Effect of Tillage on Soil Properties and Cotton (Gossypium Barbadence L) Yield in Sudan Gezira

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ABSTRACT

The effects of three tillage practices (minimum tillage7cm depth, conventional tillage 15cm depth, and deep tillage 50 cm depth) on some soil physical properties and Cotton (Gossypium barbadence L.) performance and yield were studied at the Gezira Research Station Farm , at Wad Medani during 1989/ 1990 season. It was found that bulk density values were not significantly different at the upper depths (0-15 cm and 15-30 cm) but at 45-60 cm depth bulk density was significantly lower under deep tillage than under minimum tillage .conventional tillage resulted in higher bulk density compared to deep tillage but the differences were not significant. The differences between conventional tillage and minimum tillage were not significant. Soil penetration resistance was periodically measured to 40 cm depth. At all measurement periods, deep tillage resulted in the lowest soil penetration resistance (SPR) for all depths followed by minimum tillage and conventional tillage. There were no significant differences in SPR between tillage practices at the upper depths (10-20 cm and 20-30 cm), while at the lower depth (30-40 cm) tillage treatments were significantly different. It was found that moisture depletion decreased with increasing depth for all measurement periods. Maximum depletion was limited to the top 30 cm for all treatments. Results showed no significant differences between tillage treatments but moisture depletion under deep tillage was higher compared to conventional and minimum tillage. No significant differences were observed in infiltration rate, wetting front depth and cumulative intake between the treatments 28 weeks after sowing however, deep tillage improved soil infiltration over conventional and minimum tillage after 5 hours. Results showed that roots under deep tillage were bigger, and were not subjected to deformation compared to those under conventional and minimum tillage. Deep tillage produced significantly higher root dry weight followed by conventional and minimum tillage .At135 days after sowing; roots under deep tillage were significantly longer than those under minimum and conventional tillage. Plant height under different tillage systems was significantly different. At 135 days after sowing, deep tillage produced taller plants and heavier shoots dry weight followed by conventional and minimum tillage. Different tillage practices significantly influenced cotton yield. Deep tillage produced significantly higher yield over minimum tillage .Although, there were no significant differences between conventional and deep tillage, the latter produced higher yield. There were no significant differences between minimum and conventional tillage. Cotton yield, however, was lowest in plots with minimum tillage.

Keywords: *Tillage, soil physical properties, cotton, Gezira, Sudan*

1. INTRODUCTION

Cotton (Gossypium sp) is the most important cash crop in the Sudan. It is grown in most irrigated and some rain fed areas. The total cotton growing area is about 420000 ha. Variations in yield of cotton in Sudan Gezira have been known science the early years of the scheme. The fluctuations in cotton yield have been attributed to many factors which are vulnerable to variation from season to another and which may cause consequent variable effects on cotton yield. These factors can be divided into two main categories, uncontrollable factors which include climatic and soil factors. Controllable factors which include cultural practices and management. Adequate control of the latter factors would lead to consistent high yield. Seedbed preparation has an important role in modifying the soil conditions especially with regard to its physical properties. In Gezira, tillage for cotton is made by the 3-bottom disc. Sometimes, only ridging is done followed by hand sowing of cotton seeds when implements are not available, the continuous use of the 3-bottom disc which give tillage depth of less than 15 cm and rough soil surface together with using ridging alone had contributed greatly to deterioration of cotton yield. It has been realized for many years that low productivity of land may be associated with unfavorable physical conditions for plant growth. Root growth is affected by soil physical conditions, optimum crops yield are dependent upon optimum root growth. When the soil is in a good physical condition, the root system can grow extensively into the soil. Undesirable compaction levels may be due to soil forming factors, or to agricultural machines and transportation vehicles used in the seedbed preparation and harvesting of crops. These operations are accompanied by application of pressures to the soil which can be high enough to cause compaction. Another important factor which can cause a compacted layer is the continuous use of plows provided the depth of plowing remains constant for a long time. Furthermore, the effect of the plow itself and the influence of tractor wheels may hasten compaction. Extensive compaction is believed to cause, or is at least partially responsible for decreasing the productivity of soils. Naturally occurring soil compaction or plowing induced compaction have been shown to restrict root growth and water infiltration consequently affecting yield. As soil factors are considered to be the main factors causing fluctuation in cotton yield, attempts have been made to solve this problem by using tillage to improve soil physical properties and hence plant growth and yield. The study was conducted to evaluate the effect of different tillage practices on some soil physical properties and to relate variations in these soil physical properties to cotton performance, root development and yield.

