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Performance Study of Moldboard Plow with Two Types of Disc Harrows and Their Effect on Some Soil Properties Under Different Operating Conditions

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Abstract: A field experiment was conducted in two different locations at Agricultural Research Station of Garmat Ali in Basrah-Iraq. The aim of this investigation is to evaluate the effective field capacity, field efficiency, draft force, pulverization index (PI), soil bulk density and soil porosity for moldboard plow (primary tillage), mounted disk harrow and offset disk harrow (secondary tillage) under different operating speed (2.54 (S1), 3.84 (S2) and 5.77 (S3) km hr^{-1}) in two different soil textures (silty loam soil and clay soil). The design of the experiment was complete randomized blocks design in factorial experiment. The results showed that the moldboard plow had high values of draft force, pulverization index (PI) and soil porosity and lower soil bulk density, effective field capacity and field efficiency than that of mounted disk harrow and offset disk harrow in both soils. The operating speed and the interaction between operating speed and implements tillage type had significantly affect ($p < 0.05$) on all the studied parameters. The silty loam soil achieved higher effective field capacity, field efficiency, soil porosity (low bulk density) and considerable pulverization of soil clods than that of clay soil. The results also showed that the optimal operation conditions of implements tillage were associated with high operating speed of 5.77 km hr^{-1} in silty loam soil especially with using the disks harrow.

Key word: Moldboard plow, Disk harrow, Soil physical properties, Draft force, Field performance efficiency.

Introduction

Soil tillage is considered to be one of the important processes affecting on physical and mechanical properties of soil (Keshavarzpour and Rashidi, 2008). Tillage method affects the sustainable use of soil resources through its influence on soil properties (Hammel, 1989). Therefore, to insure a good preparation of soil must to use primary tillage implements such as moldboard plow and after that use secondary tillage implements such as disk harrow (Gbadamosi, 2013), thereby creating a desirable soil condition for seed germination and growth through improvement the pulverization of soil (Ati *et al*., 2014).

The tillage operation requires the most energy and power spent on farms (Abbaspour *et al*., 2006). Therefore, draft and power requirements are important in order to determine the size of the tractor that could be used for a specific implement (Al-Suhaibani and Ghaly, 2013). The draft force required for a given implement will also be affected by the soil conditions, geometry of the tillage implement (Olatunji and Davies, 2009), operating depth and travel speed (Nkakini, 2015). Al-Suhaibani *et al*. (2010) evaluated the effects of tillage depth and forward speed on draft of moldboard, disk and chisel plows on sandy loam soil, the results showed that draft increased with increasing of forward speed and tillage depth for all the implements and the moldboard and chisel plow had highest draft force. Moeenifar *et al*. (2014) found that draft force increased by 33.41% when the forward speed increased from 0.75 to1.70 m sec^{-1}. Rashidi *et al*. (2013) noted that draft force of offset disk harrow increased with increasing the operating depth or/and tractor speed. Soil type had considerable effect on draft force, whereas El-Shazly *et al*.(2008) found that draft force increased from 19.73 kN in sandy soil to 20.35 kN in clay soil for disk plow.

The field efficiency is one of an important factor to evaluate performance of the tillage implements. Field performances of agricultural machineries are affected by many factors such as the power unit/machine condition, operating speed, working depth and geometry of the tillage implement (Sale *et al*., 2013; Abualgasim and Dahab, 2013). Alnahas (2007) reported that the field efficiency affected by soil type and implements tillage type, where he found that field efficiency for the chisel and ridger plow were higher in the sandy clay (74.33 % and 74.37%) than in clay soil (71.94% and 72.90%). While the disc harrow recorded the highest field efficiency compared to other implements, which was 79.90%.

The field capacity of a machine is the number of unit, which it can process or cover in a specific time and it may be expressed as the area covered per hour. It is affected by soil conditions, surface roughness of soil, tractor wheels slippage and failure to utilize the full operating width of the machine (Bashir *et al*., 2015). Oduma *et al*. (2015) indicated that disc harrow had effective capacity higher than of the disc plough and ridger at same work conditions. As well as they found that effective field capacity increased by 25.41% when the operating speed for disc harrow increased from 6.58 to 6.71 km hr^{-1}.

Conventional tillage practices modify soil structure by changing its properties such as soil bulk density, porosity, soil penetration resistance and mean weight diameter (MWD) (Osunbitan *et al*., 2005). Different types of tillage systems have different tillage depths and capacity to change soil physical and chemical properties that affect the crop yield and quality (Strudley *et al*., 2008). In study conducted by Abrougui *et al*. (2014) who found that bulk density affected by tillage methods, where the conventional tillage by moldboard plow had bulk density amount of 1.6 Mg m^{-3} while was 1.2 Mg m^{-3} for minimum tillage by disk harrow at same operating condition. Nassir *et al*. (2016) stated that bulk density reduce with increasing operating speed for disk plow and disk harrow. Researchers found that increasing operating speed from 1.62 to 5.65 km hr^{-1} resulted in a decreasing the bulk density from 1.39 to 1.30 Mg m^{-3} and from 1.22 to 1.15 Mg m^{-3} for disk plow and disk harrow, respectively.

