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Effect of Some Tillage Systems on Surface Run off and Soil Erosion in Northern Gedarif Area, Sudan

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Abstract: The study was carried out during three consecutive seasons 2005/06 , 2006/07 and 2007/08 under rain fed condition, to investigate the effect of some tillage systems on surface runoff and soil erosion in northern Gedarif. The study was conducted at the pilot farm of the Faculty of Agricultural Sciences and Environment, University of Gedarif in the Northern area of Gedarif State (Latitude 12° 45' N, Longitude 35° 15' E, Elevation 540m above sea level). The experimental design was randomize complete block design (RCBD) with three replications, three tillage systems: No tillage or zero tillage (ZT), Offset Disc as post harvest tillage (PHT) and Wide Level Disc Farmers practices control (WLD). Rain gauge was used to measure the rainfall, whilst the surface runoff and soil losses were measured using runoff plot technique . Total recorded annual rainfall were 368.1mm (2005), 463.6 mm (2006) and 495.2 mm (2007) which was spread over 32, 30 and 32 rainy days during the first , second and third growing seasons, respectively. The results showed that the second season had the best distribution and satisfaction pattern. It recorded 15%, 36%, 26% and 5% for July, August, September and October, respectively compared to 24% , 53% 13% and 2% ; and 29% , 41% , 21% and 1% for first and third seasons in the same months. Zero tillage treatment showed more runoff and soil loss than PHT and WLD. In terms of accumulation , ZT produced more runoff by 28% and 9% and soil loss by 53% and 28% over PHT and WLD respectively for first season , 30% and 13% runoff and 28% and 13% soil loss for second season and 55% and 23% runoff and 105% and 24% soil loss for third season . The post harvest tillage reduced the average annual runoff and soil loss to the lowest values compared with the Wide level disk and Zero Tillage.

Key words: Tillage・Surface Runoff and Soil Erosion

INDRUDUCTION

Runoff: Runoff is defined by [1] as the portion of the precipitation, snowmelt or irrigation water that appears in uncontrolled surface streams, rivers, drains or sewers. The process of runoff generation continues as long as the rainfall intensity exceeds the actual infiltration rate of the soil but it stops as soon as the rate of rainfall drops below the actual rate of infiltration [2]. Runoff from agricultural land can carry with it deplete plant nutrients such as nitrogen and phosphorus into streams, Lakes and ground water and deprives soil from essential plant nutrient elements. Malind [3] studied runoff and soil losses with applications effect of 3 levels of stubble retention (0.3, 3.0, 5.0 t/ha per year) and 4 types of tillage including no-tillage, direct drill, reduced tillage, conventional tillage cultivation. He concluded that no-tillage and increased amount of stubble retained annually reduce the runoff and soil losses The results show that runoff was reduced due to adequate stubble residues provided by the no-till. Similar findings were observed by Martin [4], who stated that no-tillage resulted in low soil loss (40 kg/ha) and high runoff (6.1 mm) compared with light-duty mould board plowing, mustard intercrop and superficial tillage. Similar trend of the effect of these tillage practices was reported by Lindstorm *et al.* [5]. Their results indicated that rainwater runoff from the mould board ploughed treatments averages were 24 and 66% of the rainfall resulting in soil loss level of 6.7 and 18.2 t/ha for the two run respectively, while the maximum observed water runoff for the no-tillage treatment was only 3% of the rainfall resulting in soil loss of 0.2 t/ha. Carroll *et al*. [6] found that the zero tillage with wheat had the lowest average annual runoff and soil loss, whereas conventional sunflowers had the highest.