2. MATERIALS AND METHODS

The experiment was conducted at the Gezira Research Station Farm at Wad Medani during the 1989/1990 season. The soil of the experimental plots was classified as fine montomorillonitic isohyperthermic Entic Chromusterts, Suliemi series [14].A soil profile was dug and soil samples were collected for physical analysis. Three tillage treatments were used (A) disc harrowing to 7 cm depth as minimum tillage (MT), plowing with the (B) 3-bottom disc to 15 cm depth followed by harrowing once for fine seedbed as conventional tillage (CT) and (C) sub-soiling to 50 cm depth followed by harrowing twice as deep tillage (DT).The total experimental area was 3feddans (1.26 hectare) divided into 18 plots, each was 100m × 7m, consisting of 8 ridges 80cm apart and 100m long. 'Barakat' long stable cotton (Gossypium barbadence L.) was manually sown. Randomized complete block design with 6 replicates was used .Soil physical parameters such as soil strength, bulk density, moisture depletion, infiltration rate and measurements for growth analysis were done. Soil strength was determined as resistance to penetration, it was measured periodically at 1, 16, 22 and 28 weeks after sowing (WAS).Proving ring penetrometer was used for measuring soil penetration resistance (SPR) as described by [4], readings were taken per plot to a depth of 40 cm at 10 cm interval, with corresponding moisture content determined gravimetrically to the same depths and intervals. The pentrometer readings were taken at field capacity (3 to 4 days after irrigation). Measurement of moisture content was done at 15 cm intervals to 90 cm depth, for moisture determination a neutron moisture meter (Troxler Model 3322) was used as described by [7]. Readings were taken at field capacity (3 to 4 days after irrigation) and just before subsequent irrigation. Moisture depletion during this period was calculated for each depth, and the soil moisture depletion profile was obtained. Bulk density was determined in the laboratory by the clod method and sand method was used to determine bulk density in the field as described by [3]. Infiltration rate was determined before treatments application and at the end of the season; a double ring infiltrometer as described by [10] was used. The measurement was terminated when steady state was reached (usually 5 hours).The depth of the wetting front was determined using steel rod. For growth attributes measurements five plants were randomly selected from each plot, plant height was measured periodically at 45, 75, 105, and 135 days after sowing (DAS).Root length was also measured for the same period. Samples for yield were taken from each plot with a sampling area of 6m × 10m , yield was obtained from the center 6 rows of each sampling area. Three pickings were done manually and the gross yield was calculated for each treatment. Analysis of variance and test of significance were made according to the standard procedure for randomized complete block design [15]. Means were differentiated according to Duncan's Multiple Range Test.

3. RESULTS AND DISCUSSON

3.1 Soil Physical Properties

Table 1 shows some of the physical properties of the soil for six depths. These were determined at the beginning of the study before tillage treatments were applied .The clayey soil on which this work was carried out has high bulk density (1.64 to 1.90 g cm^{-3},clod method),high water retention at low suction(-⅓ bar) between 38% to 47% and between 20% to 24% at high suction (-15 bars).Hydraulic conductivity for the upper depths (0-15 cm and 15-30 cm) was moderate (1.65 and 0.83 cm hr^{-1}), while it was very low at the lower depths from30 cm to 90 cm (0.22 to 0.02 cm hr^{-1}).Tillage affected bulk density ,at 215 days after sowing for different treatments ,bulk density increased with depth. At most depths, minimum tillage gave the highest bulk density except at 15-30 cm depth .Table 2shows that measurements were not significantly different at 0-15 and 30-45cm depths. At 45-60 cm depth deep tillage was significantly different ($p \geq 0.05$) from minimum tillage but there was no significant different between deep and conventional tillage .Values increased with depth but decreased with increasing cultivation .At 15-30 cm depth conventional tillage had the highest value probably due to the plowing effect which was induced by the 3- bottom disc used. At all depths, deep tillage had the lowest bulk density followed by conventional tillage and minimum tillage. This may have been due to soil loosening at these depths, this supported by [5] findings.

