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Effect of Moldboard Plow Types on Soil Physical Properties Under Different Soil Moisture Content and Tractor Speed

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Abstract: An experiment was conducted in fields of Agriculture college, University of Basrah. The experiment was designed with split-spilt plots in Complete Randomized Blocks Design Treatments included three types of moldboard plows: helical, semi digger and general –purpose, three soil moisture content levels (10.23,16.47 and 24.68%), and four tractor speed of 0.41, 0.56, 0.86 and 1.21 m sec $^{-1}$. The soil physical properties were determined after plowing soil by using three types of moldboard plow. The results showed that there was significant effect of moldboard plow types, soil moisture content and tractor speed on soil physical properties including bulk density, soil porosity, soil penetration resistance and pulverization ratio. Results also indicated that the effect of interaction among plow types, soil moisture content and tractor speed was significantly on soil penetration resistance and pulverization ratios while it had not significantly effect on bulk density, soil porosity. In general, soil physical properties, had been improved when using high tractor speed and moderate soil moisture content whereas optimal operation was obtained when using general-purpose plow type and high tractor speed of 1.12 m sec $^{-1}$ and soil moisture content of 16.47% where this combination gives low bulk density (0.96Mg m^{-3}), high soil porosity (63.90%) high soil pulverization ratio (74%) and low soil penetration resistance (623.47 kN m^{-2})

Keywords: Helical, semi digger and general –purpose, Soil moisture content, Soil physical properties.

Introduction

The moldboard plow considered to be the most important tillage implement, it's available with different types depend to design of shape (degree of curvature) of moldboards. The main job of all types of moldboard plow is cutting, lifting, inverting and pulverizing the furrow slice (Dahab, 2011); therefore; that moldboard plow achieved most of tillage aims (Olatunji and Davies, 2009),. Tillage operating improvement the soil physical properties, thereby, available a suitable seedbed for germination and root growth (Lal, and Stewart 2013). Physical manipulation of soil do to kill weeds, fill crop residues and modifications into soil, increase infiltration, decrease evaporation, prepare seedbed and loose hard layers to assistance roots penetration of soil (Gbadamosi, 2013). Soil tillage and soil moisture content had considerable effect on soil physical properties. If the soil is plowed in very low soil moisture or high soil moisture content, it will produce large soil blocks in both cases (Shittu *et al.,* 2017) Tillage practices modify the soil bulk density, porosity, and penetration resistance. The bulk density is one of important soil physical properties, its increase with increasing soil moisture content. Legahri. *et al.* (2016) found that the bulk density of the soil before tillage were 1.28, 1.29 and 1.33 $Mg.m^{-3}$ when the soil moisture level amount were 11-13%, 14-16% and 17-19%, respectively, which reduced considerably to 1.14, 1.18, and 1.27 $Mg.m^3$. Bogunovic and Kisi (2017) reported that tillage practice led to improve soil physical properties such as bulk density, soil porosity, and penetration resistance, compared with initial soil physical properties of soil (before tillage Practice). Soil physical properties affected by operating conditions such as plowing depth, tractor speed and soil moisture content (Muhsin, 2017). He found that increasing tractor speed from 2.54 to 5.77 km h^{-1}, reduced the bulk density, by percentages 3.03 and 7.09%, while soil porosity increased by percentage 3.44 and 6.57% in clay soil and silty loam soil, respectively. Soils are generally subjected to two sorts of traffic: one that creates loosening of soil layers (tillage traffic). And another one that creates compaction (wheel traffic) (Millington *et al*., 2016). Soil response to compaction depends on traffic quality, soil properties and moisture. When the traffic occurs; soil compaction is usually expressed by the means of bulk density, porosity or penetration resistance (Javadi and Spoor, 2006; Loghavi and Khadem, 2006; Rashidi *et al*., 2007). In some studies, comparing conventional tillage and direct seeding of soil, greater penetration resistance was found under no-tillage (Hajabbasi, 2010; Kahlon *et al*., 2013) that means tillage operation led to reduce soil penetration resistance. Pulverization index (mean weight diameter (MWD) or pulverization ratio could be expressed degree of fragmentation of soil. Pulverization ratio affected by soil moisture content, soil texture and operating of plowing conditions (Abbaspour-Gilandeh *et al.* (2009). Aday and Al-Edan (2004a) found that friable soil had higher pulverization than wet soil by percentage 47.76%. They also, indicated that serrate moldboard plow surpassed conventional moldboard plow (general purpose moldboard) in increasing the soil pulverization. Nassir (2017) noted that the moldboard plow had soil pulverization greater than chisel plow by 32.57%.