Soil porosity is one of important soil physical properties affecting not only on root growth, but also improving assistance in spread of plant roots and facilitates the movement of water in the agricultural soil layer, thus the plant considerably benefits from nutrients that found in soil layer (Askari and Khalifahamzehghasem, 2013). Nkakini and Fubara-Manuel (2012) found that disc harrow had higher soil porosity than that of moldboard plow.

Pulverization Index (PI) which is an indicator to the soil pulverization, depends on the work conditions in term the plowing depth and forward speed and on the soil physical properties such as moisture content and bulk density (Aday *et al*., 2001). As well as, their results indicated that the plow type has appreciable effect on soil pulverization, where the moldboard plow gave lower pulverization Index (PI) (greater soil pulverization) than the disc plow. In general pulverization Index (PI) decrease with increasing operating speed or using harrowing soil implements such as disk harrow (Nassir *et al*., 2016).

The objective of the present work is to evaluate the performance of moldboard plow and two type of disks harrow in two soil types in term field efficiency, effective field capacity and draft force, and show the effect of the tillage and harrowing practice on some physical soil characters such as pulverization Index (PI), bulk density and soil porosity.

Material and methods

The experiment design: The field experiment was carried out in two locations, the first location soil texture was silty loam, and second location was clay. The two locations (two soils) were plowed at 20 cm depth by moldboard plow, after that each site divided into two parts, first part was pulverized by mounted disk harrow and second part was pulverized by offset disk harrow at 20 cm depth for each harrow. Complete randomized blocks design in factorial experiment was used with three replications. The factors were two soil type (silty loam and clay soil), three implements of tillage (moldboard plow, offset disk harrow and mounted disk harrow) and three tractor speeds (2.54 (S1), 3.84 (S2) and 5.77 (S3) km hr^{-1}). Means values of parameters were tested by RLSD to identifying a significant difference at probability level of 0.05. Means values of parameter for two soil types were tested by T-test. Draft force, field efficiency, effective field capacity, pulverization Index, bulk density and soil porosity were obtained.

The primary and secondary impalements tillage:

(1)- Moldboard plow: A mounted moldboard plow was used in the study. The plow specifications are: weight 293.50 kg, width 1.50 m, and consists of four moldboards (general purpose) of 35 cm width for each moldboard.

(2)- Offset disk harrow: After soil plowed by moldboard plow, offset disk harrow was used to fragmentation of soil blocks. The offset disk harrow consists of two rows of disks, front row had 12 disks with serrated edge, and the rear row had 12 disks with smooth edge. The diameter of each disk is 0.56 m and distance between neighboring disks is 0.22 m. The design width of offset disk harrow is 2.64 m.

(3)- Mounted disk harrow: A tandem disk harrow (X-type) was used to pulverization soil block after soil plowing by moldboard plow. The mounted disk harrow consist of two gangs in front row and two gangs in rear row and each gang had 8 disks (16 disks in row). The diameter of each disk is 0.50 m. The design width of mounted disk harrow is 3.04 m.

Tractors: Two different tractors were used namely, Massy-Ferguson 440 xtra (MF) and Case Hi 1056 (CH). Their specifications are illustration in table (1).

Table (1): Tractor specifications.

Parameters	MF tractor	CH tractor
Engine power (kW)	61.1	65.6
Engine speed (rpm)	2200	2000
Engine type	Perkins (diesel)	Perkins (diesel)
Engine capacity (litter)	4.40	4.06
No. of cylinder	4	4
Compression ratio	18.5:1	17:1
Engine torque (N m)	288	256
P.T.O speed (rpm)	5400 (single speed)	5400 (single speed)
Thrust generation	MFWD	2WD

Basic properties of soil:

The initial properties of two soil (two different locations) were assay at 0-20 cm depth. The soil properties were included: bulk density, moisture content, penetration resistance, cohesion, adhesion and soil texture. The soil texture, bulk density and moisture content were determined according to Black *et al*. (1965) method. The soil penetration resistance was performed according to Roozbeh *et al*. (2010) method by using a penetrometer. The cohesion and adhesion were determined according to Gill and Vandenberg (1968) method. The results were presented in table (2).

Table (2): Basic physical and mechanical properties for two different types of soil.

Soil specifications	Soil 1	Soil 2
Moisture content (%)	14.63	15.25
Penetration resistance (kN m^{-2})	1754	2241
Bulk density (Mg m^{-3})	1.44	1.49
Cohesion (kN m^{-2})	11.62	18.85
Adhesion (kN m^{-2})	0.15	0.28
Clay (%)	24.15	55.56
Silt (%)	54.72	25.63
Sand (%)	21.13	18.81
Soil texture	**Silty loam**	**Clay**

Calculating parameters after conducting experiments:

Draft force: A load cell used to estimating plows draft force. Load cell attached to drawbar of the towing tractor (MF) and the end flexible cable which attaching with the front of tractor CH-plow combination. A tractor MF moves from the beginning to the end of distance was chosen with the another tractor (CH) which was working on the neutral gear but the plow in the operating position. The draft force was recorded for all treatments during the field experiment and saved on the portable computer.

