Original Research Article

Effect of Land Ploughing Methods and Leveling Techniques on Wheat Production in the Upper Terraces of the Northern State - Sudan

Abstract: Precision land leveling must be treated as a precursor technology for improving crop yield, enhancing input-use efficiency and ensuring long-term sustainability of the resources. A field experiment was conducted in Dongola Agricultural Research Farm, Northern State, for two successive seasons to investigate the effect of three type of ploughing; heavy disc harrow (H1), disc plough (H2) and no-ploughing (H3), and three land leveling techniques, Laser (L), Scraper (S) and traditional (T),on wheat production. The experiment was arranged in a strip split plot design and the treatments were replicated three times. The main plot was assigned to the ploughing methods, and the sub-plots for the leveling treatments.

The results indicated that effective field capacity, fuel consumption, and slippage were significantly affected by ploughing method. Laser land leveling recorded the highest fuel consumption (74L/ha), and the lowest effective field capacity (0.22ha/hr). while the scraper leveling recorded the lowest fuel consumption (21.2L/ha) and highest effective field capacity (0.43ha/hr). The soil moisture content (db %) was increased with time and depth. The highest mean soil moisture content was obtained with the laser land leveling and heavy disc harrow treatment at 75-100cm soil depth in both seasons. The results revealed that the highest average grain yield (5.08 ton/ha) and infiltration rate (31cm/hr) were recorded by the laser land leveling and heavy disc harrow. The treatments showed significant differences at the 5% level between the treatments for the parameters measured. Multiple regression analysis showed a highly significant effect (P≤ 0.001) of laser leveling with disc harrow ploughing on grain yield, compared to the other treatments used in the study (R^2 = 0.40). The relation between the grain yield (Y) and the treatments: X_1 ploughing, X_2 leveling is summarized in the following equation:

$$\mathbf{Y = 2.875 + 0.552X_1 + 0.254X_2}$$

The study concluded that, although Laser leveling has increased the grain yield with high cost, yet it is not an expensive technique when the cost is distributed over the period of Laser leveling. The highest return was obtained by the heavy disc plough with laser leveling.

Keywords: plough, levelling, laser, traditional, upper terraces, Dongola

1. INTRODUCTION

Tillage is an important practice for preparing land for agricultural crops growth and production. However, many studies showed that tillage at least consumes around 30 percent of the total power required for crop production [1. 2]. Land preparation for crop production is probably the most time consuming and expensive operation in agriculture and may be more in wheat crop among the cereals as mentioned by [3]. It was concluded that the beneficial effects of tillage on the irrigated soil in the semi-arid region could be reduced due to the frequent use of machines and recommended that an appropriate knowledge of tillage practices for the various groups of soils and crops is inevitable [4. 5]. Tillage systems are practiced for modifying the state of the soil by one or more tillage action and machine in order to provide conditions favorable to crop growth [6, 7, 8, 9]. One of the significant factors identified for inefficient use of irrigation water under farmer conditions is poor land leveling practices. The unleveled fields are characterized with non-uniform distribution of irrigation water and deep percolation. Precise land leveling is a prerequisite for achieving high irrigation efficiencies at the field level [10, 11].

Studies indicate significant increase in irrigation efficiencies of wheat and rice through precision leveling using Laser land leveler [12]. Laser leveling thus will not save only precious irrigation water but also help achieve high water use efficiency through more uniform water application, increase in cultivable area, and smoothness of land surface permits larger plot size for irrigation. A significant reduction in total water use in wheat as well as rice was recorded due to precision land leveling compared to traditional land leveling. The total water use in wheat and rice in laser leveling was reduced to 49.5 and 31.7%, respectively, [13]. Farmers level their fields using animal drawn or tractor drawn levelers. These levelers are implements consisting of blade acting as small bucket for shifting the soil from higher to low-lying positions. Precision land leveling is known to enhance water-use efficiency and consequently water productivity and helps in increasing the cultivable land area up to 3 – 5% [14,15]. Also improves crop establishment, reduces weed intensity [16] and results in saving of irrigation water [13]. Precision land leveling must be treated as a precursor technology for improving crop yield, enhancing input-use efficiency and ensuring long-term sustainability of the resources base in intensively cultivated areas. Land leveling is a compromise between surface drainage and surface irrigation [17]. Studies have indicated that significant (20 – 25%) amount of irrigation water is lost during its application at farm due to poor farm designing and unevenness of the fields which leads to inefficient use of irrigation water and also delay tillage and crop establishment options.

Wheat is the most important crop in the Northern State. The government of the Sudan aim to grow more than (4,500,000 Feddan) throughout Merowe high dam, under national strategy for wheat production in Northern State, [18]. Unevenness of the soil surface has major impact on the germination, stand and yield of the crop through nutrient water interaction. Leveling is a precursor to goal of agronomic and soil crop management. Arable land in the Northern and the River Nile State estimated to be 4.8 million feddan (2.02 million hectares). In season 2009/2010, the total area cultivated in the Northern State was (162070 ha) and the main crop was wheat (44.4%) of the cultivated area [18].

Land topography in the Northern State is uneven, and because the main irrigation method is the surface irrigation, the land needs to be properly leveled to insure even distribution of water, improve uniform crop maturity and allow full mechanization of the crop. In the Northern State some studies were carried out for land preparation, sowing method and economics of wheat crop in the upper terraces [19, 20], but it needs more elaboration and studies for confirming or evaluating some tillage findings. The main objectives of the present study is to evaluate the effect of different land leveling system and some ploughing methods on wheat crop yield.

