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RESEARCH ARTICLE

WHEAT CROP PRODUCTION BY DIFFERENT PLOUGHING, LEVELING AND SOWING METHODS IN THE UPPER TERRACES OF THE NORTHERN STATE- SUDAN

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ABSTRACT

Wheat is an important field and food crop worldwide and in Sudan it is grown in many areas using different types of cultural practices. A field experiment was conducted in Dongola Agricultural Research Farm, Northern State, for two successive seasons to investigate the effect of three leveling techniques; Laser (L), Scraper (S) and traditional (T); three type of ploughing; heavy disc harrow (H1), disc plough (H2) and no-ploughing (H3), and two sowing methods; seed drill machine (S1) and manual seed broadcasting (S2)on wheat production. The experiment was arranged in split-split plot design and the treatments were replicated three times in both seasons. The results showed significant differences at the 5% between machinery treatments effect on the parameters measured. The laser land leveling recorded the highest fuel consumption (16.3L/hr), and lower effective field capacity (0.25ha/hr), while the seed drill recorded the lowest fuel consumption (6.2 L/hr) and the highest effective field capacity(0.94 ha/hr)and wheel slippage (8.3%) were recorded by the heavy disc harrow. The soil moisture content (db %) was increased with time and depth. The highest mean soil moisture content at 75-100cm soil depth was obtained by the laser land leveling with heavy disc harrow treatment, while the lowest moisture was recorded by no-ploughing with traditional leveling in both seasons. The highest average grain yield (5.08 ton/ha), plant population (381 plants/m^2), total biological yield (13.6 ton/ha), infiltration rate (31cm/hr) and harvest index (37%) were recorded by the laser land leveling and heavy disc harrow with machine seed drilling. The lowest grain yield was recorded by the combination of no-till, animal-drawn leveling and seed drilling and also scraper leveling with manual seeding recorded, 2.5 and 2.7 ton/ha for the two seasons, respectively. The study concluded that, a highly significant effect (P≤ 0.001) of laser leveling with disc harrow ploughing and seeding by seed drill machine on grain yield, compared to the other treatments used in the study, and 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.

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INTRODUCTION

Agriculture is the primary source of food for the majority of the world population through plant and animal products. Wheat (*Triticum aestivum* L.) is one of the most worldwide, important food crop. It is almost the third most-produced cereal after maize and rice. The crop grown on about 220 million hectares worldwide, covering more land area than any other crop FAO, (2016). In the Sudan, wheat production is mainly in Gezira scheme, the Northern and Nile States in addition to little areas in Rahad and New Halfa schemes MASTAT (2016). Northern state of Sudan is located in the desert zone between longitude 32°,25´E and latitude 22°,16´N. rainfall varies from 100 mm in the south to 25mm in the north or none in the northern part of the state. It is obvious that local rail fall contribution as well as intermittent stream to the Nile is negligible (MFG, 2006). The main source of water in the Northern State is the flood of the Nile river and crop production here, are only through irrigation, by pumping water from the main Nile or by using the ground water. High terrace soils constitute the largest proportion of land available for future agricultural expansion in the northern state, especially after the completion of the Merowe dam.

The need for more food to satisfy the demand of the ever-increasing population necessitates the cultivation of these problematic soils (Dahab *et al*., 2021). Due to these limitations, many farmers moved to the upper terrace. Governmental agricultural schemes in northern state are also established in the upper terrace soils. The Northern State environment is the most suitable for wheat production and this is mainly attributed to the relatively suitable climate, fertile soils, expert farmers and availability of water and some infrastructures (Dahab and Mahgoub, 2009). Recently in Sudan it was plannedto reach self-sufficiency in wheat production via vertical and horizontal expansion by rehabilitation of the existing agricultural schemes and cultivation of new areas Shambat, (2017). This should depend mainly on mechanized farming and usage of modern agricultural technical packages such as improved seeds, fertilizers, insecticides and mechanized services. The large areas cultivation will depend upon mechanized production systems efficiently used and managed. Special attention should be given during the selection of the appropriate machine for proper land preparation and suitable sowing methods for high and profitable crop yield. Some research work was done worldwide (Singh *et al*., 2017, Bartaula *et al*., 2020, Rajkumar *et al*., 2018, Khan *et al*., 2017, Haemanpreet *et al*., 2021) and, in the Sudan, thereare some research to study the adaptation and wheat yield and production in the irrigated schemes (Alsayim *et al*., 2018, Dahab *et al*., 2023). Some studies indicate significant increase in irrigation efficiencies of wheat and rice through precision leveling using Laser and land levelers (Rajut and Patel, 2004). 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. This helps in saving precious land also adds additional land after removal of extra bunds and canals (Kumar *et al*., 2022, Kanannavar *et al*., 2020, Ashraf *et al*., 2017). Conventional surface irrigation practices in unleveled bended units normally results in over irrigation and this results in excessive loss of irrigation water through deep percolation and reduces the application efficiency up to 25% (Satter, *et al*. 2003). Precision land leveling increases the cultivable land area up to 3 – 5% (Jat *et al*. 2011). Unevenness of fields leads to inefficient use of irrigation water and also delay tillage and crop establishment options and increase weed burdens and uneven maturing of crops (Niamatullah, 2015, Naresh *et al*., 2012, Abdelraouf *et al*., 2014). All these factors tend to contribute to the yield and grain quality, which reduce the potential of farm income. Land topography in the Northern State of Sudan 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. There are some studies carried out for wheat crop production in the Northern state (Abdalla *et al*., 2022), but it needs more elaboration and studies with other and more parameters. The main objective of the present study is to produce wheat crop in the upper terraces of the Northern state by using different land ploughing, leveling and sowing methods.

