Effect of Tillage Systems on Soil Physical Properties and Cotton Yield Components Under the Conditions of Gezira Clay Soil

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Abstract

Tillage has a direct effect on soil physical properties, and influences plant growing conditions. Thus the choice of the right tillage practice is very important for sustainable and economic cotton production. The study was planned to evaluate the effect of tillage on some soil physical properties (bulk density, infiltration rate, penetration resistance and wetting front) and yield components (number of leaves, number of bolls, plant height, stem diameter and length of roots) for three cotton varieties. The study was conducted during season 2008/09 at the Demonstration Farm of the Faculty of Agricultural Sciences, University of Gezira. Five tillage systems were used: ridger, disk harrow plus ridger, disk plow plus ridger, disk plow plus harrow plus ridger, and chisel plow plus harrow plus ridger, and three cotton varieties namely: Abdin, Hamid and Barac 90. A randomized complete block design (RCBD) with five treatments and three replications was used. The statistical analyses showed that there was a significant difference between tillage treatments in soil physical properties. Chisel Plowing plus harrowing plus ridging treatment recorded the lowest values of bulk density (1.1 gm/cm^3) at depth of 0-10 cm and (1.3 gm/cm^3) at depth of 10-20 cm. Also, chisel plowing plus harrowing plus ridging obtained the highest values of infiltration rate (2.4 cm/hr), highest values of wetting front (33 cm), as well as the lowest soil penetration resistance (789 Pa). The results of tillage treatment versus cotton varieties indicated that chisel plowing plus harrowing and ridging treatment for all cotton varieties produced the highest number of leaves, tallest plants, largest stem diameter, longest roots, highest number of bolls/plant and highest cotton yield. The results indicated that cotton yield was directly affected by land preparation. Chisel plowing, disk harrowing and ridging treatment is the most appropriate tillage package for cotton land preparation under the conditions of Gezira clay soil.

Introduction

Tillage is an important component of agro ecosystems, and its methods and frequency vary depending on the specific cropping system. Tillage occurs for several

reasons such as: to prepare the seedbed, decrease surface compaction, manage crop residue, and control weed species (Guthrie et al., 1993).

As cotton production has become more mechanized, utilization of heavy machinery to perform field operations has increased the occurrence of root limiting soil compaction. Soil compaction may also occur due to natural soil properties such as the leaching of clays with subsurface accumulation as mentioned by Brady and Weil (2008). Soil compaction as a result of mechanized agriculture and continuous tillage to the same depth are summarized by Amanullah et al. (2010).

Crop establishment and growth depends highly on root interactions within the soil. Development of a healthy and extensive root system early in the growing season is important to allow for maximum water and nutrient uptake. Any factor which inhibits early season development may result in decreased plant growth, and ultimately lower lint yields (Ritchie et al., 2007).

The bulk of the root system is located in the upper 3 feet, but this is dependent upon the soil moisture, soil physical structure and vigor of the individual plant (Pearson et al, 1970; Taylor and Gardner, 1983). Furthermore, root activity begins to decline as the boll load develops and carbohydrates are increasingly directed toward developing the fruit (McMichael, 1986).

Land preparation is the most expensive component of crop cultural practices. Patterson et al (1980) reported that chiseling and rotary spading have the highest cost and energy requirement, while shallow plowing and rotary digging have the lowest requirement.

Tillage effect is either closely linked to soil aggregation, water infiltration rate and water storage capacity, or indirectly related to soil and water conservation. Moisture conservation is particularly important in semi-arid conditions. Soil types and their various reactions to tillage are of paramount importance in determining the superiority of one practice over the other.

Zou et al (2001) and Rosolem et al (2002) reported that deep tillage improves crop yield by increasing the volume of soil that the crop roots can explore for water and nutrients. Although most crop root systems respond to loosened hard soil layers by improving growth, their response varies because of inherent differences such as the existence of shallow rooted crop varieties (Bodhinayake et al, 1998) or varieties that have differences in their tolerance to soil compaction (Rosolem et al, 2002).

Reports on the effect of tillage on cotton yield are varied; some researchers obtaining higher yields in conservation than in conventional tillage (Nyakatawa and Reddy, 2000; Boquet et al, 2004), while others observing higher yields in conventional tillage than in no-till (Ishaq et al 2001; Ozpinar and Isik, 2004).