2. MATERIALS AND METHODS

2.1 Location of the experimental area.

The experiment was conducted at Dolgola Research Station farm which is situated in the upper terrace soils, south of the Arab Sudanese Seed Company (ASSCO) premises, and the location is about five kilometer south of Dongola city. The physical and chemical properties of the site soil are shown in table (1).

Table (1). The physio-chemical properties of the soil in Dongola Research Station Farm

Depth (cm)	pH (paste)	Ec ds/m	SAR	BD	Mechanical analysis		
			meq/l	g/cc	Clay%	Silt%	Sand%
0– 25	7.40	0.88	0.56	1.04	26	18	55
25-50	7.30	1.51	0.92	1.09	36	17	47
50-75	7.34	2.50	1.21	1.39	38	16	46
75-100	7.40	2.69	1.21	1.46	38	16	46

2.2 Experimental equipment

Massey Ferguson tractors model 660, 285 of size 150 HP, 70 HP, respectively, were used. The specifications of the tractors are given in table (2). A heavy offset disc harrow (H1), Disc plough (H2), were used to carry out the ploughing treatment. Three leveling equipments, which are laser (L), scraper (S), and traditional method using animal power (T), were used. A seed drill machine (S1), was used for sowing the crop. The specifications of each implement are given in table (3). Other equipment's used were:

The laser-controlled system which requires: A laser transmitter, A laser receiver, An electrical control panel and A twin solenoid hydraulic control valve.

Tape: one-hundred-meter measuring tape, a stop watch used for recording time, a meter squire steel shape to compute the plant data when it was dropped randomly into each plot, an auger was used for collection of soil samples, a doubled ring infiltrometer for determining the infiltration rate, a note book is required to make the sense of survey work completed in the field. Pegs / hammer are required especially for marking.

Table (2). Technical specifications of the tractors used

Tractor type	GIAD Sudan	Massey Ferguson
Model	285	660
Engine Fuel	Diesel	Diesel
Engine type	PerkinsA4-248	Perkinturbo charge
No. of cylinders	4 cylinders	6 cylinders
Weight	2.8 ton	6 ton
Engine speed	2000 rpm	2200 rpm
Tank capacity	90 liters	267 liters
Max. Power	70 HP	150 HP

Table (3). Specifications of different implements used

Description	Model	No. of units	Width of cut (cm)
Heavy offset disc harrow	Brazil (Baldan)	24 disc (12+12)	3.3
Disc plough	GIAD (Sudan)	3 disc	0.75
Laser leveler	ATESPAR(Turky)	3 blade	4.5
Scraper leveler	GIAD	1 blade	1.5
Animal leveler	Local	1 blade	1.5

2.3 Experimental area preparation and design:

A total area of 4980m^2 (166 × 30m), was divided into three blocks representing replicates. Each block was divided into six main plots. All treatments were replicated three times, giving a total of twenty-seven plots. The size of each plot was 72m2 (9×8m). There was one -meter space between the plots and two meters space between the replicates. The main plot allocated for tillage, and sub-plots for leveling methods. The strip plot design was used in which treatments were distributed at random in each of the three replicates.

Treatments used were the following (Fig.1).

- Primary tillage of three types; heavy disc harrow (H1), disc plough (H2 and no tillage (H3).
- Leveling of three types which are: Laser (L1), tractor scraper (L2) and traditional animal leveler (L3).

2.4 Crop husbandry:

The crop sowing was done with variety Wadi Elneil at the rate of 50kg/feddan (120kg/ha.). Nitrogen fertilizer was applied at rate of 80kg/fed. A dose of 40kg/feddan, was applied at the third irrigation, while the second dose of 40kg/feddan was given at the fifth irrigation. Triple super phosphate fertilizer was applied at sowing at the rate of 40kg/feddan.