MATERIALS AND METHODS

Location of the experimental area: The experiment was conducted at Dongola Research Station farm (DRSF). The farm 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 soilat the experimental area are shown in Table (1).

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 fifty -four 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 (tillage, H1, H2 and H3).) Sub-plots, leveling (L1, L2and L3); sub-subplots, seeding methods (S1 and S2). The strip split-split plot design was used in which treatments were distributed at random in each of three replicates.

Factors used were the following:

H1L1S1, H1L1S2, H1L2S1, H1L2S2, H1L3S1, H1L3S2
H2L1S1, H2L1S2, H2L2S1, H2L2S2, H2L3S1, H2L3S2
H3L1S1, H3L1S2, H3L2S1, H3L2S2, H3L3S1, H3L3S2

Afterploughing the field, land leveling using the laser leveler was carried out according to the procedure mentioned by……

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.

Estimation of crop water requirement (CWR): One quantity of water estimated from knowledge of the potential evapo-transpiration (ETp), crop factor and WAE value was applied at fixed 10 days interval for all plots by the following Penman's equation, as modified by Ibrahim, (1995) to suit Sudan's conditions. It was adopted for computation of monthly potential evapo-transpiration.

(ETp) for Dongola area

$ETp = H + 0.5\ Ea + 0.5$ ………………(1)

Where:

ETp = daily rate of potential evapo-transpiration
Ea = slope of saturation vapour pressure
H = net radiation in unit of evaporating

Table 1. The physio-chemicalproperties of the soil in Dongola Research Station

Depth (cm)	pH (paste)	Ec ds/m	ESP %	$CaCO_3$ %	BD g/cc	Mechanical analysis		
						Clay%	Silt%	Sand%
0– 25	7.40	0.88	0	6.4	1.05	26	18	55
25-50	7.30	1.51	0	6.5	1.21	36	17	47
50-75	7.34	2.50	1	6.1	1.37	38	16	46
75-100	7.40	2.69	1	5.2	1.45	38	16	46

Table (2). Different tractors and tillage implement models

Description	**Model**
Tractor 75hp	285 GIAD, Sudan
Tractor MF	660, Brazil
Heavy offset DH	Brazil, (Baldan)
Disc plough	GIAD, (Sudan)
Seed drill	ATESPAR, Turky)
Laser leveler	ATESPAR, Turky)
Scraper leveler	GIAD
Animal leveler	Local

Experimental equipment: A Massey Ferguson tractors model 660, 285 of size 150 HP, 70 HP, respectively, was used. The specifications of the tractor are given in table. A heavy offset disc harrow (H1), Disc plough (H2), were used to carry out the experimental treatments for land preparation. Three leveling equipment, 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 implement are given in Table (3-3). There are other equipment used to carry out the different field experiments and operations.

ETp data reported in Table (3). Crop evapotranspiration (ETp crop) was calculated from the following empirical relationship.

$ETp\ crop = Kc – ETp$ ……………………(2)

Where:

Kc = crop coefficient which varies with the crop stage of growth, and prevalent environment conditions.