Soil Erosion: FOA [7] defined soil erosion as the washing or blowing away of surface soil, sometimes down to bed rock as a basic component of soil degradation. Soil erosion also referred to the removal, transportation and

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net loss of soil including the loss of the soil fertility [1]. Arnaez *et al.* [8] showed that the runoff and soil erosion increased linearly with rainfall intensity, but increase in runoff with rainfall was linear. Seid Ahmed *et al.* [9] found that the mean amount of eroded soil was 11.2 t/ha for control and only 5.2 t/ha for cut off drain technique which lead to about 46.4% reduction of soil loss. Cullum *et al.* [10] found that the no-tillage had 86% less soil than conventional till-plots. No till and reduced tillage practices definitely produce less soil erosion and sediment than conventional plough tillage [11]. Omer and Elamin [12] reported that reduced tillage combined with in-situ water conservation provided by terracing produced little run off and soil loss. Adam [13] stated that the water harvesting techniques proved very effective in decreasing surface runoff and increasing soil water storage. Tarig [14] found that chisel and ridge tillage system have significantly reduced the seasonal mean run off and soil loss over no-tillage by 21% and 12 and 60% and 47%.

Gedarif region is the most important farming area for the rain-fed crop production in the country [15]. Vertisols are one of the major soil orders found in the semi-arid of Gedarif State [16]. He added that, these soils become hard when dry and sticky when wet. An important observation which has been associated with continuous washing of good top soil is creation of situation in which soil compaction impairs water penetration and quick surface dryness after 24 hours from any rainfall event [17]. This loss of rainwater through those prescribed forms lead to plant water stress, therefore dry land crop production either decreased or completely failed [17]. Runoff also carries away the essential plant nutrient elements and consequently low soil fertility and hence decreased productivity. Under these circumstances introduction of appropriate methods of management are highly needed to utilize and conserve these valuable natural resources. Therefore, this research was conducted to study the effect of different tillage systems on surface runoff and soil erosion to improve soil and water management practices in order to maximize utilization of seasonal rainfall and soil conservation in addition to increasing crop productivity.

MATERIALS AND METHODS

Field experiments were carried out during 2005/06/, 2006/07 and 2007/08 growing seasons under rain fed condition, to study the effect of some tillage systems on surface runoff and soil erosion in northern Gedarif. The study was conducted at the pilot farm of the Faculty of Agricultural Sciences and Environment, University of Gedarif in the Northern area of Gedarif State . Latitude 12° 45' N, Longitude 35° 15' E, Elevation 540m above sea. The experiment was laid out in randomize complete block design (RCBD) with three replications. The plot size was 36 m long by12 m width, zero tillage (ZT), offset disc as post harvest tillage (PHT) and wide level disc (WLD) as local farmers practices - control were implemented. Zero tillage system, which limits the soil disturbance, was applied to soil except for opening small holes for seeds placement. Offset disc ploughing to 20 cm depth was done for three consecutive seasons on second week of November as post harvest tillage. The wide level disc (WLD) was used as a primary tillage during the summer time on July just before the rainy season to mix the previous crop residues in the soil.

Surface Run off and Soil Erosion: Surface run off and soil loss were directly measured on each treatment from two replication plots for three seasons. The measurements were performed for each rainfall event producing runoff.

Measurement of Surface Runoff: To evaluate the effect of tillage system on water loss through the surface runoff during growing seasons, a plot of 5 m by 3 m was made in each plot of treatment towards its end and surrounded with earth embankments. A PVC pipe leading from this plot was connected as a supply runoff line to an excavated pit (3x2x0.9 m) lined with plastic sheet to prevent water seepage. The pit lined with the plastic sheet was protected with earth embankments of 30 cm high. After each rain storm runoff water that has been collected into the pit was measured by 8 liters capacity plastic container (jerrican). Then the volume of runoff water for each rain storm calculated as follows:

Net runoff volume = Volume of runoff measured – volume of direct rainwater falling into the pit (liters)

It is worth noting that volume of direct rainfall = record of rain gauge times the area of collecting pit.