Table 1: Some physical properties of the soil used

Depth(cm)	Mechanical analysis			Bulk density (gm cm^{-3})	Hydraulic conductivity (cm hr^{-1})	Moisture retention %	
	Clay%	Silt%	Sand%			-⅓ bar	-15 bar
0-15	53	32	15	1.64	1.65	30	20
15-30	55	32	13	1.74	0.83	40.6	21.3
30-45	52	35	13	1.87	0.22	41.7	22.1
45-60	57	32	11	1.86	0.06	44	23.1
60-75	56	31	13	1.86	0.03	47	24.8
75-90	55	31	14	1.90	0.02	43.4	21.2

Table 2: Effect of tillage on dry bulk density (gm cm $^{-3}$) 215 DAS*

Treatments	Depth (cm)			
	0-15	15-30	30-45	45-60
A(MT)	1.07** a	1.11 b	1.42 c	1.46 a
B(CT)	1.04 a	1.18 b	1.40 c	1.44 ab
C(DT)	1.05a	1.09 b	1.31 c	1.36 bc
S.E ±	0.02	0.04	0.03	0.03
C.V%	4.7	8.9	6.16	5.76

Means within the same column having the same letter are not significantly different at $p \geq 0.05$ according to Duncan's Multiple Range Test.
MT- minimum tillage
CT- conventional tillage
DT- deep tillage
*DAS- Days after sowing
** Each data point is the arithmetic mean of 18 readings

Penetrometer readings provide some measure of the energy that must be exerted by the young seedling to emerge from the soil and the root to penetrate into the soil. Results in Table 3a showed that at 16 WAS, no significant differences were obtained in SPR between tillage treatments at the upper depths ,but the deep tillage has the lowest value of resistance to penetration followed by conventional and minimum tillage .At 40 cm depth, deep tillage was significantly (p 0.05) different from the minimum tillage. Although deep tillage has lower values of SPR than conventional tillage, they were not statistically different. Table 3c shows the same results of those in Table 3b.At the upper depths there were no significant differences between treatments, while at 40 cm tillage treatments differed significantly (p 0.01) from each other, that is to say minimum tillage showed the highest values of penetration resistance followed by conventional tillage . The lowest values were obtained under deep tillage. At 30 and 40 cm depth, penetration resistance values following minimum tillage were higher than values obtained for either treatment. Deep tillage resulted in lower penetration resistance values than other treatments which did not cause any loosening at these depths. Table 3d shows that at 10 cm depth , there were no significant differences between treatments, while at 20 cm depth ,SPR under minimum tillage was significantly higher ($p \geq 0.01$) than other treatments. At 30cm depth, there were no significant differences between treatments. At 40 cm depth, however, deep tillage had significantly lower ($p \geq 0.01$) SPR (0.63 MPa) than conventional (0.76 MPa) and minimum tillage (0.74 MPa).This study showed that deep tillage resulted in lower soil penetration resistance , most probably because of soil loosening at the lower depths. Similar results were reported by [12]. That tillage was found to decrease soil penetration resistance significantly.

Table 3: Effect of tillage on soil penetration resistance (MPa)

a. One week after sowing				
Treatments	**Depth (cm)**			
	10	20	30	40
A (MT)	0.33* a	0.38 b	0.50 e	0.67 ab
B (CT)	0.34 a	0.41 b	0.51 e	0.71 a
C (DT)	0.30 a	0.34 b	0.39 e	0.45 c
S.E ±	0.02	0.02	0.03	0.04
C.V%	13.72	12	18.18	16.64
b. 16 weeks after sowing				
A (MT)	0.55 a	0.55 b	0.62 e	0.71 a
B (CT)	0.52 a	0.55 b	0.56 e	0.60 b
C (DT)	0.49 a	0.53 b	0.53 e	0.58 bc
S.E ±	0.03	0.02	0.03	0.03
C.V%	12.6	9.6	13.66	12.79
c. 22 weeks after sowing				
A (MT)	0.49 f	0.54 g	0.60 h	0.73 a
B (CT)	0.42 f	0.46 g	0.59 h	0.68 b
C (DT)	0.44 f	0.49 g	0.55 h	0.59 c

S.E ±	0.03	0.03	0.02	0.01
C.V%	15.5	15.7	7.1	5.8
d. 28 weeks after sowing				
A (MT)	0.29 d	0.47 a	0.60 f	0.74 ab
B (CT)	0.29 d	0.36 b	0.59 f	0.76 a
C (DT)	0.29 d	0.39 bc	0.53 f	0.63 c
S.E ±	0.01	0.01	0.04	0.02
C.V%	10	8.6	15.4	6.3

Means within the same column having the same letter are not significantly different at $p \geq 0.05$ according to Duncan's Multiple Range Test.