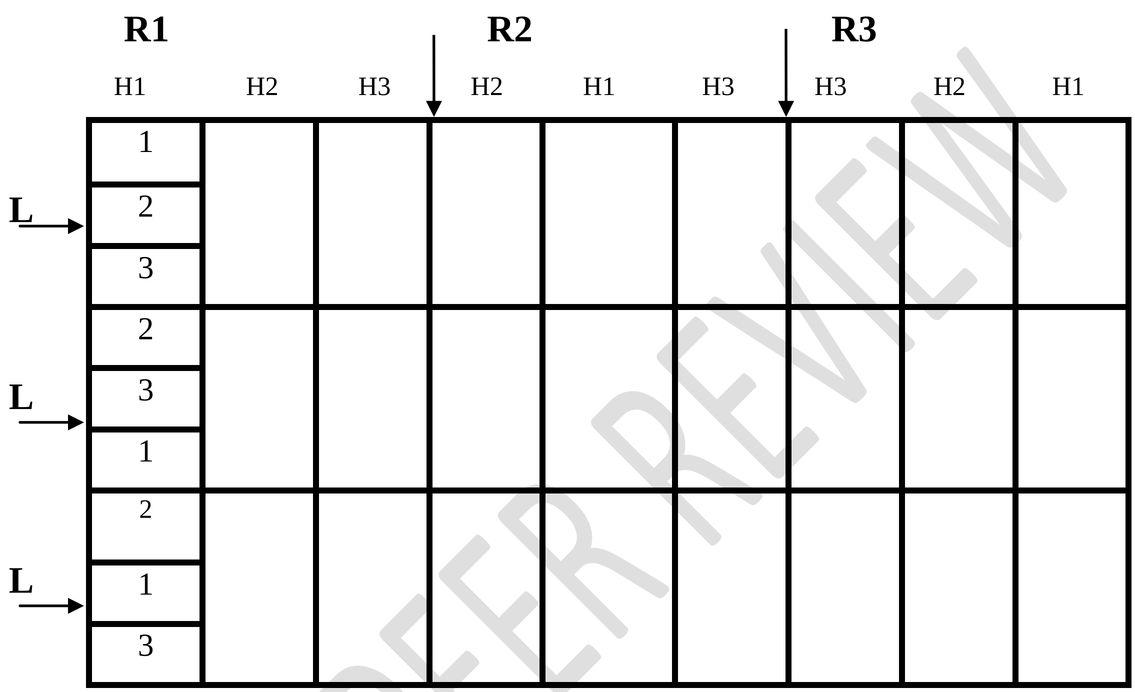

Fig. 1. Field experiment layout

2.5 Field parameters measurements

a/ Measurement of field capacities and efficiencies of machinery:

Field efficiency (FE %) was calculated as follows

$$FE(\%) = \frac{\text{Productive time}}{\text{Total time}} \times 100$$

The effective (actual) field capacity (EFC) was calculated as follows:

$$EFC = (S \times W \times FE) / CF.$$

Where: EFC = Effective field capacity (ha/hr).

S = Travel speed of machine (km/hr).

W = Effective width of cut in meters.

FE = Field efficiency %

CF = Conversion factor, for ha. = 10

b/ Measurement of wheel slippage of tractor.

The slippage of rear wheat measurement for the tractor linked with the different implements as follows:

$$\text{Slippage \%} = \frac{D1 - D2}{D1}$$

Where: D1 = Distance without load
D2 = Distance with load.

c/ Measurement of fuel consumption 0f tractor:

The fuel consumption for different operations was measured as follows:

$$\text{Fuel consumption rate (liter/ha)} = \frac{\text{Reading of the cylinder (L)}}{\text{Time required to finish the plot (hr.)}}$$

Steps in Laser Land Leveling

Land leveling was carried out according to [16].

. - The field should then be re-surveyed to make sure that the desired level has been attained [22].

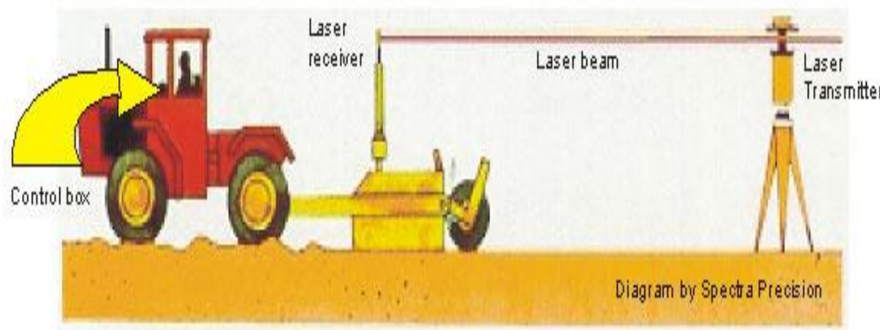

Fig.2. Land laser leveling components

d/ Soil moisture content measurement.

Soil samples were taken at the depth of 0-25, 25-50, 50-75 and 75-100 cm, before treatment and before each irrigation, and at harvest by a metal auger, and Soil moisture content percent was determined as follows:

$$\text{The soil moisture content (\%db)}, = \frac{W1 - W2}{W2} \times 100$$

Where: W1 = Wet sample weigh (g), W2 = Dry sample weigh (g)

e/ Infiltration rate measurement.

A doubled ring infiltrometer was used to measure the infiltration rate of the water into the soil, following the procedure described by [21]. Reading of the water level in the inner cylinder was recorded a pre-determined time interval of 5, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 75, 90, 105, 120 and 240 minutes from start of the test until steady state infiltration was attained two times. Before and after ploughing, infiltration rate (I) and elapsed time (t) were related by the following equation:

$$I = kt^n$$

Where:

I = accumulated infiltration (cm) in time (t) minutes.
t = elapsed time (minutes).
n and k = are characteristic constants.

f/ Plant population/m^2:
To determine plant population, square metal steel was used. it was thrown randomly over plants in each plot, at plant age 85 days from the first irrigation. The samples were taken from each plot, and plant population per meter square was determined

g/ Crop grain yield (ton/hectare)
Harvesting was done by cutting an area of 15m2 randomly from each plot. The crop materials from each plot threshed, cleaned and weighed. The grain yield in ton/hectare was calculated.