Soil Loss Measurement: After each rain storm resulted in surface runoff and before measuring the runoff water, the pit was steered sufficiently by hands and then samples were taken in 500 ml glass bottle. The samples were taken to the laboratory allowing it to settle for 24 hours or more until clear of any sediment. The clear water was discarded and the remaining moist sediment on the bottom was oven dried at 105° C, then their weights were determined. The total soil loss for each rain storm from each plot was determined as follows:

$$\text{Total soil loss in } (\text{gm/m}^2) = \frac{\text{Soil loss/ 0.5L* Total runoff}}{\text{Area of plot (15 m}^2)}$$

RESULTS AND DISSCUSSION

Table 1 showed that, the total rainfall was 368.1mm, 463.6mm and 495.2 mm in the first, second and third seasons respectively. They were distributed successively in 32, 30 and 32 rainy days (Table 1). Rainy days 8, 7 and 6 storms recorded measurable runoff during the first, second and third seasons, respectively. Rainfall records induced runoff was in the range of 11 mm to 53 mm, depending on the soil moisture condition prior to rainfall and rainfall intensity. The analysis of variance showed significant effects (at P $\leq$ 0.05) on both runoff and soil losses due tillage treatments effect for the three growing seasons (Tables 2, 3 and 4) . Post- harvest tillage (PHT) resulted in significantly the lowest runoff and soil losses compared with Zero tillage (ZT) in most rain fall events through the three growing seasons , however PHT and Wide level disc (WLD) treatments showed no significant differences in most rain fall events during the three growing seasons .The total soil and water loss under the different soil treatments for the three successive seasons were shown in Tables (2, 3 & 4) and Figs. (1 to 6) (1, 2, 3 and 4) and (5 and 6) respectively. From the result and an irrespective for the number of rainstorm measured per season. The third season recorded the lowest runoff and soil losses at different growing season (Table 4). While the second season retained more runoff and highest erosion soil (Table 3). The variation of amount of

Table 1: Monthly total rainfall and Rainy days for the three seasons

Month	Rainfall (mm)	Rainy days
Season 2005/06		
June	21.5	2
July	107.7	8
August	151.3	13
September	82.6	8
October	5	1
Total	368.1	32
Season 2006/07		
June	87.3	6
July	67.7	6
August	166.4	10
September	118.2	7
October	24.0	1
Total	463.6	30
Season 2007/08		
June	39.6	4
July	120.5	12
August	261.5	11
September	64.8	3
October	8.8	2
Total	495.2	32

surface runoff and soil loss could be attributed to amount of rainfall per event. Similar results were reported by [13, 14]. The results indicated that high rainfall was not only the main factor causing the highest surface runoff and soil loss, but also , rain fall intensity and frequency (interval between events) increased the surface runoff and soil losses. The zero tillage produced the highest runoff and soil loss in all growing seasons. Zero tillage produced more runoff by 80% and 18% and soil loss by 60% and

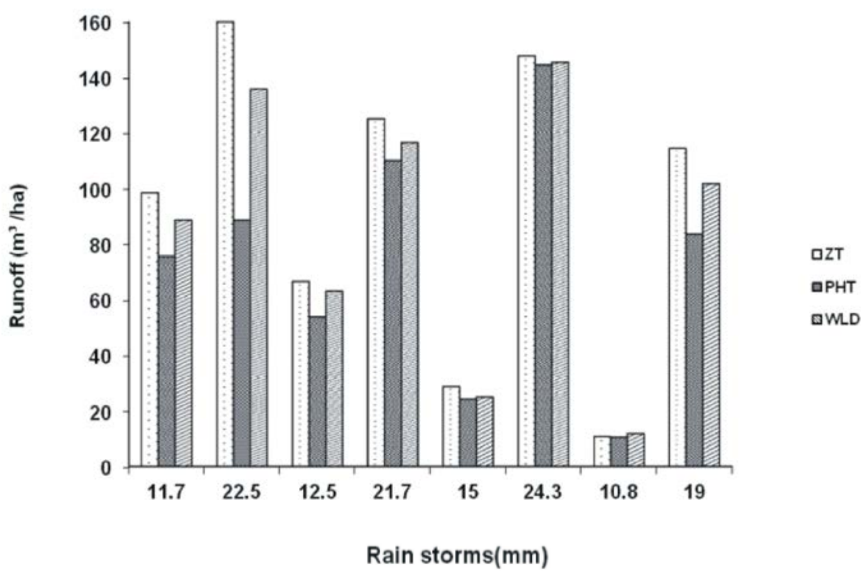

Fig. 1: Effect of tillage on surface runoff (Season 2005/2006)