The crop water requirement was calculated according to equation (2) for the two successive seasons and reported in Table (3). In the irrigation requirement (IR), the actual quantity of water applied in each irrigation to secure the CWR in the root zone was calculated by the following equation assuming irrigation efficiency as 70%.

Table 3. Monthly water requirements (m^3/feddan) for wheat in the upper terrace soils of Dongola area (2008-2009)

Month	ETp mm/day	Kc	ET crop mm/day	IR	
				Mm/day	m^3/feddan
December	3.47	0.8	2.78	4.0	504.0
January	3.64	1.2	4.37	6.2	781.2
February	4.32	1.1	4.75	6.8	856.8
March	5.79	1.0	5.79	8.3	1045.8

(Source: IzzEldeen *et al*., 2000)

Where:

Kc = Crop coefficient which varies with crop.
ETp = Evapo-transpiration of plant (mm/day).
ETc = Evapo-transpiration of crop (mm/day).
ETc = Kc x ETp
IR = Irrigation requirement.

Machinery performance parameters measurements: Some performance parameters e.g. field efficiency, effective field capacity, wheel slippage and fuel consumption, were measured according to procedures described by Hunt (2015).

Soil moisture content: 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. For each treatment, soil samples were taken by a metal auger, and were kept in labeled plastic bags in a metal cans. The procedure was repeated out in the three replicates. Sub-samples were weighed and dried in an oven at 105˚C for 24 hours, the samples were weighed again. 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)

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 Michael (2011). Infiltrationrate (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.

Plant population measurement: Plant population per meter 3quire was determined by usingone meter squadron. It was thrown randomly over the growing plants in each plot; three samples were taken from each plot and averaged.

Plant height measurement: Three samples from each treatment in each replicate were selected randomly at age of 85 day from sowing (first irrigation). These samples were weighed, and the average was taken to represent plant height for each treatment.

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 as:

$$\text{grain yield (ton/ha)} = \frac{\text{grain wt(gm)} \times 10000}{15m^2 \times 1000 \times 1000}$$

Total biological yield (ton/ha.): Crop materials, which were collected for grain yield, was weighed after drying for each plot before threshing and recorded as total biological yield, then converted to ton/ha.

Harvesting index (%): Harvesting index is the percentage of total grain yield to the total biological yield was calculated as follows:

$$\text{Harvesting Index} = \frac{\text{Final grain yield (ton/ha)}}{\text{Total biomass (ton/ha).}} \times 100$$

RESULTS AND DISCUSSION

Machinery performance parameters measurements: It was observed that the implements used are tractor mounted or drawn, therefore the measured parameters mainly dependent on tractor output, operator, soil condition and implements size.The highest field efficiency and effective field capacity was recorded by heavy disc harrow (71.2%) and (0.94 ha/hr), respectively, while the lowest (55%) and 0.25 ha/hr) were recorded by laser leveler. This could be due to lower speed and greater time loss in the field with soil turnings (Table 4).The highest fuel consumption rate in liters per hour was recorded by thelaser leveler (16.3 L/hr) followed by the heavy disc harrow which recorded 13.6 lit/hr. This highest fuel consumption obtained by the laser leveler could be due to its long time taken in the field and lower effective field capacity. Table (4) shows that the heavy disc harrow recorded the highest slippage (8.1%), could be due to the deep working depth (22cm) and high load, while the lowest slippage value was recorded by the seed drill machine (2.2%). This may be due to lower load and depth of work.

Effect of tillage and leveling treatments on soil moisture content (db %) and infiltration rate (cm/hr): The result of the soil moisture content (db %) before irrigation for the two seasons averageis given in table 5. The analysis of variance for soil moisture content showed the highest moisture content at (50 – 75) and (75 – 100) cm depth in both seasons. Soil moisture content (%) was observed to be the lowest at the top surface for the two seasons, recording (2.6%). This could be due to the fact that surface layer is subject to drying more quickly because of the direct exposure to sun and air. The average soil moisture content (db%) in the two seasons showed significant differences between treatments in both seasons. The highest moisture content (db%) was recorded by laser leveling used after heavy disc harrow, followed by laser leveling used after disc ploughing and laser leveling used after no tillage treatment. In the first season recorded 21.6%, 20.5% and 20.4%, while in the second season they recorded 21.35, 20.83 and 20.49, respectively, (Fig. 1). 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, infiltration rate and increases with depth. These results are in conformity with that of Sattar *et al*, 2003 and Rajput and Patel 2004. Generally, it was observed that soil moisture content increased with depth and decreased for all treatmentsand also increased with time.