Many studies were conducted to evaluate the effectiveness of tillage methods or plow types on soil physical properties under different operating conditions, but it did not take into account the effect of moldboard types on soil physical properties, therefore main purpose of the current study is evaluating the effect moldboards types under different operating conditions in terms soil moisture content, plowing depths and tractor speeds on soil physical properties which including bulk density, soil porosity, soil penetration resistance and pulverization ratio.

Material and Methods:

Description of moldboard plows:

Three different types of moldboard plows were used in all tests depending on the shapes of moldboards. Types of moldboards were helical moldboard, semi helical moldboard, and general purpose moldboard. The geometric characteristics of each moldboard are presented in table (1).

Table (1): Geometric characteristics of the moldboards used for the study

Moldboard type	θ_s (deg)	θ_i (deg)	W_S (mm)	L_L (mm)	L_0 (mm)
Helical	39	31	360	300	1220
Semi helical	37	28	290	250	1105
General-purpose	33	28	260	150	90

L_L= landslide length. *Lo* = overall length of bottom W_S= share culling width perpendicular to the direction of travel. θ_i = share wing angle. And θ_i= lateral directional moldboard tail angle.

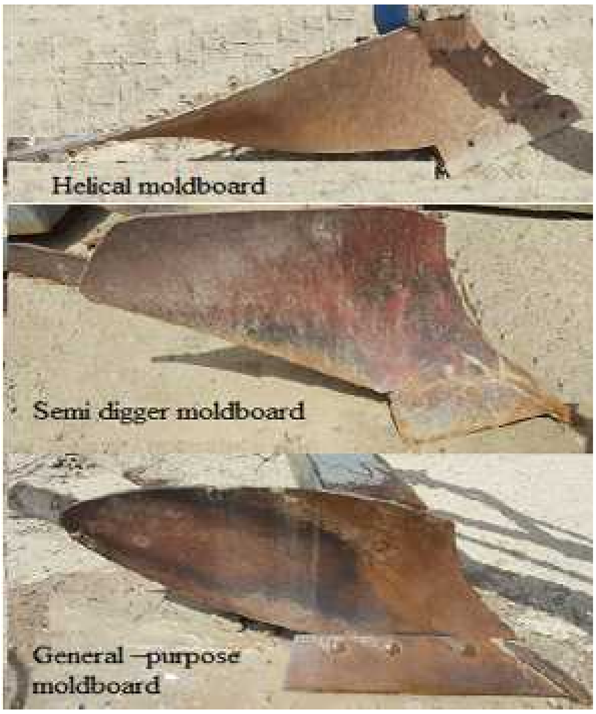

Fig. (1): Moldboard types used in test.

Experimental design:

The experiment was conducted in 2017 in silty loam soil. The experimental design according to split-split plot (Sleel and Torrie 1980). The main plots unit included the three replicates of moldboards types. Three levels of soil moisture content were arranged in sub plots, and sub-sub plots were included three tractor speed. Length of each plot is 135m whereas main plots, sub plots and sub-sub plots had width of 40.5, 13.5 and 4.5 m .

Measuring the soil penetration resistance:

In this study penetrologger was used that showed in fig. (1). When handling of machine is pushed down, the cone penetrates the soil to specific depth. This machine can read data of soil penetration for each 1 cm until 80 cm. The data view numerically or graphically through screen of the digital device. Each measurement was replicated three times per treatment and all data of soil penetration were saved in machine memory after samples are done. The machine was connected to the computer, where all recorded data were transferred to the computer and had been analyzed it. Across section of cone is 2 cm^2, angle of top cone is 60^o, length of probing rod is 80 cm and speeds of penetration of soil reach to 2 cm sec^{-1} .