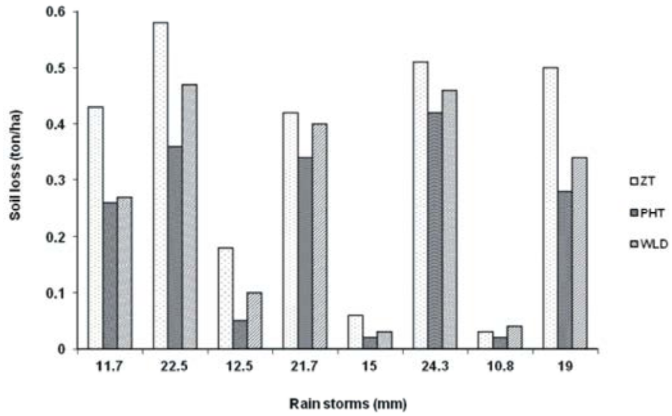

Fig. 2: Effect of tillage on soil loss(ton/ha) (Season 2005/2006)

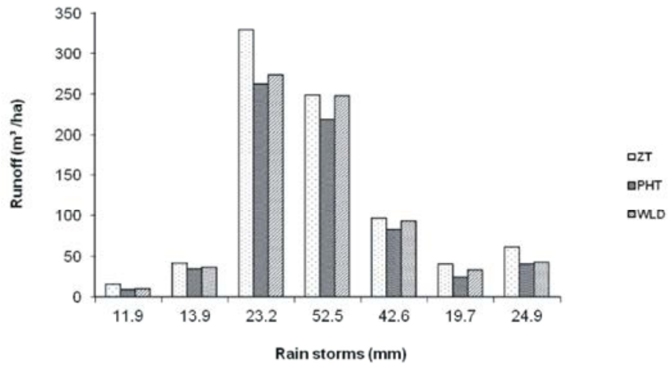

Fig. 3: Effect of tillage on surface runoff (Season 2006/2007)

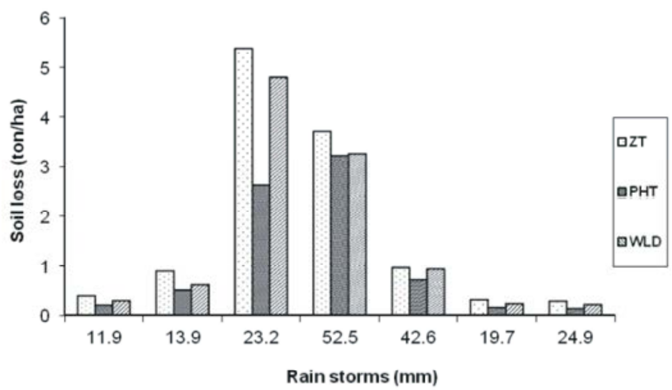

Fig. 4: Effect of tillage on soil loss (Season 2006/2007)

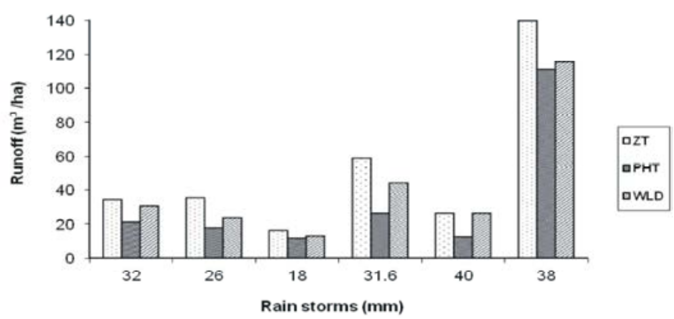

Fig. 5: Effect of tillage on surface runoff (Season 2007/2008)