3. RESULTS AND DISCUSSION

3.1 Machinery performance parameters

The results of field performance parameters of machineries used in this study is given in table 4. The highest field efficiency and effective field capacity was recorded by heavy disc harrow as 71.2% and 0.89 ha/hr, respectively, while the lowest field efficiency and efficient field capacity (55%) and 0.22 ha/hr) recorded by laser leveler. This could be due to lower speed and greater time loss in the field with soil condition (Fig. 3). The highest fuel consumption rate in liters per hour was recorded by the laser leveler (16.3 L/hr) followed by the heavy disc harrow as 13.6 L/hr. This higher fuel consumption obtained by the laser leveler could be due to its long time taken in the field and lower effective field capacity. These results in line with the findings of [23, 24]. It was observed that the highest slippage (8.1%), was recorded by the heavy disc harrow followed by the disc plough (6.3%). This could be due to the deep working depth and high load of the machine on the soil (Fig.4).

Table (4). Some measured machinery performance parameters.

Implement used	Speed (km/hr)	Width of cut (m)	Slippage (%)	FE (%)	E.F.C (ha/hr)	FC L/hr
Heavy disc harrow	4.3	3.3	8.1	71.2	0.89	13.6
Disc plough	4.7	0.76	6.3	70.6	0.24	7.3
Seed drill machine	5.2	1.65	2.2	69.0	0.65	6.2
Laser leveler	1.5	3.5	5.9	55.0	0.22	16.3

Scraper leveler	4.8	1.5	3.2	60.7	0.34	7.2
Animal scraper	2.5	1.5	3.4	60.2	0.24	0.0

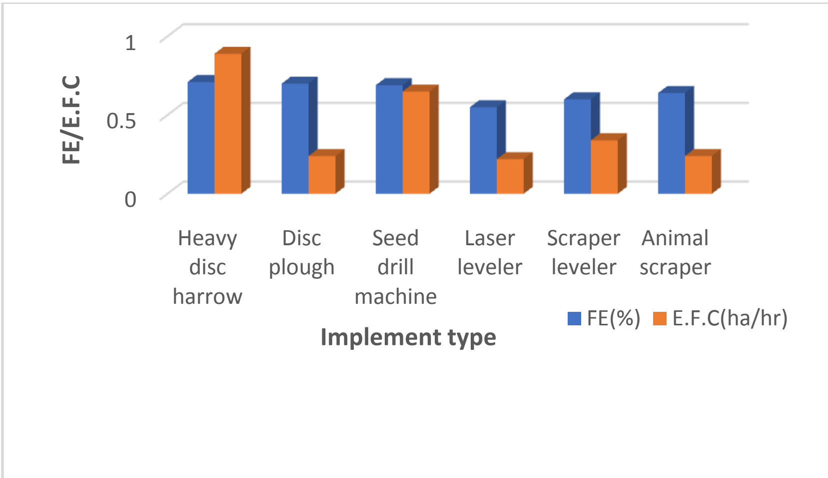

Fig.3. Effect of implement type on field efficiency and effective field capcity

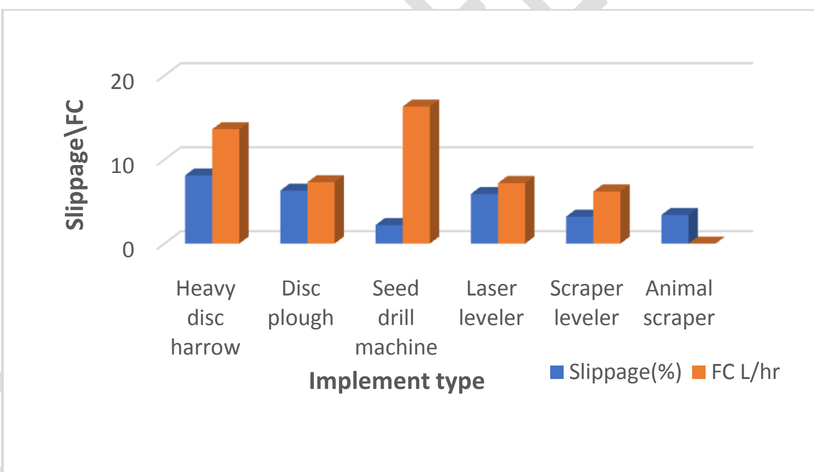

Fig4 : Effect of implement type on slippage and fuel consumption

3.2 Effect of tillage treatment on soil moisture content and infiltration rate

The soil moisture content (db%) distribution was generally affected by the tillage treatments for the two seasons. The trend was increased moisture content (db%) with increased depth and then decreased (table 5). These results were in line with that of [19]. In the two seasons, the analysis of variance for the effect of different treatments at different depth on average soil moisture content showed significant differences between treatments. The average soil moisture content (db%) of the two seasons was recorded as 22.0%, 21.5% and 20.4%, respectively. for (H1 L), (H2 L) and (H3 L), respectively, (table 5). It was clear that for two seasons soil moisture content (db%) increased significantly under precision laser leveling due to improved application and distribution efficiency of irrigation water and increases with depth. These results are in conformity with that of [25,17,12]. The results of soil moisture content (db%) obtained after all irrigations followed the same trend.in both seasons. The trend was increase in soil moisture content with increase in depth and then decrease (Fig.5). Significant differences between treatments in the first season, while in the second season, no significant differences were found between treatments. This study indicates that, the precision leveling using laser land leveler [10] with heavy disc harrow, could help to save s irrigation water and also achieve high water use efficiency through more uniform water application.