The studied infiltration rate values in (cm/hr) as affected by different tillage treatments are shown in Figure (2). Heavy disc harrowing obtained the highest initial infiltration rate (31 cm/hr), followed by the disc ploughing and zero tillage which recorded (28.4 cm/hr) and (18cm/hr), respectively. The increase in the infiltration rate for heavy disc harrow could be due to increase in porosity and aggregation of the surface soil. The heavy disc harrow recorded the greatest value of average accumulative in (cm) at (180 minute), as (15.55cm). Generally, it was observed that for all treatments, the infiltration rate decreases with time until it reached constant rate as the time elapsed. [30]Michael (2011) reported that, the initial infiltration rate decreases during irrigation with time

Table 4. Some measured implement performance parameters

Implement type	Width of cut (cm)	Slippage (%)	FE (%)	EFC (ha/hr)	TFC (ha/hr)	Speed (Km/hr)	FC (Lit/hr)
Heavy disc harrow	3.3	8.13	71.2	0.94	1.32	4.0	13.6
Disc plough	0.72	6.27	70.6	0.24	0.34	4.7	7.3
Laser leveler	3.5	5.9	55.0	0.25	0.40	1.2	16.3
Scraper leveler	1.5	3.2	60.7	0.35	0.56	3.8	7.2
Seed drill machine	1.64	2.2	69.0	0.55	0.82	5.0	6.2
Animal scraper	1.5	--	60.0	0.22	0.36	2.4	0.0

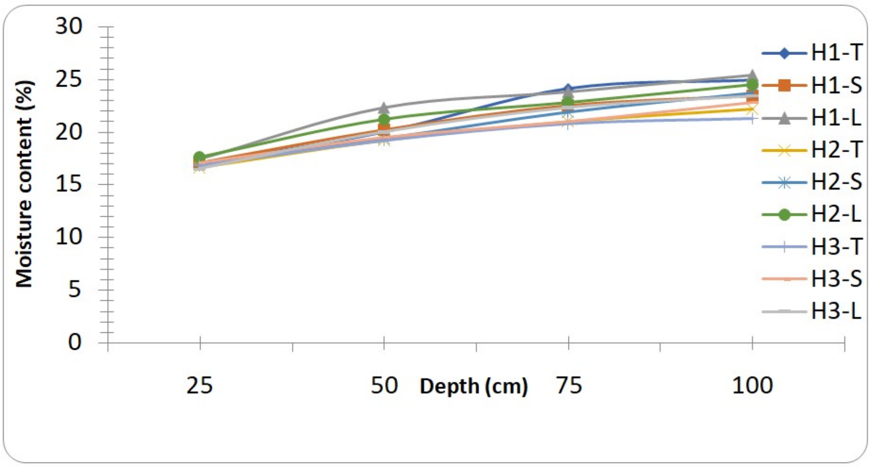

Fig. 1a. Effect of tillage and leveling on soil moisture content (average of all irrigations 1)

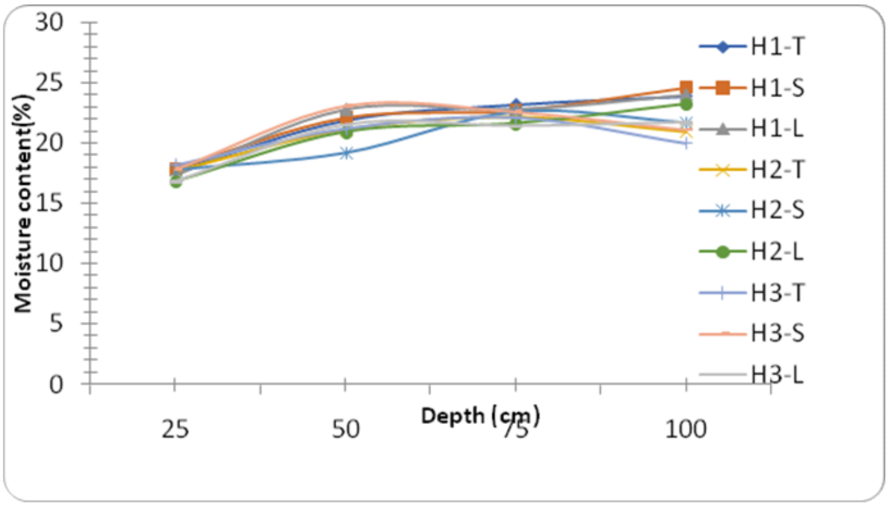

Fig.1b. Effect of tillage and leveling on soil moisture content (average of all irrigations 2)