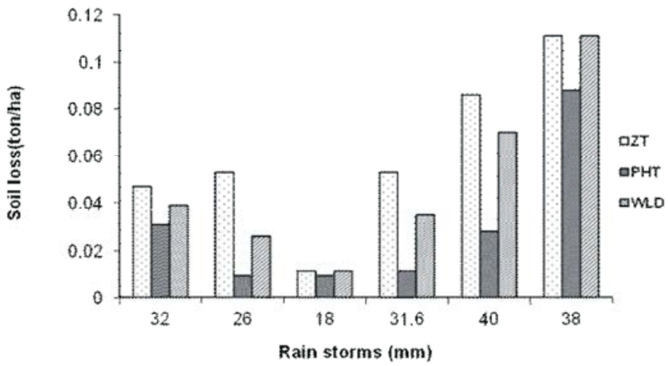

Fig. 6: Effect of tillage on soil loss (Season 2007/2008)

Table 2: Effect of tillage treatments on Runoff and soil loss during 8 rain storms in season 2005

Date	Rainfall (mm)	Acc.Rainfall(mm)	Treatment	Runoff (m^3/ha)	Runoff (mm)	Acc.runoff(mm)	Eroded soil (ton/ha)	Acc.eroded soil .(ton/ha)
28.7	11.7	11.7	Zero-tillage	98.66 a	10.0	10.0	0.430 a	0.430
			Post-har.tillage	75.73 b	7.6	7.6	0.258 a	0.258
			WLD(control)	88.66 a	8.9	8.9	0.274 a	0.274
			Mean	87.68	8.8		0.320	
			Cv	1.75	0.85		28.2	
			SE±	0.88			0.05	
3.8	22.5	34.2	Zero-tillage	160 a	16.0	26.0	0.577 a	0.987
			Post-har.tillage	88.66 b	8.9	16.5	0.361 a	0.619
			WLD(control)	136 ab	13.6	22.5	0.473 a	0.717
			Mean	128.22	12.8		0.470	
			C.V %	6.4	1.3		14.45	
			SE±	4.74			0.04	
5.8	12.5	46.7	Zero-tillage	66.66 a	6.7	32.7	0.180 a	1.167
			Post-har.tillage	54.00 a	5.4	21.9	0.051 c	0.67
			WLD(control)	63.33 a	6.3	28.8	0.102 b	0.819
			Mean	61.33	6.1		0.111	
			C.V %	12.45	0.47	0.04	2.21	
			SE±	4.41			0.001	
16.8	21.7	68.4	Zero-tillage	125.33 a	12.5	45.2	0.421a	1.588
			Post-har.tillage	110.33 b	11.0	32.9	0.334 b	1.004
			WLD(control)	116.66 ab	11.7	40.5	0.401 ab	1.22
			Mean	117.44	11.7		0.385	
			C.V %	2.24	0.53	0.03	1.5	
			SE±	1.51			0.003	
23.8	15	83.4	Zero-tillage	28.93 a	3.0	48.2	0.056 a	1.644
			Post-har.tillage	24.38 b	2.4	35.3	0.022 a	1.026
			WLD(control)	25.20 b	2.6	43.3	0.031 a	1.251
			Mean	26.17	2.6		0.036	
			C.V %	2.5	0.03		5.5	
			SE±	0.37			0.012	
26.8	24.3	107.7	Zero-tillage	147.83 a	14.8	63.0	0.506 a	2.15
			Post-har.tillage	144.60 a	14.5	49.8	0.418 c	1.444
			WLD(control)	145.60 a	14.6	57.7	0.456 b	1.707
			Mean	145.91	14.6		0.459	
			C.V %	6.95	5.84		1.33	
			SE±				0.009	
9.9	10.8	118.5	Zero-tillage	10.87 a	1.1	64.1	0.027 a	2.177
			Post-har.tillage	10.66 a	1.1	50.9	0.021 a	1.465
			WLD(control)	12.00 a	1.2	58.9	0.038 a	1.745
			Mean	11.16	1.2		0.028	
			C.V %	9.54	0.22		13.2	
			SE±	0.59			0.04	
18.9	19	137.5	Zero-tillage	114.66 a	11.5	75.6	0.494 a	2.671
			Post-har.tillage	83.76 b	8.4	59.3	0.278 b	1.743
			WLD(control)	101.80 a	10.2	69.1	0.337 b	2.082
			Mean	100.00	10.0		0.369	
			C.V %	1.72	1.10		8.9	
			SE±	1.002			0.02	