Field efficiency: Field efficiency is the ratio of effective field capacity to theoretical field capacity, and it can be affected by time lost in the field and full width of the machine (Kepner *et al*., 1982). The field efficiency was calculated for all treatments by following equation which was mentioned in Oduma *et al*. (2015).

$$FE = \frac{EFC}{TFC} * 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where:

FE: Field efficiency (%)

EFC: Effective field capacity (ha hr^{-1})
TFC: Theoretical field capacity (ha hr^{-1})

Effective field capacity: The effective field capacity is the measure of a machines ability to do a job under actual field conditions. To estimate effective field capacity, calculate the theoretical field capacity and multiply by the field efficiency for all treatments from the following equation, which was mentioned in Oduma *et al*. (2015).

$$EFC = TFC * FE \ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

The theoretical field capacity (ha hr^{-1}) estimated from the following equation:

$$TFC = \frac{V * B}{10} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Where:

V: Operating speed (km hr^{-1})
B: Implement width (m)

Pulverization index (PI) (dry mean weight diameter**):** After tillage by moldboard plow or soil pulverization by disk harrow, clods of soil were left on field surface to air-drying for two weeks, then the soil clods were collected and taken to laboratory, weighted and passed through set sieves of 100, 70, 50, 30, 10, 5 and 2 mm. Pulverization index (PI) was calculated from the following equation as it is mentioned in Aday *et al.* (2001).

$$PI = \frac{\sum_{i=1}^{n} Wi * \bar{d}i}{W_{total}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Where:

PI : Pulverization index (mm)
Wi : The mass of the soil obtained between two sieve openings *di* and *di+1*
W_{total} : Weight of the total mass
n : Number of sieves
In Eq. 4, d_i was calculated using the following equation:

$$\bar{d\imath} = \frac{1}{2}(d_i + d_{i+1}) \ldots\ldots\ldots\ldots\ldots\ldots (5)$$

Bulk density: After soil plowing by moldboard plow and soil pulverization by offset disk harrow or mounted at specific operating depth of 20 cm, the bulk density was determined for each implement tillage and soil type at specific operating speed of 2.54, 3.84 and 5.77 km hr^{-1}. Soil samples were randomly taken from field experiment and weighed in laboratory, then dried at 105 ˚C for 48 hr. Mass of dried soils were weighted, and dry bulk density was determined from the following equation (Black *et al*., 1965).

$$\rho b = \frac{ms}{vt} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

Where:

ρb : Dry bulk density (Mg m^{-3})
ms : Weight of the dried soil sample (Mg)
vt : Total volume of the soil sample (m^{3})

Total soil porosity: The total porosity of soil samples collected for each treatment was calculated using following equation (Black *et al*.,1965), an assumed particle density of 2.65 Mg m^{-3}.

$$TSP = \left(1 - \frac{\rho b}{\rho s}\right) * 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots (7)$$

Where:

TSP: Total soil porsity (%)
ρb: Dry bulk density (Mg m^{-3})
ρs: Partical density (Mg m^{-3})

Results and discussion

Draft force:

Draft force results are shown in table (3). The moldboard plow, mounted disk harrow and offset disk harrow revealed significant differences for draft force ($p < 0.05$) in both soil. The moldboard plow recorded higher value of draft force than that of mounted disk harrow and offset disk harrow by percentage of 106.37 and 163.76% respectively at silty loam soil, and by 77.39 and 105.30% at clay soil. These increments are due to that the moldboard plow need more power to cut, lifting turning over and partly pulverizing soil while disks harrow need power just to pulverization clods soil, therefor require lesser power from tractor (Al-Suhaibani *et al*., 2010). Moreover, mounted disk harrow recorded value of draft force higher than that of offset disk harrow by percentage of 27.81% and 15.73% in silty loam soil and clay soil respectively, which would be attributed to different between disks harrow in term width and weight as well as part of dynamic load of tractor weigh moved to the mounted disk harrow thought tractor's hitch points causing increase in draft force of mounted disk harrow. This was in accordance with the results reported by Serrano and peca (2008) and Askari and Khalifahamzehghasem (2013).

The effect of operating speed in draft force are shown in table (3). The draft force increased significantly with increasing the operating speed ($p < 0.05$). Increasing operating speed from 2.54 to 5.77 km hr^{-1} increased the draft force from 4.74 to 6.96 kN at silty loam soil and from 7.55 to 9.92 kN at clay soil. This was because the increasing in operating speed was led to increase the soil clods acceleration and the collision between soil clods resulted in greater draft force, as well as increasing sliding resistance, which contributes most to the increased draft force (Muhsin, 2010). This result was in accordance with the results reported by Nkakini (2015).