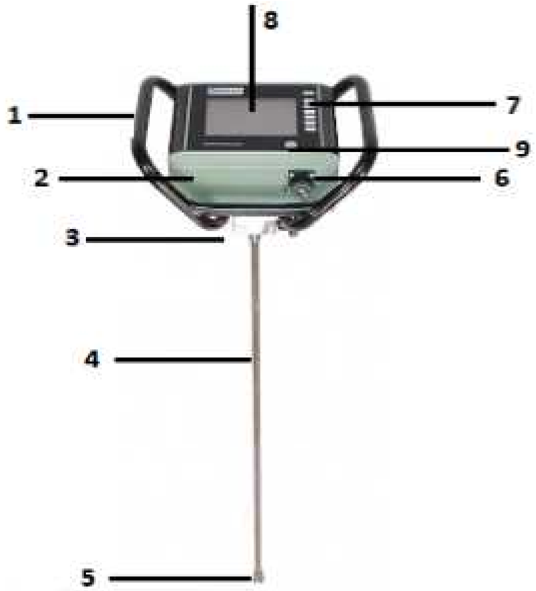

Fig. (2): Digital Penetrometer: 1. Electrically insulated grips 2. Protecting housing, 3. Impact absorber, 3. Bipartite probing rod, 5. Cone, 6. Communication port, 7. Control Panel, 8. LCD screen 9. Level,

Soil texture: pipette method was used to determine soil texture. Soil texture is presented in table (2).

Table (2): Texture analysis of soil.

Clay%	Silt%	Sand %
35	47	18
Silty loam soil		

Soil physical properties:

The test of soil physical properties was conducted before and after soil plowing and results are illustrated in table (3).

The bulk density: Bulk density was evaluated by core method. Core dimensions were 4.5*6.42 cm, whereas three replications of soil sample were collected per plot from specific depths in this study. Each sample was dried in oven at 105 °C and weighed then bulk density was calculated from equation (1) which noted in Black *et al*. (1965).

$$pd = \frac{ms}{vt} \dots\dots\dots\dots\dots.(1)$$

Where:

pd: The dry bulk density (Mg.m^{-3})

Ms: The weight of the dried soil sample (Mg)

Vt: The total volume of the soil sample (m^{3})

Total porosity: Calculated from equation '(2) which mentioned in black et al (1965). The particle density was equal 2.65 Mg m^{-3}

$$f = 1 - \frac{pd}{ps} \square 100 \dots\dots\dots\dots\dots (2)$$

Where:

f: Total soil porosity (%)

pd: The dry bulk density (Mg.m^{-3})

ps: The particle density (Mg.m^{-3})

The moisture content of the soil was determined on wet weight base where the samples of soil were collected from specific depths with three replications per plot, then samples dried in oven at 105 °C for 24 hour. Soil moisture content was calculated from equation (3).

$$M.C = \frac{W_{wet} - W_{dry}}{W_{dry}} \square 100 \dots\dots\dots\dots\dots.(3)$$

Where:

M.C= moisture content (%)

W_{wet} = The weight of the wet soil sample (g)

W_{dry} = The weight of the dried soil sample (g)

Soil pulverization ratio: Is the percentage of the soil weight fraction composed of soil clods less than or equal 25 mm (Φ ≤ 25 mm) which passes from the sieve mesh of 25 mm to the total weight of soil sample. Soil pulverization ratio was calculated from equation (4) which noted in Khadr. (2008).

$$S.p = \frac{soil\ clods \leq 25\ mm}{Total\ soil\ sample\ weight} \square 100 \dots\dots\dots.(4)$$

Where:

$S.p$: Soil pulverization ratio (%)

Table (3): Initial soil properties at depth of 20 cm.