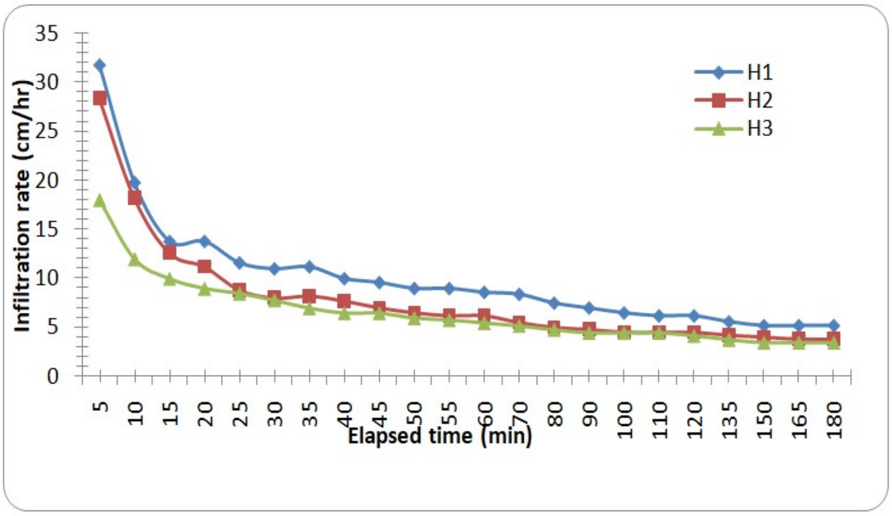

Fig. 2. Effect of tillage treatments on infiltration rate with time

Effect of treatments applied on wheat plant height: Plant height results for the two seasons as affected by tillage, leveling and sowing method are shown in Fig. 3. The analysis of variance indicated highly significant differences among the tillage treatments effects on plant height at (5%) level in the first season, but there were no significant differences in the second season as shown in Table (6). The heavy disc harrow treatment resulted in the highest plant height in both seasons recording an average height 87.4 cm.laser land leveling recorded the largest average plant height as 86.7 (Fig. 3). The analysis of variance indicated no significant difference between treatment effect on plant height in both seasons, (Table 6). The seed drill machine treatment resulted in the greatest plant height in both seasons and recorded an average of 86.4cm.In both seasons, the seed drill machine used after laser land leveling and heavy disc harrow gave the highest plant height and recorded 90.03, cm. Analysis of variance sowed no significant difference between the interactions of all treatments in both seasons (Table 8).

of leveling methods at (1%) level in the first seasontable (6). The laser land leveling treatment resulted in the highest average plant population in both seasons as 370 plants/m^2.This could be due to laser land leveling resulting in uniform distribution of the entire field and allowing uniform crop stand and growth thus resulting in lesser weed infestation and this agreed with that recorded by (Jat *et al* 2011) and Richman, 2002). The analysis of variance indicated significant differences between the sowing methods treatment effect at 5% probability level for the first season, but in the second seasonno significant differences. In both seasons, the highest plant population was recorded by the seed drill machine after leveling by laser and heavy disc harrow giving values of 367 and 364 plants/m^2 for the first and second season, respectively, and that could be due to proper controlled seed rate by seed drill machine. The analysis of variance showed no significant difference between the effect of all treatmentinteractions in both seasons (Table 8).

Table 6. Some statistical analysis for effect of treatments on plant height

Plant height	Season 1			Season 2		
Treatments	Tillage	Leveling	Sowing	Tillage	Leveling	Sowing
SE±	0.183	0.183	0.277	0.818	0.656	0.706
Significant level	**	ns	ns	Ns	*	ns
Plant population						
SE±	0.643	1.075	1.205	1.226	1.839	1.576
Significant level	**	**	*	*	ns	ns