The interaction between the tillage implements and operating speed had significant effects ($p < 0.05$) on draft force in both soils (table 3). When increasing operating speed from 2.54 to 5.77 km hr^{-1} the draft force in silty loam soil increased by percentage 34.83, 57.10 and 69.03% while the increasing percentage of draft force in clay soil were 31.07, 30.05 and 33.58% respectively for moldboard plow, mounted disk harrow and offset disk harrow. The maximum values of the draft force was obtained at the moldboard plow and operating speed of 5.77 km hr^{-1}, which was 10.80 kN at silty loam soil and 14.51 kN at clay soil, respectively.

Table (3): Effect of tillage implement and operating speed on draft force (kN) for two types of soil.

Implements (IM)	Silty loam soil				Clay soil			
	Operating speed (km hr^{-1})(S)				Operating speed (km hr^{-1})(S)			
	S1	S2	S3	Mean	S1	S2	S3	Mean
Moldboard plow	8.01	9.36	10.80	9.39	11.07	12.79	14.51	12.79
Mounted disk harrow	3.52	4.61	5.53	4.55	6.29	7.15	8.18	7.21
Offset disk harrow	2.68	3.45	4.54	3.56	5.30	6.32	7.08	6.23
Mean	4.74	5.81	6.96		7.55	8.75	9.92	
RLSD	**IM (0.247) S (0.247) IM × S (0.427)**				**IM (0.289) S (0.289) IM × S (0.501)**			

While, the minimum values of the draft force was obtained at the offset disk harrow and operating speed of 2.54 km hr^{-1}, which was 2.68 kN at silty loam soil and 5.30 kN at clay soil, respectively. This was because of increasing acceleration of soil blocks and accumulation in front of the implement tools, therefore, increase the draft force.

The effect of soil type on draft force are presented in figure (1). There were high significant differences between soil types in draft force, whereas clay soil had higher draft force than that of silty loam soil. Clay soil recorded draft force amounted of 8.74 kN while silty loam soil recorded draft force lesser was 5.84 kN. This was because that clay soil had high initial bulk density, penetration resistance, adhesion and cohesion (table 2) so this led to increasing the draft force. Similar results were found by El-Shazly *et al*.(2008).

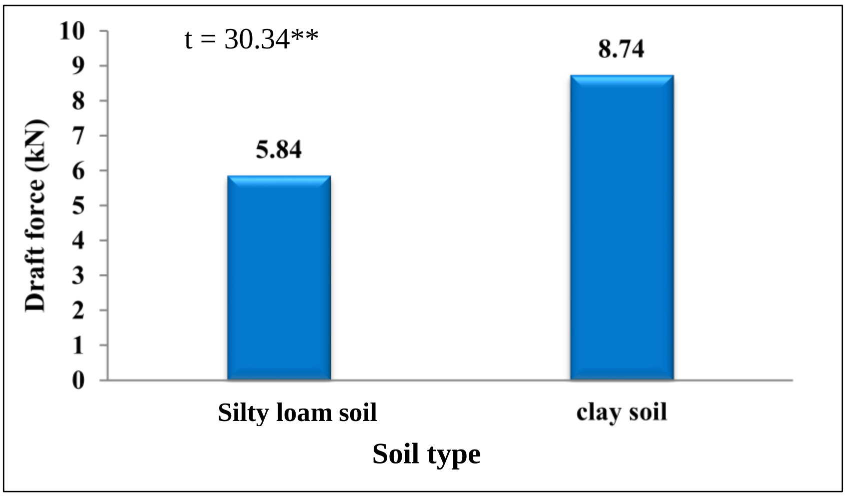

Fig. (1): Effect of soil type on draft force.

Effective field capacity and field efficiency:

The effective field capacity and efficiency in silty loam and clay soil were significantly differed ($P < 0.05$) with different tillage implements (tables 4 and 5). The results showed that the mounted disk harrow recorded the highest values of field capacity and efficiency in both soils, they were 1.15 ha hr^{-1} and 90.33% at silty loam soil and 1.07 ha hr^{-1} and 86.37% at clay soil respectively. While, the moldboard plow recorded the lowest values of effective field capacity and efficiency whereas, at silty loam soil, the effective field capacity and efficiency were 0.45 ha hr^{-1} and 72.40% respectively, while they were 0.39 ha hr^{-1} and 65.50% at the clay soil respectively. This was because the moldboard plow had smaller width than that of mounted and offset disk harrow, in addition to the operating speed will reduce due to increasing tractor wheels slippage, therefor, reduce the effective field capacity and efficiency. Same trend found by Oduma *et al*. (2015) who found that the effective field capacity and efficiency were increased with disk harrow by 125.40 and 8.43% respectively, compared with the moldboard plow.