* Each data point is the arithmetic mean of 18 readings

Results in Table 4 showed that there were no significant differences in moisture depletion during the measurement periods. Similar results were obtained by [6] and [13] who found no significant differences between the levels of soil moisture at specified depth. Results in Table 5 shows no significant differences in the intake rate after 5 hours infiltration, however, deep tillage gave the highest value. These results gave evidence that tillage operations increases infiltration, most probably because of loosening. This agrees with the findings that sub soiling to more than 45 cm depth improved infiltration [16 and 11], but the results of the study, however, contradicted with [18]who reported that the infiltration rate of two tropical soils was found to decrease after plowing and tillage operations. After 5 hours, cumulative intake showed no significant differences between treatments (Table 5), however, deep tillage gave the higher value followed by conventional tillage and minimum tillage. Deep tillage resulted in deepest wetting front compared to conventional tillage and minimum tillage, although, the differences were not significant. The results gave strong evidence that tillage enhanced infiltration of water, which agrees with results obtained by [16] and [11].

Table 4: Effect of tillage on moisture depletion (kgm^{-3} day^{-1})

Treatments	Weeks after sowing						
	7	15	17	19	22	24	27
A (MT)	23.6* a	20.36 b	18.79 c	13.79 d	11.13 e	10.07 f	11.04 g
B (CT)	23.9 a	18.43 b	23.02 c	15.29 d	14.32 e	11.18 f	10.84 g
C (DT)	24.9 a	17.15 b	22.32 c	15.52 d	13.18 e	12.97 f	11.63 g
S.E ±	3.15	1.78	2.99	0.74	1.29	1.17	1.79
C.V%	26	19.53	25.96	10	19.8	21.6	33.9

Means within the same column having the same letter are not significantly different at $p \geq 0.05$ according to Duncan's Multiple Range Test.

* Each data point is the arithmetic mean of 24 readings

Table 5: Effect of tillage on water infiltration 28 weeks after sowing

Treatments	Cumulative intake (cm)	Intake rate ($cm\ hr^{-1}$)	Wetting front (cm)
A (MT)	3.9* a	0.75 b	44 c
B (CT)	4.3 a	0.80 b	51 c
C (DT)	5.1 a	1.03 b	57 c
S.E ±	0.75	0.15	3.15
C.V%	29.5	30.4	10.8

Means within the same column having the same letter are not significantly different at $p \geq 0.05$ according to Duncan's Multiple Range Test.

* Each data point is the arithmetic mean of 12 readings

3.2 Plant Parameters

Results in(Table 6a) showed that no significant differences between treatments for root length were observed at 45 days after sowing but at 75 DAS roots were significantly longer ($p \geq 0.05$) for deep tillage compared with minimum tillage ,while no significant differences between conventional and deep tillage were observed for the same period . Deep tillage was significantly different ($p \geq 0.05$) from conventional and minimum tillage at 105 DAS with regard to root length. At 135 DAS there were highly significant differences between all treatments ($p \geq 0.01$) ,but at 165 DAS only deep tillage was significantly different from other treatments .In general, for all measurement periods , deep tillage resulted in longer roots ,while shorter ones were produced under minimum tillage. This may indicate that plants under deep tillage encountered less soil resistance for elongation and proliferation processes when their root systems were developing. Roots under deep tillage were bigger and were not subjected to deformation. They penetrated straight downward and they showed no signs of restriction, whereas, roots under conventional tillage showed slight deformation and branching. Roots under minimum tillage were clearly deformed, branched and their downward extension was not straight. Results in (Table 6b) showed that deep tillage was significantly different ($p \le 0.05$) from minimum tillage, while conventional and minimum tillage were not significantly different from each other 45 DAS. While, no significant difference between treatments was found 75 DAS .Deep tillage produced the highest root dry weight at 105 DAS, although there were no significant differences between tillage treatments were observed .At 135 DAS deep tillage gave significantly ($p \le 0.01$) higher root dry weight than other treatments .Values at 165 DAS were significantly different ($p \le 0.01$), roots under deep tillage were heavier than under conventional and minimum tillage. The results of the study indicated that deep tillage improved soil physical conditions resulting in vigorous, well developed root system reflected on root length and dry weight. These results agreed with findings obtained by [9] and [17] who reported that when the soil is in a good condition the root systems are large, deep and expanded. Plant height was significantly affected by tillage (Table 6c), at different periods whenever plants height was measured, deep tillage produced taller plants followed by conventional and minimum tillage. These results agreed with results obtained by [1]. Results of the study (Table 6d) indicated that deep tillage enhanced more vegetative growth than conventional and minimum tillage which was reflected in shoot dry weight. Shoot dry weight was significantly ($p \geq 0.05$) higher under deep tillage compared with other treatments. The explanation of these results is that deep tillage improved soil physical conditions resulting in a good stand and root penetration to the deeper layers with full utilization of moisture and nutrition in the soil. This improvement was reflected on taller plants and heavier shoots dry weight.