Table (5). Mean soil moisture content (db), average of all irrigations

Treatment	Depth (cm)				
	0-25	26 -50	51 - 75	76 -100	Mean
H1 – T	17.78	20.65	24.20	24.41	21.76
H1 – S	17.41	20.25	21.99	23.05	20.68
H1 - L	17.64	21.92	23.61	24.82	22.00
H2 – T	16.98	19.34	20.79	21.38	19.62
H2 – S	17.36	19.90	21.33	22.61	20.30
H2 - L	17.45	20.76	22.28	23.89	21.10
H3 – T	16.99	19.32	20.98	21.32	19.65
H3 – S	17.22	19.82	21.55	22.16	20.19
H3 – L	16.85	19.98	22.10	22.98	20.48

H1-T: heavy disc harrow + Animal land leveling. H1-S: H.D.H. + scarper land leveling. H1-L: H.D.H + Laser leveling
H2-T: Disc plough + Animal land leveling. H2-S: D.P + scraper land leveling. H2L: D.P + laser leveling
H3-T: Zero tillage + Animal land leveling. H3-S: Zero tillage + scraper land leveling. H3-L: Zero tillage + Laser leveling

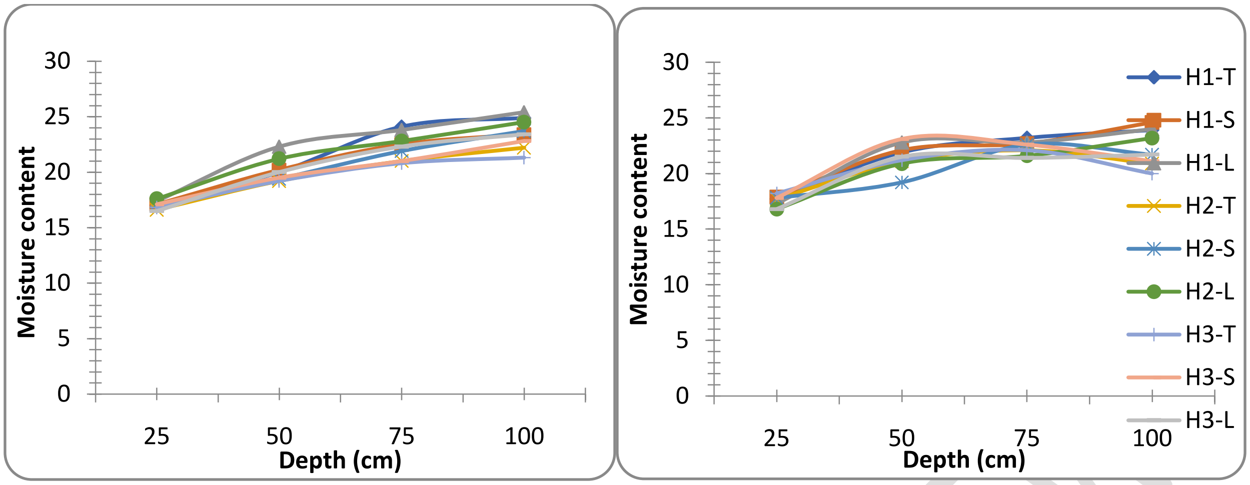

Fig. (5). Effect of tillage and leveling on soil moisture content (%db) average of all irrigations, season (1,2)

The infiltration rate was observed to increase with different tillage treatments. Heavy disc harrowing recorded the highest initial infiltration rate (31 cm/hr), and the lowest by zero tillage which recorded (18cm/hr). The increase in the infiltration rate could be due to increase in porosity and aggregation of the surface soil. These results agreed with those obtained by [26,19,11]. For all treatments the infiltration rate decreases with time until it reached a constant rate as the time elapsed (Fig. 6). This is in line with that reported by [21]. The heavy disc harrow also recorded the highest value of average accumulative in (cm) at (180 minute), (Fig, 4). It was clear that, infiltration rate values in (cm/hr) as affected by different levelers used after ploughing treatments showed that the highest initial infiltration rate was recorded by laser leveler used after heavy disc harrow (H1- L), followed by the animal leveler (H1- T) and scraper leveler used after heavy disc harrowing (H1 S), recording 30, 26 and 24cm/hr, respectively.