The study was conducted to evaluate the effect of different tillage systems on some soil physical properties and cotton performance,

Material and Methods

The experiment was carried out at the Demonstration Farm of the Faculty of Agricultural Sciences, University of Gezira which lies north of Wad Medani town at the intersection of latitude 14 23' N. and longitude 33 29'E. The experiment was carried out during the period from June 2008 to April 2009, in a total area of about 4500 m^2. The soil of the site is typical central Gezira soil which is classified as vertisol; and is characterized by its deep dark color, low organic matter content, low permeability, and deep cracks when dry.

An 80 hp, 2WD FARMTRAC tractor was used in the experimental work as a power source for the tillage implements. The types of implements selected for this research work are those commonly used for soil tillage in Sudan. These implements, which constituted the main treatment, were as follows: A Balddan, Brazilian make, fully–mounted disk plow was used. The plow has three disks each of which is 66 cm in diameter. A Balddan, offset disk harrow, made in Brazil, was used. The harrow is trailed and has two disk gangs. Each disk gang consists of 11disks. A Nardi ridger, of Italian origin, was used in this experimental work. A chisel plow, made in West Germany, was used. The chisel plow is fully mounted, and consists of seven shanks arranged in two rows, the front row having three shanks, and the rear row having four shanks.

The standard core sampler was used to take the soil sample to be tested at 0 to 10 and 10 to 20 cm depths from each tillage treatment for the determination of soil bulk density. A standard double ring infiltiometer, as described by FAO (1986), was used to measure the rate of water infiltration into the soil. The Eijkel Kamp Bush recording penetrometers was used to measure the soil resistance to penetration.

The five tillage treatments, which were replicated three times, were as follows: (1) Ridging (T_1), Disk harrowing plus ridging (T_2), Disk plowing plus ridging (T_3), Disk plowing plus harrowing plus ridging (T_4) and Chisel plowing plus harrowing plus ridging (T_5).

Three varieties of cotton [(Abdin (N_1), Hamid (N_2) and Barac 90 (N_3)] were selected. The crop was sown manually, on the 5th of August 2008, on the top of 80 cm spaced ridges, with 50 cm between holes. Five to seven seeds were dropped into each hole and covered with loose soil. After emergence, the crop was thinned to three plants per hole.

The different measurements for the cotton plant components at the end of the experimental work included six plants for each plot taken randomly for counting the number of leaves and bolls, root length, plant height, stem diameter. Samples for crop yield were taken from each plant using a sampling area of 4 x12 m^2. The yield was obtained from the center five rows of each sampling area. Three picking operations were performed manually for each plot. The cotton yield for each tillage treatment was then calculated.

Results and Discussion

In order to assess the effect of the different tillage treatments on both the soil physical properties and the yield of the cotton crop, the data collected from the experimental work concerning the soil parameters and the cotton crop parameters were statistically analyzed to determine the end results of this research work.

Soil Parameters:

The soil parameters tested to evaluate the effect of the tillage treatments included:

Soil bulk density:

The results obtained for soil bulk density (gm/cm^3) under the different tillage treatments at the depths of 10 cm and 20 cm are shown in Table 1 .The analysis of variance showed that there were significant differences (P=0.05) between the tillage treatments. At the depth of 10 cm, the Duncan's Multiple Range Test indicated that chisel plowing plus harrowing plus ridging (T_5) and disk plowing plus disk harrowing plus ridging (T_4) have the significantly lowest bulk density ($1.1gm/cm^3$), followed by disk harrowing plus ridging (T_2), while both disk plowing plus ridging (T_3) and ridging (T_1) have the significantly highest bulk density ($1.5\ gm/cm^3$). On the other hand, at the 20 cm depth chisel plowing plus disk harrowing plus ridging (T_5) had the significantly lowest bulk density ($1.3\ gm/cm^3$), followed by disk plowing plus disk harrowing plus ridging (T_4), disk harrowing plus ridging (T_2), disk plowing plus ridging (T_3), while ridging (T_1) had the significantly highest bulk density ($1.7gm/cm^3$). Generally the

obtained results indicated that soil bulk density decreased with increased depth of tillage. These results agreed with the studies carried out by Hobbs, et al (1961) who concluded that deep tillage improved the soil bulk density and permeability of the dense layers of the soil.