The operating speed had a significant effect ($p < 0.05$) on the effective field capacity and efficiency at both soils (tables 4 and 5). The results showed when the operating speed increased from 2.54 to 5.77 km hr^{-1}, the mean of the effective field capacity and efficiency increased by 181.25 and 10.89% respectively in silty loam soil and by 150.00 and 11.10% respectively in clay soil. This was because that increasing the operating speed was led to increase the effective field capacity due to positive relationship between them, where the effective field capacity approached from theoretical field capacity thereby the field efficiency increased according to equation (1). Similar findings were observed by Bashir *et al*. (2015) and Nassir *et al*. (2016).

The interaction between the tillage implements and operating speed had significant effects ($p < 0.05$) on the effective field capacity and efficiency at both soil (tables 4 and 5). The maximum values of the effective field capacity and efficiency were obtained at the mounted disk harrow and operating speed of 5.77 km hr^{-1}, they were 1.70 ha hr^{-1} and 94.67% at silty loam soil and 1.58 ha hr^{-1} and 90.45% at clay soil, respectively. While, the minimum values of the effective field capacity and efficiency were obtained at the moldboard plow and operating speed of 2.54 km hr^{-1}, they were 0.25 ha hr^{-1} and 68.67% at silty loam soil, 0.22 ha hr^{-1} and 61.00% at clay soil, respectively.

Table (4): Effect of tillage implement and operating speed on effective field capacity (ha hr^{-1}) for two types of soil.

Implements (IM)	Silty loam soil				Clay soil			
	Operating speed (km hr^{-1})(S)				Operating speed (km hr^{-1})(S)			
	S1	S2	S3	Mean	S1	S2	S3	Mean
Moldboard plow	0.25	0.32	0.78	0.45	0.22	0.38	0.57	0.39
Mounted disk harrow	0.66	1.08	1.70	1.15	0.63	1.01	1.58	1.07
Offset disk harrow	0.54	0.89	1.56	1.00	0.53	0.84	1.31	0.89
Mean	0.48	0.76	1.35		0.46	0.74	1.15	
RLSD	IM (0.008) S (0.008) IM × S (0.015)				IM (0.007) S (0.007) IM × S (0.012)			

Table (5): Effect of tillage implement and operating speed on field efficiency (%) for two types of soil.

Implements (IM)	Silty loam soil				Clay soil			
	Operating speed (km hr^{-1})(S)				Operating speed (km hr^{-1})(S)			
	S1	S2	S3	Mean	S1	S2	S3	Mean
Moldboard plow	68.67	72.95	75.58	72.40	61.00	65.00	70.50	65.50
Mounted disk harrow	86.00	90.33	94.67	90.33	81.67	87.00	90.45	86.37
Offset disk harrow	80.33	85.32	90.34	85.33	79.32	82.85	85.67	82.61
Mean	78.33	82.87	86.86		74.00	78.28	82.21	
RLSD	IM (0.797) S (0.797) IM × S (1.381)				IM (0.791) S (0.791) IM × S (1.370)			

The effect of soil type on effective field capacity was presented in figure (2). It was found from t-test that the effective field capacity was significantly affected by soil type. The silty loam soil surpassed in achieve highly effective field capacity (0.86 ha hr^{-1}) compared with the clay soil (0.79 ha hr^{-1}). This was because the silty loam soil had lower cohesion, adhesion and bulk density than that of clay soil and this led to reduction tractor wheels slippage then increasing the operating speed, therefor, increasing the effective field capacity. Same trend found by Bashir *et al*. (2015). The results also showed that the field efficiency was significantly affected by different soil type (fig. 3). The silty loam soil achieved high field efficiency (82.69%) while clay soil achieved low field efficiency (78.16%). This can be attributed to increasing the effective field capacity and make it approaching from the theoretical field capacity therefore increase the field efficiency. This result was in accordance with the results reported by Sale *et al.* (2013).

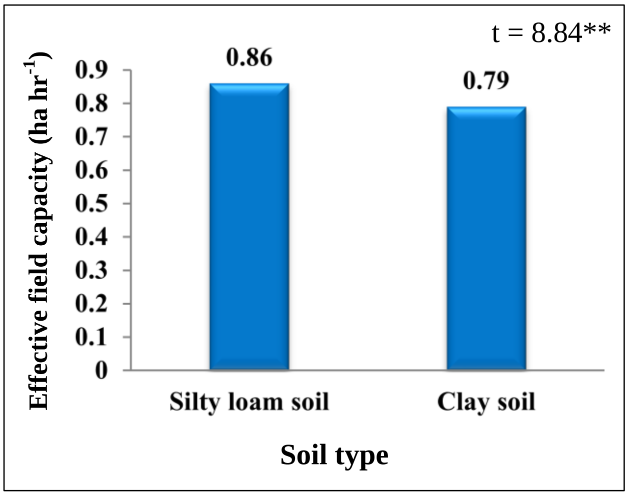

Fig. (2): Effect of soil type on effective field capacity.