Soil moisture content (%)	10.23%	16.47%	24.68%
Bulk Density (Mg m^{-3})	1.36	1.29	1.44
Porosity (%)	17.5	21.8	12.70
Penetration Resistance (kN m^{-2})	3548.57	2247.36	2044.73
Cohesion (kN m^{-2})	15.41	11.39	13.58
Adhesion (kN m^{-2})	0.18	0.15	0.26

Results and Discussion

Bulk density: The effect of moldboard plows on bulk density is shown in table (4). The results showed that bulk density was affected significantly ($p \leq 0.05$) with changing of moldboard plow type. The general- purpose plow type had the lowest value of bulk density of 1.10 Mg m^{-3} while the helical and semi digger had high values of bulk density of 1.34 and 1.27 Mg m^{-3}, respectively. That was because the general- purpose plow type performed to pulverization soil higher than of soil overturning, whereas the soil volume increase with increasing pulverization thereby the bulk density was reduced.

Soil moisture content had a significant effect ($p \leq 0.05$) on bulk density (table 4). The soil of lower moisture content level (10.23%) and soil of high moisture content level of 24.68% had a greater bulk density than that of soil of moisture content level of 16.47%. This was because of soil strengths in case wet soil, increasing due to increasing adhesion forces between soil clods and the plow's moldboards which reduce of soil pulverization, however, in case dry soil pulverization of soil was reduced due to increase cohesion forces with decreasing the moisture content of soil where soil particles cohere strongly. This study agreed with Legahri. *et al.* (2016) and Shitu, *et al.* (2017).

The effect of tractor speed on the bulk density as shown in table (4). The minimum value of bulk density was 1.21 Mg m^{-3} at high tractor speed of 1.12 m sec^{-1} and maximum value of bulk density was 1.26 Mg m^{-3} at low tractor speed of 0.41 m sec^{-1} . This was mainly because of increasing soil pulverization with increasing tractor speed and this make soil had a considerable volume. In addition to that increasing of tractor speed made moldboard plow work in shallow depth,

Table (4): The effect of plow type, soil moisture content and tractor speed on bulk density, porosity, pulverization ratio and penetration resistance.

	Bulk Density (Mgm^{-3})	Porosity (%)	Pulverization Ratio (%)	Penetration Resistance (kNm^{-2})
Plow type				
Helical	1.34	49.18	40	816.06
Semi digger	1.1	58.55	60	721.35
Deep digger	1.272	52.01	53	765.19
L.S.D. (0.05)	0.0035	0.134	0.174	3.520
Moisture content (%)				
10.23	1.363	54.90	48	788.16
16.47	1.158	56.29	57	678.57
24.68	1.195	48.56	47	835.86
L.S.D. (0.05)	0.0027	0.104	0.201	2.76
Tractor speed (m sec^{-1})				
0.41	1.265	52.26	40	1115.156
0.57	1.246	52.98	48	1014.509
0.88	1.233	53.48	55	890.2811
1.12	1.212	54.28	61	800.5944
L.S.D. (0.05)	0.0096	0.364	0.441	8.49

whereas the soil strength be weak due to reducing adhesion and cohesion forces of the soil with presentence a lot of organic matter in the soil in the upper soil layer (Kouwenhoven *et al.,* 2002) thus increasing the bulk density. This results agree with findings by Legahri. *et al.* (2016) and Muhsin (2017).

Interaction among plow type, soil moisture content and tractor speed had not significant effect on bulk density (table 5). The results indicated that the highest value of bulk density recorded by helical plow type at low tractor speed of 0.41m sec^{-1} and high soil moisture content of 24.68%. It as an amount of 1.48 Mg m^{-3} while the lowest value of bulk density recorded by general-purpose plow type at moderate soil moisture content of 16.47% and high tractor speed of 1.12 m sec^{-1}. It was an amount of 0.95 Mg m^{-3}.

Soil porosity: From table (4) it could noticed that moldboard plow had a significant effect ($p \leq 0.05$) on soil porosity. Whereas general-purpose moldboard type had higher value of soil porosity than that of semi digger and helical respectively. General- purpose moldboard type had soil porosity value of 58.55%, where semi digger and helical had values of soil porosity were 52.01 and 49.18% respectively. These results could be attributed to increasing pores among soil particles due to increasing the soil pulverization at general purpose type whereas the general purpose type of plow pulverizes the soil greater than inverting it, thereby general- purpose moldboard type surpassed in increase soil porosity comparing with other types of the moldboard. These results agreed with the findings of Muhsin, (2017).