Table .1: Soil bulk density (gm/cm^3) for the different tillage treatments in two depths.

Tillage treatment	Bulk density(g/cm)^3 (0-10 cm)	Bulk density(gm/cm^3) (10-20 cm)
T_1	1.5 a	1.7 a
T_2	1.4 b	1.5 c
T_3	1.5 a	1.6 b
T_4	1.1 c	1.4 d
T_5	1.1 c	1.3 e
C v	9.35	7.0
S d	0.086	0.061
Sig. level	*	*

Means followed by the same letter(s) in the same column are not significantly different at P = 0.05 according to Duncan´s Multiple Range Test.

Infiltration rate:

The results of the infiltration rate (cm/hr) for the different tillage treatments are shown in Table 2. The analysis of variance revealed that there were significant differences (P=0.05) between the tillage treatments. The Dunant's Multiple Range Test showed that chisel plowing plus disk harrowing plus ridging (T_5) gave the significantly highest infiltration rate (2.4 cm/hr), followed by disk plowing plus disk harrowing plus ridging (T_4), disk harrowing plus ridging (T_2) and disk plowing plus ridging (T_3), while ridging (T_1) gave the significantly lowest infiltration rate (1.1 cm/hr). These results could be attributed to the ability of the chisel plow to segregate the soil particles to a deeper depth, as well as the presence of the compacted layers under the shallow working zone of the ridger. The superiority of the effect of chisel plowing on the infiltration rate over the other tillage treatments was reported by Tomar and Singh (1975).

Depth of wetting front:

The results of the depth of wetting front (cm) for the different tillage treatments are shown in Table 2. The analysis of variance indicated that there were significant differences (P=0.05) between the tillage treatments. The Duncan's Multiple Range Test indicated that chisel plowing plus disk harrowing plus ridging (T_5) had the significantly highest depth of wetting front (33 cm), followed by disk plowing plus disk harrowing plus ridging (T_4), disk plowing plus ridging (T_2), while ridging (T_1) had the significantly lowest depth of the wetting front (18 cm). These results are conformity with the results obtained for the infiltration rate under the different tillage treatments.

Table 2: Infiltration rate (cm/hr) and depth of wetting front (cm) for the different tillage treatment.

Treatment	Infiltration Rate(cm/hr)	Depth of Wetting front(cm)
T_1	1.1 d	18 a
T_2	1.8 c	22 b
T_3	1.8 c	24 c
T_4	2.1b	28 d
T_5	2.4a	33 e
C.V	25.11	21.8
S.E	0.116	1.47
Sig. Level	*	*

Means followed by the same letter (s) in the same column are not significantly different at P = 0.05 according to Duncan´s Multiple Range Test.

Penetration resistance:

The results obtained for penetration resistance (Pa) under the different tillage treatments are shown in Table 3. The analysis of variance showed that there were significant differences (P= 0.05) between the tillage the treatments. The Duncan's Multiple Range Test showed that ridging (T_1) had the significantly highest penetration resistance (1325 Pa), while chisel plowing plus harrowing plus ridging (T_5) recorded the lowest penetration resistance (789 Pa). The results revealed that there were no significant difference between the tillage treatments of disk plowing plus ridging (T_3), disk plowing plus disk harrowing plus ridging (T_4), and chisel plowing plus disk harrowing plus ridging (T_5). These results are in agreement with the findings of Dawelbeit and Salih (1994) who reported that changing the depth of tillage did not result in any significant difference in soil penetration resistance.

Table 3: Penetration resistance (Pa) for the different tillage treatments:

Treatment	Penetration Resistance (Pa)
T_1	1325 a
T_2	981 b
T_3	958 c
T_4	892 c
T_5	789 c
C.V	6.51
S.E	631
Sig. level	*

Means followed by the same letter(s) in the same column are not significantly different at P = 0.05 according to Duncan´s Multiple Range Test.