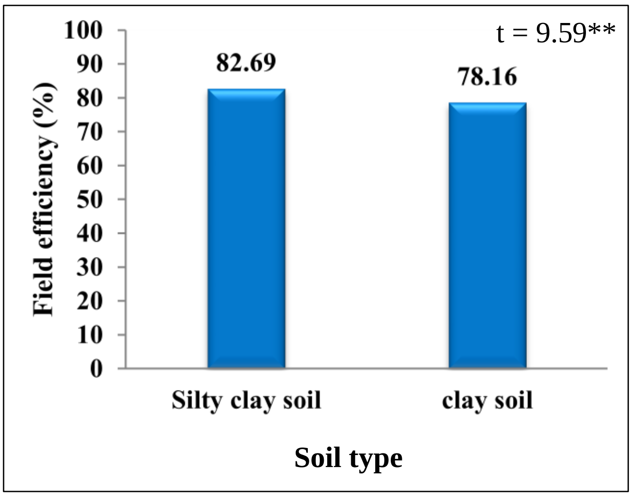

Fig. (3): Effect of soil type on field efficiency.

Soil bulk density and total porosity:

Tables 6 and 7 show the effect of implements tillage in bulk density and soil porosity. Significant effects ($p < 0.05$) were found of implements tillage on bulk density and soil porosity at both soils. The results showed that the bulk density increased with using primary tillage and decreased with using secondary tillage in both soils, however primary tillage had lower soil porosity, while secondary tillage had higher soil porosity in both soils. For example at silty loam soil, the moldboard plow recorded the highest value of bulk density of 1.32 Mg m^{-3} and the lowest value of soil porosity of 50.27% While both disks harrow achieved lesser values of the bulk density of 1.14 and 1.25 Mg m^{-3} and lower value of soil porosity of 57.10 and 52.75% for mounted disk harrow and offset disk harrow, respectively. This was because the moldboard plow left great blocks of soil on surface field that led to decrease quantity of pores (low porosity), thereby the bulk density increased according to equation (7). While both disks harrow work to pulverizing of soil to small clods and this led to increasing the pores of soil (high porosity), decreasing the bulk density according to equation (6). Similar results were reported by Nkakini and Fubara-Manuel (2012) who found that primary tillage recorded lower value of soil porosity which was 29.67% while the secondary tillage recorded higher value of soil porosity which was 31.78%.

The operating speed had a significant effect ($p < 0.05$) on bulk density and soil porosity for both soil (tables 4 and 5). The bulk density was decreased with increasing the operating speed (high porosity). When increasing operating speed from 2.54 to 5.77 km hr^{-1}, the bulk density decreased by 7.09 and 3.03% at silty loam soil and clay soil respectively, while soil porosity increased by 6.57 and 3.44% respectively. This results could be attributed to increasing the soil volume due to increasing the soil pulverization and this led to increase quantity of pores in soil (high porosity), thereby the bulk density decreased according to equation (7) and increasing the soil porosity according to equation (8). Similar results were reported by El-Shazly *et al*.(2008).

The results of interaction between implements tillage type and operating speed are shown in tables 7 and 8. This interaction had a significant effect on the bulk density and soil porosity for both soil. The moldboard plow and lower operating speed (2.54 km hr^{-1}) recorded the highest values of bulk density of 1.35 and 1.37 Mg m^{-3} at silty loam soil and clay soil respectively, and the lowest soil porosity of 48.93 and 48.17% respectively. In the contrast, the mounted disk harrow and operating speed of 5.77 km hr^{-1} recorded the lowest value of bulk density of 1.04 and 1.24 Mg m^{-3} at silty loam soil and clay soil respectively, and the highest soil porosity of 60.75 and 53.20%, respectively.

Table (6): Effect of tillage implement and operating speed on bulk density (Mg m^{-3}) for two types of soil.

Implements (IM)	Silty loam soil				Clay soil			
	Operating speed (km hr^{-1})(S)				Operating speed (km hr^{-1})(S)			
	S1	S2	S3	Mean	S1	S2	S3	Mean
Moldboard plow	1.35	1.31	1.29	1.32	1.37	1.36	1.34	1.36
Mounted disk harrow	1.20	1.17	1.04	1.14	1.28	1.26	1.24	1.26
Offset disk harrow	1.27	1.25	1.22	1.25	1.31	1.28	1.25	1.28
Mean	1.27	1.24	1.18		1.32	1.30	1.28	
RLSD	IM (0.009) S (0.009) IM × S (0.016)				IM (0.005) S (0.005) IM × S (0.009)			

Table (7): Effect of tillage implement and operating speed on soil porosity (%) for two types of soil.