Table 6: Effect of tillage on cotton plant parameters

a. Effect of tillage on root length (cm)

Treatments	Days after sowing				
	45	75	105	135	165
A (MT)	18.03* a	28.13 bc	37.22 bc	37.26 c	46.7 bc
B (CT)	19.84 a	30.75 ab	38.10 b	39.68 b	48.4 b
C (DT)	21.51 a	32.91 a	42.13 a	43.09 a	53.3 a
S.E ±	1.0	1.14	0.98	0.65	0.73
C.V%	12.44	9.16	6.11	3.96	3.6

b. Effect of tillage on root dry weight (gm/ plant)

Treatments	Days after sowing				
	45	75	105	135	165
A (MT)	0.53* c	2.50 a	3.98 c	4.81 bc	5.47 c
B (CT)	0.73 ab	2.82 a	4.77 bc	5.39 b	6.41 b
C (DT)	0.85 a	3.28 a	5.34 ab	7.65 a	8.52 a
S.E ±	0.06	0.23	0.27	0.28	0.22
C.V%	22.5	20	14.1	11.58	8.96

c. Effect of tillage on plant height (cm)

Treatments	Days after sowing				
	45	75	105	135	165
A (MT)	34.98* bc	48.55 c	58.42 c	61.74 c	-
B (CT)	37.30 b	57.63 ab	64.75 b	68.63 b	-
C (DT)	43.22 a	60.35 a	70.43 a	76.76 a	-
S.E ±	1.34	1.53	1.69	0.75	-
C.V%	8.55	6.73	6.4	2.66	-

d. Effect of tillage on shoot dry weight (gm)

Treatments	Days after sowing				
	45	75	105	135	165
A (MT)	4.21* c	15.54 bc	29.76 bc	48.25 c	-
B (CT)	6.42 ab	19.26 b	37.54 ab	57.15 bc	-
C (DT)	7.93 a	23.76 a	48.63 a	79.83 a	-
S.E ±	0.50	1.23	3.57	5.27	-
C.V%	19.68	15.3	22.61	20.9	-

Means within the same column having the same letter are not significantly different at $p \le 0.05$ according to Duncan's Multiple Range Test.

* Each data point is the arithmetic mean of 30 plants

3.3 Yield

Cotton gross yield was presented in Table 7. Different tillage systems significantly ($p \le 0.05$) influenced cotton yield. Deep tillage produced significantly higher yield than minimum tillage .Although there was no significant difference between conventional and deep tillage, the latter produced higher yield than conventional tillage .Cotton yield under minimum and conventional were not statistically different but minimum tillage produced lower yield .Results showed that deep tillage increased cotton yield by 58.7% over minimum tillage and 25.5% over conventional tillage ,while , conventional tillage increased cotton yield by 26.5% over minimum tillage. These results agreed with results recorded by [5]. The results of the study indicated that deep tillage can improve cotton yield and may be used successfully to improve cotton yield especially in soils affected by compaction caused by continuous use of shallow tillage implements.

Table 7: Effect of tillage on cotton yield

Treatments	Yield (kpf)*
A (MT)	4.19 bc
B (CT)	5.36 ab
C (DT)	6.65 a
S.E ±	0.64
C.V%	28.98

Means within the same column having the same letter are not significantly different at $p \le 0.05$ according to Duncan's Multiple Range test.

* kpf :Kantar (100 pound) per feddan (4200 m^2)

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