Crop Parameters:

The crop parameters tested to evaluate the effect of the tillage treatments on the performance of the three selected cotton crop varieties [Abdin (N_1), Hamid (N_2) and Barac 90 (N_3)] included:

Number of leaves:

The results of the number of leaves per plant for the three cotton varieties under the different tillage treatments are shown in Table 4. The analysis of variance indicated that there were significant differences (P = 0.05) between the different tillage treatment with respect to each of the cotton varieties tested. The Duncan's Multiple Range Test showed that chisel plowing plus disk harrowing plus ridging (T_5) produced the significantly highest number of leaves per plant for the three cotton varieties Abdin (44 leaves), Hamid (40 leaves) and Barac 90 (40 leaves). On the other hand, ridging (T_1) produced the significantly lowest number of leaves per plant for the three cotton varieties Abdin (22 leaves), Hamid (19 leaves) and Barac 90 (21 leaves).

Table 4: Effect of different tillage treatments on the number of leaves per plant

	Abdin	Hamid	Barac 90
T1	22d	19 d	21 d
T2	29 c	29 c	30 c
T3	30 c	28 c	30 c
T4	37 b	34 b	37 b
T5	44 a	40 a	40 a
C v	2.4	2.6	0.65
S d	25.5	25.1	5.1
Sig.level	*	*	*

Means followed by the same letter(s) in the same column are not significantly different at P = 0.05 according to Duncan´s Multiple Range Test.

Plant height:

The result of plant height (cm) for the three cotton varieties under the different tillage treatments are shown in the Table 5. The analysis of variance indicated that there were highly significant differences (P= 0.01) between tillage treatments with respect to each of the cotton varieties tested. The Duncan's Multiple Range Test showed that chisel plowing plus disk harrowing plus ridging (T_5) produced the highly significantly tallest plants for the three cotton varieties Abdin (117cm), Hamid (113 cm) and Barac 90 (116.3 cm). On the other hand, ridging (T_1) produced the highly significantly shortest plants for the three cotton varieties Abdin (76 cm), Hamid (74.3 cm) and Barac 90 (72.7 cm).

Stem diameter

The results of the stem diameter (cm) for the three cotton varieties under the different tillage treatments are shown in Table 6. The analysis of variance indicated that there were highly significant differences (P= 0.01) between tillage treatments with respect to each of the cotton varieties tested. The Duncan's Multiple Range Test showed that chisel plowing plus disk harrowing plus ridging (T_5) produced the highly significantly largest stem diameter for the three cotton varieties Abdin (1.7 cm), hamid (1.63 cm), and Barac 90 (1.46 cm). On the other hand, ridging (T_1) produced the highly

significantly smallest stem diameter for the cotton varieties Abdin (0.88 cm), Hamid (0.76 cm) and Barac 90 (0.60 cm).

Root length:

The results of crop root length (cm) for the three cotton varieties under the different tillage treatments are shown in Table 7. The analysis of variance indicated that there were significant differences (P= 0.05) between tillage treatments with respect to each of the cotton varieties tested. The Duncan's Multiple Range Test showed that chisel plowing plus disk harrowing plus ridging (T_5) produced the significantly longest crop root for the three cotton varieties Abdin (58.3 cm), Hamid (54.3 cm), and Barac 90 (27 cm). This could be attributed to the lowest soil penetration resistance produced by that tillage treatment. These results are in agreement with the findings of Camp and Busscher (1999) and Willcock (1994). On the other hand, ridging (T_1) produced the significantly shortest crop root for the three cotton varieties Abdin (27.7 cm), Hamid (27cm) and Barac 90 (22cm).

Table 5: Effect of different tillage treatments on the height of the crop (cm)

Tillage treatment	Variety		
	Abdin	Hamid	Barac 90
T1	76.0 e	74.3 e	72.6 d
T2	86.6 c	84.6 c	78.3 c
T3	82.3 d	78.3 d	78.3 c
T4	109.7 b	102.3 b	109.7 b
T5	117 a	113 a	116.3 a
C.V%	1.08	1.08 .	1.08
S.E±	0.24	0.24	0.24
Sig .level	**	**	**

Means followed by the same letter (s) in the same column are not significantly different at P = 0.05 according to Duncan´s Multiple Range Test.