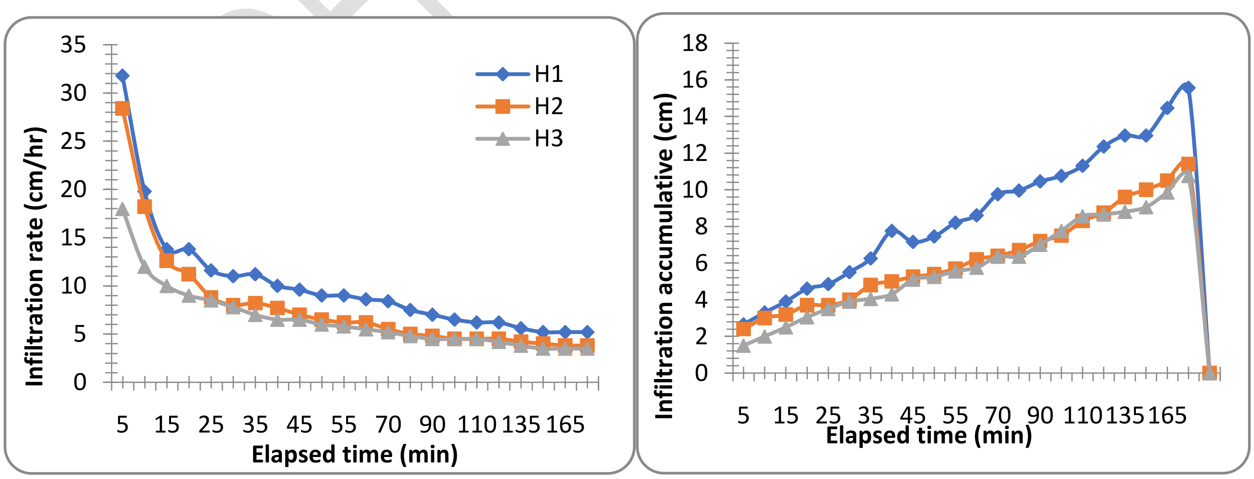

Fig. (6) Measurement of infiltration rate and accumulative intake (in cm) with time for different tillage treatments

3.3 Effect of different treatments applied on wheat plant population:

Plant population as affected by the tillage and leveling treatments is shown in table 6. The analysis of variance showed that the difference between the effects of tillage treatments was highly significant at (1%) level for the first season, while in the second season significant differences among the treatments at 5% level. In both seasons, the highest number of plant population was recorded by the heavy disc harrow giving values of (369) and (365) plants/m^2 for season one and two, respectively (Fig. 7). The highest plant population resulted from the heavy disc harrow could be attributed to the good soil pulverization. This is agreed with the findings of [27].

The analysis of variance showed significant differences between the effect of leveling methods at (1%) probability in the first season, in the second season, there were no significant differences between the treatments of leveling methods (table 6)**.** The laser land leveling recorded the highest plant population as 370 and 368 plants/m^2 for the two seasons, respecti6ely. (Fig. 7). This could be due to laser land leveling resulting in uniform distribution to the entire field and allowing uniform crop stand and growth thus resulting in lesser weed infestation and agreed to that reported under precisely leveled fields in comparison to traditional leveled fields [13, 6]. The analysis of variance indicated that there are significant differences between the tillage leveling treatments in the first season, but in the second season no significant difference affected tillage and leveling methods. The leveling by laser used after heavy disc harrow resulted in the greater plant population in both seasons than other land leveling treatments used (table 7).

Table (6) Effect of different tillage, leveling and sowing method on wheat plant population (plant/m2), seasons (1) and (2).

Tillage	Season (1)	Season (2)
H1	369	365
H2	367	364
H3	361	359
SE±	0.6427	1.2258
Significant level	**	*
Leveling		
T	362	360
S	365	360
L	370	368
SE±	1.0749	1.8394
Significant level	**	NS

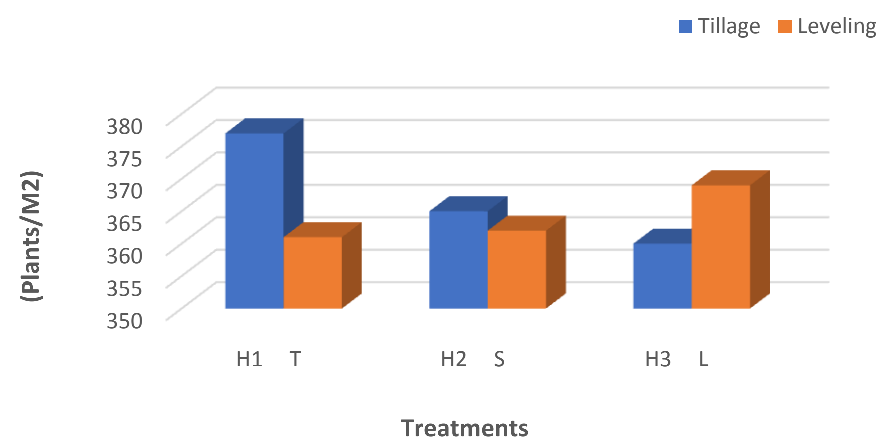

Fig.7. Effect of ploughing and leveling treatments on plant population

Table (7). Effect of different tillage and leveling treatments on plant population and wheat yield

Tillage/ leveling	Plant / m2	Plant /m2	Grain yld (ton/ha)	Grain yld (ton/ha)	Plant/m^2 Average	Grain yld ton/ha/Avg

H1 –T	360	361	3.02	3.03	361	3.02
H1 – S	363	367	3.67	3.63	365	3.65
H1 – L	371	379	4.85	4.38	375	4.63
H2 – T	360	364	2.98	3.17	362	3.07
H2 – S	361	367	3.57	3.33	364	3.45
H2 – L	371	369	4.08	3.82	370	3.95
H3 – T	361	361	2.93	3.07	361	3.00
H3 – S	356	362	2.94	2.83	359	2.88
H3 – L	361	360	3.05	2.92	361	2.98
SE±	3.1859	1.8617	0.066	0.0834		
Sig. level	NS	**	*	**		
C.V.%	2.26	1.71	8.33	5.49		

Means followed by the same letter(s) have no significant difference among them selves according to Duncan's Multiple Range Test (DMRT).