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

Table 3: Effect of tillage treatments on Runoff and soil loss during 7 rain storms in season 2006

Date	Rainfall (mm)	Acc.rainfall (mm)	Treatment	Runoff (m^3/ha)	Runoff (mm)	Acc.runoff (mm)	Eroded soil (ton/ha)	Acc.eroded soil (ton/ha)
22.7	11.9	11.9	Zero-tillage	15.33 a	1.5	1.5	0.368 a	0.368
			Post-harvest .tillage	8.66 a	0.9	0.9	0.197 b	0.197
			WLD(control)	9.70 a	1.0	1.1	0.285 ab	0.285
			Mean	11.23	1.1		0.248	
			C.V %	28.6	0.23		14.2	
			SE±	1.85			0.02	
4.8	13.9	25.8	Zero-tillage	41.2 a	4.1	5.6	0.889 a	1.257
			Post-harvest .tillage	34.3 a	3.4	4.3	0.500 b	0.697
			WLD(control)	36.3 a	3.6	4.6	0.605 ab	0.89
			Mean	37.4	3.7		0.665	
			C.V %	10.5	0.25		7.3	
			SE±	2.23			0.03	
7.8	23.2	49.1	Zero-tillage	79.2 a	7.9	13.5	0.779 a	2.036
			Post-harvest .tillage	38.4 b	3.8	8.1	0.522 b	1.219
			WLD(control)	53.1 ab	5.3	9.9	0.654 ab	1.544
			Mean	56.9	5.7		0.652	
			C.V %	8.8	1.47		8.3	
			SE±	2.89			0.03	
14.8	52.5	101.6	Zero-tillage	248.73 a	24.9	38.4	3.369 a	5.405
			Post-harvest .tillage	218.1 a	21.8	29.9	3.208 a	4.427
			WLD(control)	247.86 a	24.8	34.7	3.247 a	4.791
			Mean	238.23	23.8		3.274	
			C.V %	11.1	1.25		9.3	
			SE±	15.21			0.18	
25.8	42.6	144.2	Zero-tillage	96.46 a	9.5	47.5	0.960 a	6.365
			Post-harvest .tillage	82.4 b	8.2	38.1	0.708 a	5.135
			WLD(control)	92.93 a	9.3	44.0	0.929 a	5.72
			Mean	90.59	9.1		0.865	
			C.V %	3.3	0.52		11.0	
			SE±	1.75			0.06	
7.9	19.7	163.9	Zero-tillage	39.86 a	4.0	51.9	0.306 a	6.671
			Post-harvest .tillage	23.86 b	2.4	40.5	0.148 b	5.283
			WLD(control)	32.86 ab	3.3	47.3	0.230 ab	5.95
			Mean	31.92	3.2		0.228	
			C.V %	9.99	0.18		16.7	
			SE±	1.86			0.02	
25.9	24.9	188.8	Zero-tillage	61.20 a	6.1	58.0	0.275 a	6.946
			Post-harvest .tillage	39.75 b	4.0	44.5	0.131 b	5.414
			WLD(control)	42.2 b	4.2	51.5	0.211 ab	6.161
			Mean	47.71	4.8		0.205	
			C.V %	8.5			13.1	
			SE±	2.33	0.84		0.02	