Table 6: Effect of different tillage treatments on the stem diameter of cotton crop (cm)

Tillage Treatment	Variety		
	Abdin	Hamid	Barac 90
T1	0.8 e	0.76 e	0.60 d
T2	1.0 d	0.93 d	0.66 d
T3	0.6 d	0.66 d	0.90 c
T4	0.6 d	1.10 c	1.10 b
T5	0.6 d	1.6 3 a	1.46 a

C.V%	7.5	7.5	7.5
Sd	0.018	0.018	0.018
Sig .level	**	**	**

Means followed by the same letter (s) in the same column are not significantly different at P = 0.05 according to Duncan´s Multiple Range Test.

Number of bolls:

The results of the number of bolls per plant for the three cotton varieties under the different tillage treatments are shown in Table 8. The analysis of variance indicated that there were significant differences (P=0.05) between tillage treatments with respect to each of the cotton varieties tested. The Duncan's Multiple Range Test showed that chisel plowing plus disk harrowing plus ridging (T_5) produced the significantly highest number of bolls per plant for the three cotton varieties Abdin (23 bolls), Hamid (22 bolls) and Barac 90 (21 bolls). On the other hand, ridging (T_1) produced the significantly lowest number of bolls per plant for the three cotton varieties Abdin (7 bolls), Hamid (8 bolls), and Barac 90 (10 bolls).

Cotton yield:

The results of the cotton yield obtained from the three cotton varieties under the different tillage treatments are shown in Table 9. The analysis of variance indicated that there were significant differences (P= 0.05) between the tillage treatments with respect to each of the cotton varieties tested. The Duncan's Multiple Range Test showed that chisel plowing plus disk harrowing plus ridging (T_5) produced the significantly highest cotton yield for the three cotton varieties Abdin (300 kg/fed), Hamid (260 kg/fed), and Barac 90 (240.4 kg/fed). On the other hand, ridging (T_1) produced the significantly lowest cotton yield for the three cotton varieties Abdin (220 kg/fed), Hamid (200 kg/fed) and Barac 90 (180 kg/fed). The highest crop yields from all tested cotton varieties under chisel plowing plus disk harrowing plus ridging (T5) could be attributed mainly to the action of the chisel plow which disturbs the soil to a great depth, and thus improves the soil infiltration rate, decreases soil resistance to penetration, and allows for the ease of exploration of the crop roots for available nutrients and water. These results are in line with the findings of Mohamed (1980).

Table 7: Effect of different tillage treatments on the crop root length

Tillage treatment	Variety		
	Abdin	Hamid	Barac 90
T1	27.67 d	27 d	22.0 d

T2	26.33 d	30 c	27.33 c
T3	33 c	33 c	27.33 c
T4	42.67 b	47.33 b	53.67 a
T5	58.33 a	54.33 a	56 a
C.V%	2.27	2.27	2.27
Sd	0.31	0.31	0.31
Sig-level	*	*	*

Means followed by the same letter (s) in the same column are not significantly different at P= 0.05 according to Duncan´s Multiple Range Test.

Table 8: Effect of different tillage treatments on the number of bolls per plant

Tillage treatment	Variety		
	Abdin	Hamid	Barac 90
T1	7 d	8 e	10 d
T2	10 c	11 d	13 c
T4	17 b	15 b	17 b
T5	23 a	22 a	21 a
C.V%	7.51	7.51	7.51
C.V%	0.41	0.41	0.41
Sig-level	*	*	*

Means followed by the same letter (s) in the same column are not significantly different at P = 0.05 according to Duncan´s Multiple Range Test.

Table 9 : Effect of different tillage treatments on the yield (kg/fed)

Tillage treatment	Variety		
	Abdin	Hamed	Barac 90
T1	220 b	200 b	180 c
T2	235 b	210 b	190 b
T3	240 b	215 b	200 b
T4	280 a	250 a	230 a
T5	300 a	260 a	240 a
Mean	255	227	199
C.V%	3.51	3.48	3.48
Sd	5.16	5	4.18
Sig-level	*	*	*

Means followed by the same letter (s) in the same column are not significantly different at P = 0.05 according to Duncan´s Multiple Range Test.

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