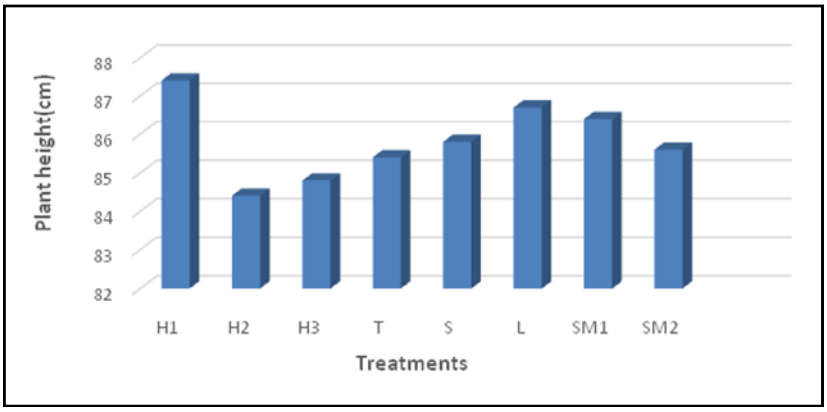

Fig. 3. Effect of tillage, leveling and sowing methods on wheat plant height

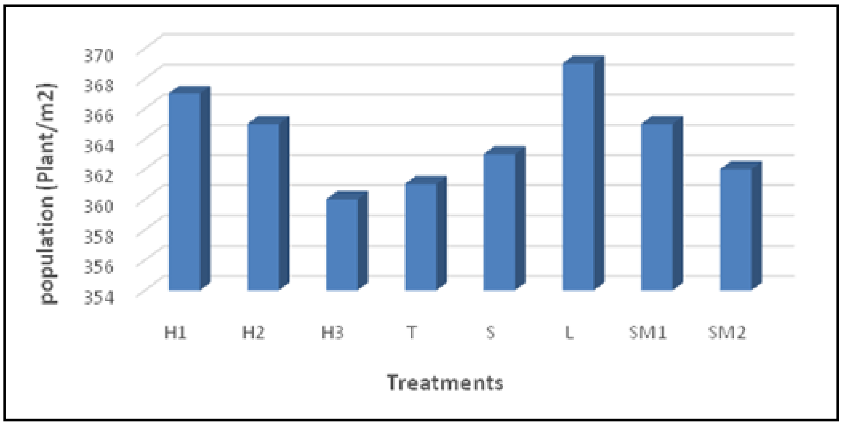

Fig. 4. Effect of tillage, leveling and sowing methods on wheat plant population

Effect of different treatments applied on wheat plant population: Figure (4) shows the plant population as affected by the tillage treatments, leveling and sowing method. The analysis of variance showed highly significant effect at (1%) level for the first season, while in the second season, no significant differences among the effect of treatments (table 6). In both seasons, the highest number of plant population was recorded by the heavy disc harrow giving an average value of (367) plants/m^2 for both seasons (Fig. 4). The analysis of variance showed significant differences between the effect

Effect of different treatments on wheat total grain yield (ton/ha): The analysis of variance indicated significant between the tillage treatment effects on grain yield at 5% and 1%, in the first and second season, respectively (Table 7). In both seasons, the highest crop yield was recorded by heavy disc harrowing tillage treatment, and the average was 3.75 ton/ha, while the lowest yield was given by no tillage treatment as 2.96 ton/ha. (Fig. 5). 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 agreed with the findings of Dahab *et al*., 2023. The analysis of variance indicated highly significant differences between the leveling treatments effect on crop grain yield at (1%) level in the two seasons (Table 6). In both seasons, the highest crop yield was recorded by laser land leveling treatment recording an average of 3.84 ton/ha, while the lowest average crop yield of 3.0 ton/ha was recorded by animal land leveling treatment (Fig. 5), 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 (Jat *et al* 2011). The highest average yield was recorded by the seed drill machine as 3.53 ton/ha. (Fig. 5). The highest crop yield obtained by the seed drill machine method used after laser land levelingtreatment could be due to the improved crop establishment and reduces weed problem at the same time, the laser leveling optimized water use efficiency compared to traditional land leveling. These results agreed with the findings of (Rajput and Patel, 2004). The highest average grain yield was recorded by laser land leveling after heavy disc harrow and sowing with seed drill machine as 5.05 ton/ha, while the lowest average yield value was 2.6ton/ha. for animal leveling with no-tillage and with seed drill machine. The analysis of variance showed that there were no significant differences among interaction effect of all treatments in both seasons (Table 8).

Effect of different treatments applied on wheat total biological yield: It was observed that, the heavy disc harrow treatment resulted in greatest average total biomass in both season and recorded 11.85ton/ha (Fig. 6).