Implements (IM)	Silty loam soil				Clay soil			
	Operating speed (km hr^{-1})(S)				Operating speed (km hr^{-1})(S)			
	S1	S2	S3	Mean	S1	S2	S3	Mean
Moldboard plow	48.93	50.56	51.32	50.27	48.17	48.68	49.55	48.80
Mounted disk harrow	54.71	55.85	60.75	57.10	51.57	52.32	53.20	52.36
Offset disk harrow	51.95	52.58	53.71	52.75	50.44	51.57	52.58	51.53
Mean	51.86	53.00	55.26		50.06	50.86	51.78	
RLSD	IM (0.361) S (0.361) IM × S (0.625)				IM (0.201) S (0.201) IM × S (0.349)			

In general, the secondary implements tillage (mounted disk harrow or offset disk harrow) with high speed was improved soil conditions in term soil bulk density and porosity compared with primary implement tillage (moldboard plow). This was because increasing the pulverization of soil and production small soil clods at using the secondary implements tillage and high operating speed. This was in agreement with the results reported by Abrougui *et al.* (2014) and Nassir *at el*. (2016).

The effect of soil type on bulk density and soil porosity are shown in figures 4 and 5. There were high significant effects of soil type on bulk density and soil porosity. Silty loam soil surpass in recorded low value of bulk density and high soil porosity of 1.23 Mg m^{-3} and 53.37% respectively, while the clay soil recorded high value of bulk density and low soil porosity of 1.30 Mg m^{-3} and 50.90%. Reduction ability of clay soil to breaking up resulting a less number of soil pores due to increasing soil cohesion and adhesion force between soil clods and surface blades of implements tillage and this leads to increase the bulk density and decrease the porosity in this soil. These results were in agreement with Nkakini and Fubara-Manuel (2012) and Omofunmi *et al*. (2016).

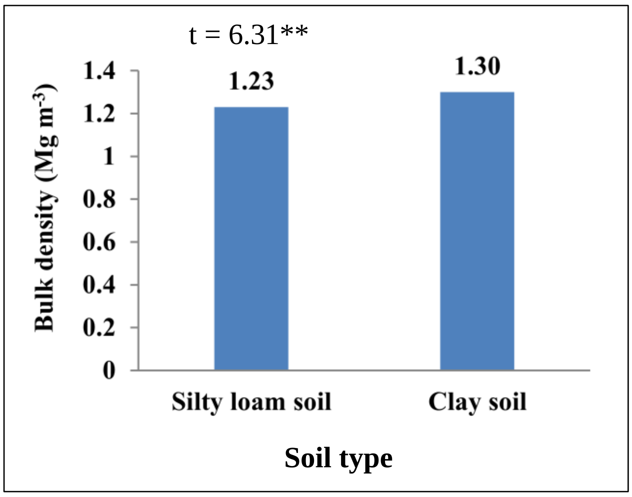

Figure (4): Effect of soil type on bulk density

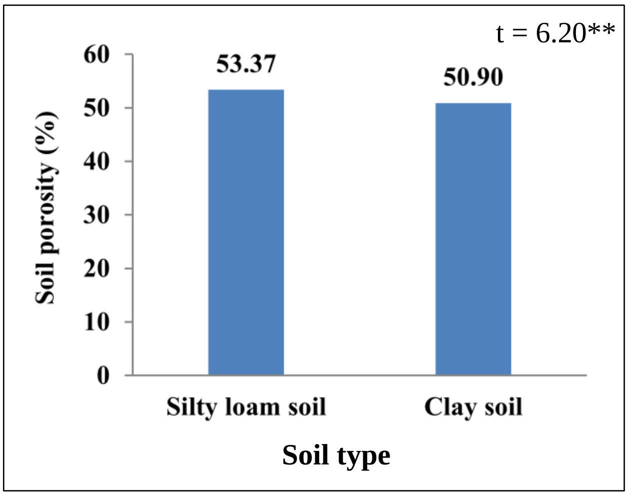

Figure (5): Effect of soil type on soil porosity

Pulverization Index (PI)

The values of pulverization index (PI) were shown in table (8). Results of pulverization index showed that significant differences ($P < 0.05$) were observed between implements at both soils. The highest pulverization index was obtained by the moldboard plow which were 39.53 and 47.02 mm at silty loam soil and clay soil respectively, while the lower values of pulverization index were obtained with mounted disk harrow and offset disk harrow which were 16.62 and 21.88 mm at silty loam soil and 21.84 and 24.73 mm at clay soil, respectively. This might be due to that the moldboard plow cut and turnover of soil without further pulverizing, this led to leave big soil blocks on field surface, then increasing values of pulverization index. These results were in agreement with Celik (2011). However, the two disk harrow were able to break the previously clods of soil up to smaller clods making values of the pulverization index lesser. This result was in accordance with Javadi and Hajiahmad (2006).

The effect of operating speed on pulverization index was shown in table (8). The pulverization index (PI) decreased with increasing the operating speed. Increasing operating speed from 2.54 to 5.77 km hr^{-1} decreased pulverization index (PI) from 30.85 to 21.07 mm at silty loam soil and from 35.68 to 26.60 mm at clay soil. This can be attribute to increasing in acceleration of the soil colds and collision it each to other lead to breaking the soil clods to small sizes causing an increasing effect on soil pulverization. These results were in agreement with Aday *et al*. (2001); Javadian and Hajiahemed (2009) and Muhsin (2017).