3.4 Effect of different treatments on wheat grain yield (ton/ha).

The results of grain yield as affected by ploughing method or leveling type is shown in table 8. The analysis of variance indicated significant different between the tillage treatment effects on grain yield at 5% and 1%, in the first and second season, respectively (table 8). In both seasons, the highest crop yield was recorded by the heavy disc harrowing tillage treatment as 3.8 ton/ha and 3.7 ton/ha and the average yield increase for the two seasons was about 20% compared to no-tillage (Fig. 8). The highest crop yield obtained by heavy disc harrow treatment could be due to the deep tillage, positive effect of this practice on plant establishment, this result is similar to findings of [28]. The analysis of variance indicated highly significant differences between the leveling treatments effect on crop grain yield at (1%) probability level in the two seasons (table 8). In both seasons, the highest crop yield was recorded by laser land leveling treatment as 4.0 ton/ha and 3.7 ton/ha and the average increase in yield for the two seasons was 20% compared to animal land leveling (Fig. 8). The highest crop yield obtained by laser land leveling treatment could be due to better environment for the development of the plant under well-leveled field [29,30]. The interaction effect of tillage and leveling methods treatments on grain yield for the two seasons is shown in table 7. The analysis of variance showed highly significant differences at 1% probability level for the two seasons. In both seasons, the highest grain yield was recorded by the heavy disc harrow with laser leveling treatment giving values of (4.85 ton/ha.) in the first season and (4.38 ton/ha.) in the second season. The higher crop yield obtained could be attributed to good soil pulverization, improve application and distribution efficiencies of irrigation which ultimately leads to higher water production.

Table (8) Effect of different tillage, leveling treatments on wheat total grain yield (ton/ha), seasons (1) and (2).

Tillage	Season (1)	Season (2)
H1	3.811	3.683
H2	3.544	3.439
H3	2.989	2.939
SE±	0.0884	0.0635
Significant level	*	**
Leveling		
T	2.978	3.089
S	3.372	3.267
L	3.994	3.706
SE±	0.0466	0.0482
Significant level	**	**

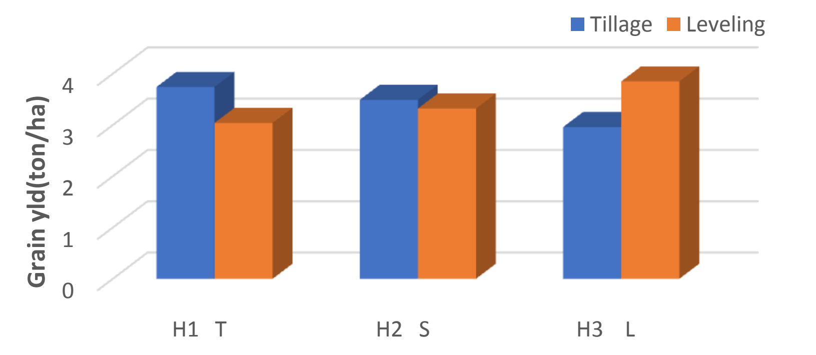

Fig.8. Effect of ploughing and leveling treatments on grain yield

4. CONCLUSION

The following conclusions can be drawn from the results of the present study:

1. Tillage treatments improve soil physical properties, and the heavy disc harrowing with laser leveler treatment recorded the highest values of soil moisture content and Infiltration rate

2.. Laser leveler recorded the lowest field efficiency, effective field capacity, and highest fuel consumption while the heavy disc harrow recorded the highest wheel slippage (8.13%), effective field capacity (0.89ha/hr) and field efficiency (71%)

3. The highest grain yield (5.33 and 4.8 ton/ha), was recorded by laser leveler used

after heavy disc harrow, and the lowest grain yield (2.5 and 2.7 ton/ha), recorded by zero tillage system in the first and second seasons, respectively.

4. The highest average plant population (381 plant/m2) was recorded by laser leveler with heavy disc harrow and the lowest average plant population (357 plant/m2) was recorded by zero tillage system in the first and second season, respectively.

5. Laser leveling of agricultural land is a recent resource-conservation technology initiative in the Northern State and the results are quite encouraging with heavy disc harrow.

REFERNCES

1. FAO (1995). Agricultural mechanization policy and strategy formulation for Sudan-Technical report. FAO TCP/SUD/4451. Rome- Italy.
2. Ranjbarian, S., Askari M. and Jannatkhah. J. (2017). Performance of a tractor and tillage implements in a clay soil. Journal of the Saudi Society of Agricultural Sciences.16, 154–162.
3. Ganguli, B.D. and Relwani, L.L. (1981). Effect of tillage and source of nitrogen on yield of wheat. Indian J. Agric. Sci. 28 (4): 511 – 518.
4. Abolanle, M., S. Singh, A. Kaur, R. Bhatt and A. Ally, 2015. Conservation tillage impacts on soil, crop and the environment. International Soil and Water Conservation Research, 3: 119-129.
5. Maurya, P.R. (1993). Tillage practice under irrigated agriculture in the semi- arid region of Nigeria. Agricultural Mechanization in Asia, Africa and Latin America. 24 (3): 14 – 18.
6. Omer A. Abdalla, M. H. Dahab, Abbas M. Mudawi, Eltayeb S. N. Babikir (2021). Effect of Tillage Implement Type and Depth of Ploughing on Field Performance Parameters in Vertisol Clay Soil of Gezira Scheme (Sudan). *Journal of Scientific and Engineering Research*, 8(1):1-7.
7. Bukhari, S.; Mori, G. R.; Shah, M. Z; Bloch, J. and Panhwar, S. (1992). Effect of disc and tilt angle on field capacity and power requirements of mounted plough. Agricultural Mechanization in Asia, Africa and Latin America.23 (2): 9 – 12.
8. ASAE, (1981). Terminology and definitions for tillage and soil tool relationships. American society of Agricultural Yearbook: 2;47 – 49.
9. Khurshid K, M Iqbal, M S Arif and A Nawaz, 2006. Effect of tillage and mulch on soil physical properties and growth of maize. International Journal of Agriculture and Biology, 8: 593-596.
10. Rajput, T.B.S and Patel N 2004. Effect of land leveling on irrigation efficiency and wheat yield. J. soil and water conservation 3(1&2): 86 – 96.
11. Kanannavar, P. S., B. D. Premanand, B. Subhas, B. Anuraja and P. Basavaraj Bhogi. 2020. Int J. Curr. Microbiol. App. Sci., 9(5), 2393-2398.