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

22% compared to PHT and WLD during the first season (RF, 22.5mm), (Table 2)14% and 0.3% runoff and 5% and 3.7% soil loss for second season (Table 3) (RF52.2 mm) and 100% and 50% runoff and 489% and 103% soil loss for third season (Table 4) (RF, 26mm) . In terms of accumulation ZT produced more runoff by 28% and 9% and soil loss by 53% and 28% over PHT and WLD respectively for the first season (Table 2) ; 30% and 13% runoff and 28% and 13% soil loss for the second season (Table 3) and 55% and 23% runoff and 105% and 24% soil loss for the third season (Table 4). The results showed that the PHT produced the lowest runoff and soil loss in all growing seasons followed by WLD. Zero tillage produces more runoff and soil loss probably because of the roughness produced by tillage permitting more time for pounded water to infiltrated and provided substantial capacity to store and detached soil particles in surface depression. These results agreed with the findings of [18, 12, 4, 19]. In contrast this result disagreed with the finding of [3, 6] who reported that the zero tillage had the lowest average annual run off and soil loss compared to the reduced tillage and conventional tillage.

Table 4: Effect of tillage treatments on Runoff and soil loss during 6 rainstorms in season 2007

Date	Rainfall(mm)	Acc.rainfall (mm)	Treatment	Runoff (m^3/ha)	Runoff (mm)	Acc.runoff (mm)	Eroded soil (ton/ha)	Acc.eroded soil .(ton/ha)
6.8	32	32	Zero-tillage	34.27 a	3.4	3.4	0.047 a	0.047
			Post-harvest .tillage	21.22 b	2.1	2.1	0.031 b	0.031
			WLD(control)	30.63 ab	3.1	3.1	0.039 ab	0.039
			Mean	28.71	2.9		0.039	
			C.V %	9.7	0.48		8.6	
			SE±	1.59			0.002	
8.8	26	58	Zero-tillage	35.44 a	3.5	6.9	0.053 a	0.100
			Post-harvest .tillage	17.72 b	1.8	3.9	0.009 b	0.040
			WLD(control)	23.59 b	2.4	5.5	0.026 ab	0.065
			Mean	21.25	2.1		0.038	
			C.V %	12.6	0.73		13.2	
			SE±	1.86			0.002	
18.8	18	76	Zero-tillage	16.16 a	1.6	8.8	0.011 a	0.111
			Post-harvest .tillage	11.52 b	1.2	5.1	0.009 a	0.049
			WLD(control)	12.86 ab	1.3	6.8	0.011 a	0.076
			Mean	13.51	1.4		0.010	
			C.V %	10.4	0.15		11.2	
			SE±	0.81			0.001	
23.8	31.6	107.6	Zero-tillage	58.88 a	5.9	14.7	0.053 a	0.164
			Post-harvest .tillage	26.16 b	2.7	7.8	0.011 b	0.06
			WLD(control)	44.05 ab	4.4	11.2	0.035 ab	0.111
			Mean	43.03	4.3		0.039	
			C.V %	8.9	1.13		18.3	
			SE±	2.2			0.002	
31.8	40	147.6	Zero-tillage	26.22 a	2.6	17.3	0.086 a	0.25
			Post-harvest .tillage	12.38 b	1.2	9.0	0.028 b	0.088
			WLD(control)	26.16 a	2.6	13.8	0.070 ab	0.181
			Mean	21.58	2.2		0.061	
			C.V %	8.6	0.57		5.7	
			SE±	1.08			0.002	
8.9	38	185.6	Zero-tillage	139.55 a	14.0	31.3	0.111 a	0.361
			Post-harvest .tillage	110.88 a	11.1	20.1	0.088 a	0.176
			WLD(control)	115.61 a	11.6	25.4	0.111 a	0.292
			Mean	122.0	12.2		0.097	
			C.V %	7.1	1.09		11.0	
			SE±	4.98			0.01	

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

CONCLUSION AND RECOMENDATION

The post harvest tillage practices produced the lowest runoff and soil loss in all growing seasons followed by Wide Level Disk.

Zero-Tillage practice leads to loss of water through cracks wall and deep percolations at starting of rainy season.

Based on the results obtained we recommend the post harvest tillage practices using offset disc in north Gedarif area to conserve water and soil

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