Table (5): The effect of interaction among plow type, soil moisture content and tractor speed on bulk density (Mg m-3).

		Tractor speed m sec^{-1}			
Plows type	M.C (%)	0.41	0.57	0.88	1.12
Helical	10.23	1.33	1.31	1.29	1.27
	16.47	1.31	1.29	1.27	1.25
	24.68	1.48	1.46	1.44	1.42
General-purpose	10.23	1.08	1.06	1.05	1.02
	16.47	1.01	0.99	0.97	0.95
	24.68	1.28	1.27	1.25	1.22
Semi digger	10.23	1.25	1.23	1.22	1.2
	16.47	1.23	1.21	1.2	1.18
	24.68	1.4	1.38	1.37	1.35

L.S.D.(0.05) plow type× M.C× tractor speed = 0.96

The results of soil moisture content are shown in table (4). Soil moisture content had a significant effect ($p \leq 0.05$) on soil porosity**.** The soil porosity change with changing of soil moisture content level. The highest value of porosity (56.29%) recorded by soil moisture content of 16.47%, while other levels of soil moisture content of 10.23 and 24.68% recorded lower soil porosity (54.90 and 48.56%, respectively). This means that increasing or reduced soil moisture content led to decrease soil porosity and this could be attributed to that wet soil had considerable adhesion force, however dry soil had high soil cohesion which increase the soil strength thereby reducing soil loosening and this led to decrease soil pores.

The results revealed significant ($p<0.05$) effect of tractor speed on soil porosity (Table 4). Tractor speed of 1.12 m sec^{-1} recorded the highest value of soil porosity (54.28%), while the lowest value of soil porosity recorded by the tractor speed of 0.41m sec^{-1} (52.26%). That attributed to increasing of soil loosening where increase the soil pores therefore increase soil porosity. This is in accordance with results reported by Bogunovic and Kisi (2017)

There was no significant effect of the interaction among plow type, soil moisture content and tractor speed on soil porosity (Table 6). In general soil porosity was improved considerably when used general – purpose plow type with moderate soil moisture content of 16.47 % and high tractor speed of 1.12 m sec^{-1} where it's reached to 63.9%. While helical and semi digger plow type at same plowing circumstances reached to 52.58 and 55.41%, respectively.

Soil pulverization ratio: The influence of moldboard plow type on soil pulverization ratio is shown in table (4), which clarified that the general- purpose plow type had a soil pulverization ratio greater than semi digger and helical plow types. General- purpose plow type surpassed significantly ($p\leq 0.05$) on others plows type, where the recorded maximum value of the soil pulverization ratio was 60%, while semi digger and helical minimum values of the soil pulverization ratio of 53 and 40% respectively. This results can attributed to that general- purpose plow type performed on pulverized soil superior than inverting it, thereby this plow produce small volumes of soil clods while both other plow types performed plowing operations with more soil clods volumes inverting and less from soil clods pulverization especially helical plow type which invert soil clods by higher percentage. This trend accords with the Aday and Al-Edan. (2004a). These findings could be attributed to that wet soil make clods adhere with moldboards of plow and its other parts which caused by reducing the soil pulverization ratio. On the other hand, dry soil makes soil particles cohere with each other and this led to increasing the soil strength, the soil showed resistance of soil to pulverization. Similar results were also reported by Abbaspour-Gilandeh *et al*. (2009). The soil pulverization ration was significantly ($p<0.05$) affected by soil moisture content. The data in table (4) indicated that soil moisture content level of 16.47% registered the highest values of 57% compared with the soil moisture content level of 10.23 and 24.68% which recorded 48 and 47 %, respectively. From results can be illustrate that the dry or wet soil recorded low soil pulverization ratio, these findings could be attributed to that wet soil make clods adhere with moldboards of a plow and its other parts which caused by reducing the soil pulverization ratio. On the other hand dry soil makes soil particles cohere with each other and this led to increasing the soil strength, thus the soil showed resistance of pulverization. Similar results were also reported by Abbaspour-Gilandeh *et al*. (2009).