The results of biomass yield as affected by leveling methods treatments for the two seasons are also shown in Fig 6. The analysis of variance revealed highly significant difference at 1% probability levelin both seasons.The laser land leveling treatment resulted in the highest average biomass as 11.78 ton/ha. The effect of sowing method treatments on biomass for the two seasons is shown in Fig. 6. The analysis of variance indicated significant effect at 5% probability level in the first season. While the second season revealed highly significant level at 1% probability (Table 7). The use of seed drill machine resulted in higher average biomass of 11.30. The highest average total biomass (13.63 ton/ha), was recorded by laser leveling with heavy disc harrow with seed drill machine, while the lowest average total biomass (9.79 ton/ha), was recorded by no-tillage with scraper leveling with both sowing methods types. The interaction effect of the three treatments was highly significant at 1% level in the first season and insignificant in the second season (Table 8).

Effect of different treatments on wheat harvest index: Harvest index results data as affected by tillage treatments are shown in Fig 7. The analysis of variance showed significant effect of tillage treatments on harvest index (Table 7). In both seasons, the highest average harvest index percentage was recorded by the heavy disc harrow as 0.32 and the lowest was given by no tillage as 0.29. Analysis of variance showed highly significant effect at 1% probability level between leveling treatment effect on harvest index (Table 7). In both seasons, the highest average harvest index was recorded by the laser land leveling as 0.31.

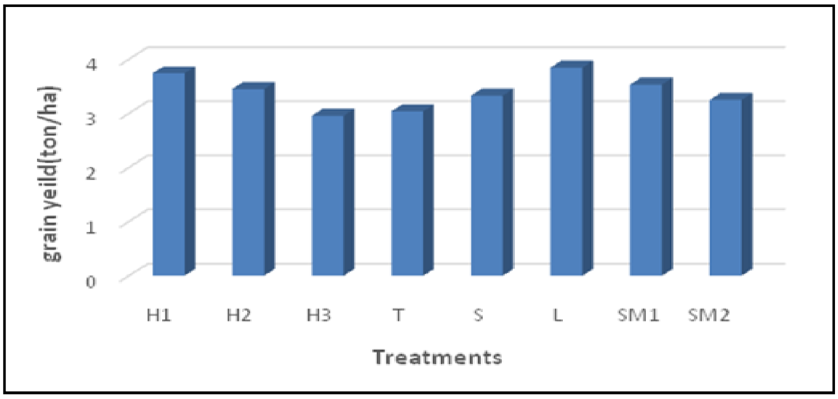

Fig. 5. Effect of tillage, leveling and sowing methods on wheat grain yield

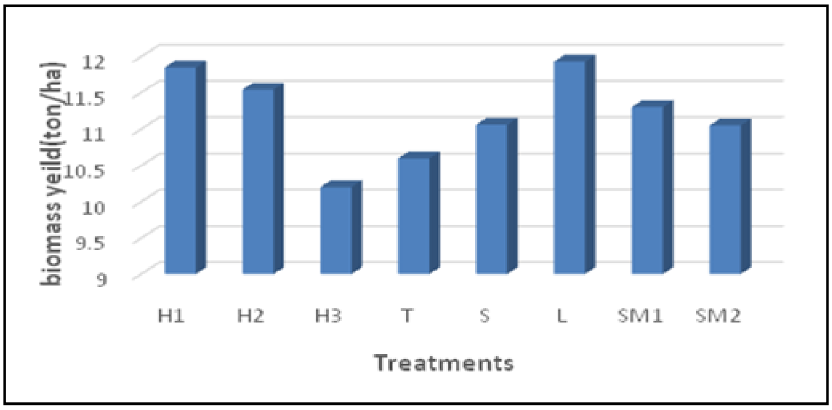

Fig. 6. Effect of tillage, leveling and sowing methods on biomass yeild

Table 7. Some statistical analysis for the effect of treatments on wheat crop yield components

Grain yield	Season 1			Season 2		
Treatments	Tillage	Leveling	Sowing	Tillage	Leveling	Sowing
SE±	0.088	0..047	0.055	0.064	0.048	0.035
Significant level	**	**	*	**	**	**
Biomass yield						
SE±	0.076	0..062	0.046	0.020	0.048	0.038
Significant level	**	**	*	**	**	**
Harvest Index						
SE±	0.007	0..005	0.005	0.005	0.004	0.003
Significant level	no	**	*	no	**	**

In both seasons, the highest average harvest index (%) was recorded by seed drill machine as 0.31 (Fig. 7). The highest average harvest index (0.37), was recorded by laser with heavy disc harrow with seed drill machine. The lowest average harvest index (0.28) was recorded by no-tillage with scraper leveling with manual sowing methods. The highest harvest index, recorded by laser leveler with heavy disc harrow with seed drill machine, could be attributed to good soil pulverization, suitable working depth for seed bed, and the proper distribution efficiency of applied water.insignificant effect of treatments interaction on harvest index in two seasons (Table 8).

