
N_4	346	373	464	395
Mean	327	367	464	
S.E. ± M = 6.20;	M X N = 5.4			
	Season 1997-98			
	M_0	M_1	M_2	S.E. Mean (N= 4.6)
N_0	365 C	408 AB	410 AB	394
N_1	370 C	416 AB	406 AB	397
N_2	399 AB	420 AB	408 AB	409
N_3	397 B	408 AB	425 A	410
N_4	399 AB	417 AB	418 AB	411
Mean	386	414	413	
SE ± M = 2.9;	M X N = 4.6 n.s.			

Table 5. Effect of the levels of FYM and urea application on the soil carbon (%) of the 0-30 cm depth, (season 1995-96 and 1997-98).

	Season 1995-96			
	M_0	M_1	M_2	S.E. Mean (N= 0.006 n.s.)
N_1	0.296	0.329	0.384	0.336
N_2	0.293	0.324	0.377	0.331
N_3	0.304	0.305	0.356	0.322
N_4	0.296	0.327	0.391	0.338
N_5	0.300	0.321	0.373	0.331
Mean	0.298	0.321	0.376	
S.E. ± M= 0.014;	M x N = 0.01			
	Season 1997-98			
	M_0	M_1	M_2	S.E. Mean (N= 0.006 n.s.)
N_1	0.338 F	0.447 CD	0.456 BC	0.414
N_2	0.333 F	0.430 CDE	0.459 BC	0.407
N_3	0.367 DEF	0.515 ABC	0.540 AB	0.474
N_4	0.357 EF	0.472 BC	0.514 ABC	0.448
N_5	0.356 G	0.431 CDE	0.585 A	0.457
Mean	0.350	0.459	0.511	
S.E. ± M = 0.010;	M x N = 0.026			

Table 6. Effect of the levels of FYM and urea on the bulk density (g cm-3) of the 0-30 cm depth (1997-98).

	M_0	M_1	M_2	(S.E. Mean (N= 0.006 n.s.)
N_1	1.52 A	1.44 BC	1.42 C	1.46
N_2	1.52 A	1.42 C	1.39 C	1.44
N_3	1.49 AB	1.41 C	1.40 C	1.43
N_4	1.49 AB	1.41 C	1.40 C	1.43
N_5	1.49 AB	1.42 C	1.40 C	1.44
Mean	1.50	1.42	1.40	
S.E. ± M = 0.014;	M x N = 0.01			

Table 7. Effect of the levels of FYM and urea on the hydraulic conductivity (cm/hour) of the 0-30 cm depth (1997-98).

	M_0	M_1	M_2	(S.E. Mean (N= 0.006 n.s.)
N_1	1.31 E	2.22 D	2.58 CD	2.04
N_2	1.13 E	2.58 CD	2.17 AB	2.29
N_3	1.23 E	2.71 BCD	2.92 ABC	2.29
N_4	1.37 E	2.34 D	3.23 A	2.31
N_5	1.28 E	2.61 CD	3.10 ABC	
Mean	1.26 E	2.49	3.00	
S.E. ± M = 0.107;	M x N = 0.161			