12. Rajput, T.B.S.; Patel, N.A.; Graval, G. (2004). Laser leveling a tool to increase irrigation efficiency at field level. J. Agric. Eng. 41 (1): 20 – 25.
13. Jat, M.L, Pol S.S, Subba Rao, A.V.M and Sharma, S.K. 2003. Improving resources use efficiency in wheat through laser land leveling an ustodirept of Indo-gangetic plain. In National Seminar on Development in soil science, 68th Annual Convention of the Indian Socity of soil Science, November 2003, CSAUAT. Kanpur (UP).
14. El-Gundy, A.A.M.; Hasan, EL.G.; Sayd and El-Banna Osman. (1996). Effect of precision land leveling system on wheat and maize production, paper presented at 2nd international conference on laser application 16 19 September, Cairo Egypt.
15. Brye, K.R.; P. Chen; L.C. Parcell; M. Mozaffari; and R.J. Norman, 2004b. First year soybean growth and production as affected by soil properties following land leveling. Plant soil 263: 323 – 334.
16. Richman, J.F. (2002). Manual for laser land leveling " Rice-wheat consortium for the indo-gangetic plains. National Agricultural Technology Project. Indian Council of Agricultural Research.
17. Sattar, A. Khan; F.H and Tahir, A.R. 2003. Impact of precision land leveling on water saving and drainage requirement. J.AMA. 34: 39-41.
18. M of A. NS. Ministry of Agriculture, planning department, Northern State, 2000). Annual report.
19. Dahab, M. H. and Mahgoub, M. A. (2009). Effect of tillage and sowing methods on wheat production in the upper terraces of the Northern State. University of Khartoum Journal of Agricultural Sciences 17(3): 112 – 116.
20. Shambat, SudElhori, A. I. S., Asma A. A. M. and AlaAldin S. M. (2017). Economics of Wheat (*Triticum spp.*) Production in Dongola Area, Northern State, Sudan. Nile Journal for Agricultural Sciences 2(1), 12 – 22.
21. Michael, A.M. (1978). Irrigation theory and practices. Vikus Publishing house. P. VT. LTD. New Delhi, India.
22. Chaudhuri, D.S.K. Nathankor, V.V.; Singh and N.A. Shirsat, (2005). Performance evaluation of laser guided and leveler for land grading in vertisol of central India, a paper presented in the 39th annual convention of ISAE held at Acharaya, N.C. Ranga Agricultural University, Hydrabad.
23. Bowers, C.G. (1989). Tillage draft and energy measurement for twelve Program. southern soil series . Trams ASAE. 32 (5) 1492- 1502.
24. Balel, M. M. and Dahab, M. H. (1997). Effect of soil condition on a two- wheel drive tractor performance by using three types of tillage implements. U. K. J. Agric. Sci. 5(2), 1-22.
25. Fadel, I.E. (1989). Influence of the tillage method on fodder sorghum yield, un-publish thesis, Faculty of Agriculture at U. of K.
26. Abdalla, M.A. (1995). Tillage Practice for soil moisture conservation in Dongola area- Sudan. M.Sc Thesis U. of K.

27. Dahab M. H., Mergani, S. S. A., Omer A. A. (2021). Effect of Some Land Preparation and Sowing Methods on Wheat Production in the Lower Terraces of Northern State of Sudan (Dongola area). *International Journal of Scientific Engineering and Science* 5 (5), 26-30.
28. Khattak, J.K.; Larsen, K.E.; Rashid, A.; Khattak, R.A. and Khan, S.V. (1991). Effect of land leveling and irrigation on wheat yield. Journal of AMA. 12:11-14.
29. Abdalla N. O. K., DAHAB, M. H. and Alhag, H. M. A. (2022). Effect of Different Land Leveling Systems and Sowing Methods on Growth and Yield of Wheat in the Upper Terraces of Northern State – Sudan. *International Journal of Academic Engineering Research 6* (10), 19-25.
30. Abdelraouf R. Eid, Mehana H. Mohamed, Sabreen Kh. Pipars, Bakry A. Bakry (2014) IMPACT OF LASER LAND LEVELING ON WATER PRODUCTIVITY OF WHEAT UNDER DEFICIT IRRIGATION CONDATIONS. Current Research in Agricultural Sciences 2014 Vol. 1, No. 2, pp. 53-64