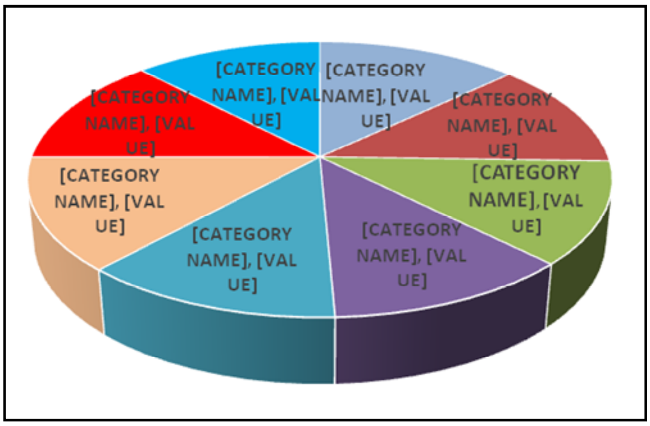

Fig. 7. Effect of tillage, leveling and sowing methods on harvest index

Table 8. Effect of tillage, leveling and sowing methods on wheat yield and yield components

Tillage/leveling	Plant height (cm)	Plant /m^2	Grain yield (ton/ha)	Biomass (ton/ha)	HI%
H1-T–S1	90.333	362	3.133	10.700^{F}	0.293
H1-T- S2	86.667	360	2.900	10.600^{F}	0.273
H1-S-S1	89.667	373	4.033	12.633^{C}	0.320
H1-S - S2	87.000	360	3.100	10.500^{F}	0.295
H1-L - S1	88.667	387	5.333	14.167^{A}	0.376
H1-L –S2	88.333	371	4.367	13.200^{B}	0.331
H2-T-S1	87.667	362	2.933	10.367^{FG}	0.283
H2-T-S2	87.333	365	3.033	10.333^{FG}	0.293
H2-S-S1	87.667	369	3.600	12.000^{DE}	0.300
H2-S-S2	87.000	365	3.533	12.000^{DE}	0.295
H2-L-S1	87.000	371	4.500	13.233^{B}	0.340
H2-L-S2	87.667	367	3.667	12.400^{CD}	0.296
H3-T-S1	85.667	357	2.500	9.317^{H}	0.268
H3-T-S2	87.000	365	3.367	11.700^{E}	0.287
H3-S-S1	86.333	361	2.967	9.920^{G}	0.301
H3-S-S2	85.333	364	3.000	10.500^{F}	0.286
H3-L-S1	85.667	362	3.167	10.300^{FG}	0.307
H3-L-S2	85.667	358	2.933	9.867^{G}	0.297
SE±	0.8315	3.6158	0,1659	0.1366	0.0154
Sig. level	NS	NS	NS	***	NS
C.V%	1.65	1.71	8.33	2.089	8.83

Means followed by the same letter(s) have no significant difference among them selves according to Duncan's Multiple Range Test (DMRT).*** = highly significant at p≤ 0.0001
NS = none significant

CONCLUSIONS

From the results of this study, the following conclusions can be made

(1) Tillage s improve soil physical properties, and the heavy disc harrowing with laser leveler treatment recorded the highest values of soil moisture content, Infiltration rate. The average soil moisture content (db%) of all treatments increased with depth and with time and the highest average moisture content (22%) was recorded by the heavy disc harrow with laser leveler,

(2) Laser leveler had the lowest field efficiency, highest fuel consumption; while the heavy disc harrow recorded the highest wheel slippage (8.13%), the highest field efficiency and effective fieldcapacity.

(3) The highest average grain yield (4.9 ton/ha), total biomass (13.5 ton/ha) and harvest index (0.37), the highest average plant height (90cm), plant population (381 plant/m2) were recorded by laser leveler with heavy disc harrow with seed drill machine.

(4) Laser leveling of agricultural land is a recent resource-conservation technology initiative in the Northern State and results are quite encouraging.This study recommends the use of laser leveling after heavy disc harrow for wheat production in the upper terrace soils of the Northern State.

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