Results of interaction effect between operating speed and implements tillage type on pulverization index (PI) at both soils were shown in table (8). The results indicated that increasing the operating speed was led to reduce the values of pulverization index significantly ($p < 0.05$) for all implements tillage in both soils. When increase operating speed from 2.54 to 5.77 km hr^{-1}, the pulverization index decreased by percentage of 33.29, 35.10 and 26.14% for moldboard plow, mounted disk harrow and offset disk harrow in silty loam soil respectively, while pulverization index decreased by percentage of 30.77, 22.48 and 17.38 % at clay soil, respectively. The results also appear clearly reduction in pulverization index at using mounted disk harrow or offset disk harrow when increasing the tractor speed in both soils. When increasing operating speed to 5.77 km hr^{-1}, the mounted disk harrow and offset disk harrow achieved the lowest values of pulverization index as compared with moldboard plow, they were 13.24 and 18.96 mm at silty loam soil, and were 19.00 and 22.54 mm respectively at clay soil. The reduction of pulverization index with increasing the operating speed could be attributed to increasing in the acceleration soil clods and collision with each other causing self-pulverization, as well as a combined effect of primary tillage and secondary tillage can reduce the pulverization index (PI) at using mounted disk harrow or offset disk harrow. This was in accordance with the results reported by Boydas and Turgut (2007) and Nassir (2017).

Table (8): Effect of tillage implement and operating speed on pulverization Index (mm) for two types of soil.

Implements (IM)	Silty loam soil				Clay soil			
	Operating speed (km hr^{-1})(S)				Operating speed (km hr^{-1})(S)			
	S1	***S2***	***S3***	***Mean***	***S1***	***S2***	***S3***	***Mean***
Moldboard plow	46.47	41.12	31.00	39.53	55.25	47.57	38.25	47.02
Mounted disk harrow	20.40	16.21	13.24	16.62	24.51	22.00	19.00	21.84
Offset disk harrow	25.67	21.00	18.96	21.88	27.28	24.37	22.54	24.73
Mean	30.85	26.11	21.07		35.68	31.31	26.60	
RLSD	**IM (0.953) S (0.953) IM × S (1.651)**				**IM (1.026) S (1.026) IM × S (1.777)**			

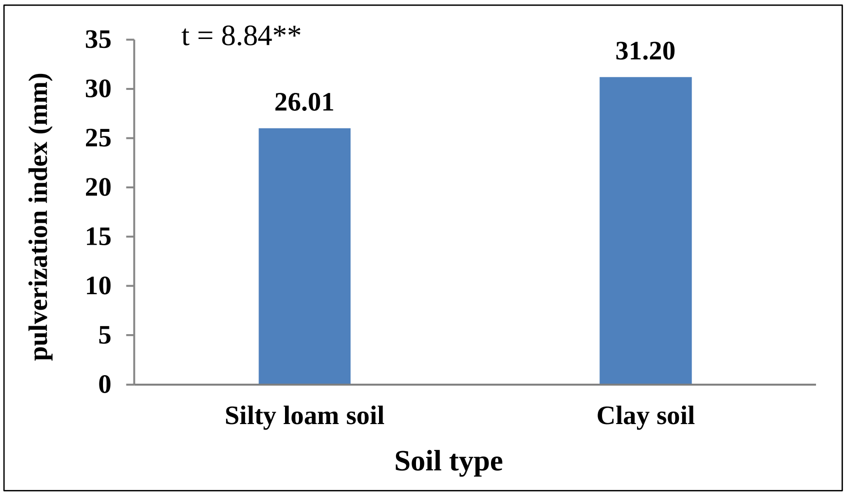

Figure (6): Effect of soil type on pulverization index (PI)

The effect of soil type on pulverization index (PI) was shown in figure (6). T-test indicated significant differences between soil types in pulverization index (PI). The clay soil recorded maximum value of pulverization index of 31.20 mm while the silty loam soil recorded minimum value of pulverization index of 26.01 mm, this mean that the silty loam soil had greater soil pulverization than that of the clay soil. The differences between soil types can be explained by the fact that the clay soil had high cohesion force and this make fragmentation of soil clods to small pieces more difficult thereby pulverization Index increase in this soil (low pulverization of soil). This was in accordance with Aday and Al-Edan (2004).

Conclusion

It can be concluded that increasing operating speed and used all implement tillage can improve the soil physical properties, as well as improved the effective field capacity and field efficiency for all tillage implements especially at silty loam soil. However, the effect of implement tillage on mentioned properties was as follow: Mounted disc harrow > offset disc harrow > moldboard plow. This investigation indicated clearly that one pass by disk harrow (mounted or offset) was enough to prepare soil for suitable seed bed to emergence and plant growth (soil soothing until 13 mm), especially at high speed at silty loam soil. Also, it can be recommended to use primary and secondary implements tillage with different soil texture and with different operating condition.

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