The effect of tractor speed on soil pulverization ratio was shown in table (4). The soil pulverization ratio increased significantly ($p<0.05$) with increasing the tractor speed. Increasing tractor speed from 0.41 to 1.12 m sec^{-1} increased soil pulverization ratio from 40 to 60 %. This might be attributed to that soil clods acquire high acceleration led to crash it each other which caused an increase in cracking clods of soil due to occurrence self-pulverization to soil clods resulting in producing small clods of soil. These results were in agreement with Aday *et al*. (2004); Javadian and Hajiahemed (2009) and Muhsin (2017).

The interaction among plow type, soil moisture content and tractor speed had significant effects ($p \leq 0.05$) on the soil pulverization ratio (table 7). The maximum value of the soil pulverization ratio (74.10%) was obtained at the general- purpose plow type, high tractor speed of 1.12 m sec^{-1}, and soil moisture content level of 16.47%. While, the minimum value of the soil pulverization ratio (25%) obtained at the helical plow type, low tractor speed of 0.41 m sec^{-1} and high soil moisture content of 24.68%. That was because soil moisture at 16.47 % makes soil in a friable state in addition to that high tractor speed of 1.12 m sec^{-1} led to collision soil clods each other, thus increasing the soil pulverization, especially when using the general- purpose plow type which pulverizing of soil more than inverting of soil, therefore, increase soil pulverization ratio.

Soil penetration resistance: The results of moldboard plows types are shown in table (4) There was significant differences ($p \leq 0.05$) among moldboard plow types on soil penetration resistance. The highest penetration resistance of soil was recorded by helical plow type (926.70 kN m^{-2}), followed by semi digger plow type (844.10 kN m^{-2}) and the least was the general-purpose plow type (774.40 kN m^{-2}). These results attributed to that the helical plow type leaves large soil blocks on the soil surface , whereas the soil particles are dense and cohere to each other which prevent the soil particle displacement and that makes soil more resistant to penetration. These results agree with Hajabbasi (2010) and Kahlon *et al*. (2013) .

Soil moisture content had a significant effect ($p \leq 0.05$) on penetration resistance of soil (table 4). The highest value of penetration resistance of soil was for soil moisture content level of 24.68 % (835.86 kN m^{-2}) while the lowest value of penetration resistance of soil was for soil moisture content level of 16.47 % was 721.35 kN m^{-2}. The presence of water in the soil works on increasing the strength of the soil , also friction angle and the adhesion between soil particles were increase due to increasing thickness of water films around soil particles, thereby the penetration resistance of soil increased. On other hand that dry soil had high cohesion and this resulting in an increasing soil strength considerably thereby the penetration resistance of soil increased in both cases in dry or wet soil. This is in accordance with Rashidi *et al.* (2007), Javadi and Spoor (2006). more ability to loosen and pulverization led to decrease in penetration resistance of soil.

Table (6). The effect of interaction among plow type, soil moisture content and tractor speed on porosity (%)

		Tractor speed m sec^{-1}			
Plows type	M.C (%)	0.41	0.57	0.88	1.12
Helical	10.23	49.81	50.56	51.07	52
	16.47	50.56	51.32	51.85	52.58
	24.68	44.15	44.9	45.41	46.16
General-purpose	10.23	59.24	60	60.5	61.26
	16.47	61.88	62.64	63.14	63.90
	24.68	51.69	52.12	52.58	53.71
Semi digger	10.23	52.64	53.4	54	54.61
	16.47	53.39	54.15	54.66	55.41
	24.68	46.98	47.73	48.24	49.01

L.S.D.(0.05) plow type× M.C× tractor speed = 1.09

Table (7): The effect of interaction among plow type, soil moisture content and tractor speed on soil pulverization ratio (%)

Plows type	M.C (%)	Tractor speed m sec^{-1} 0.41	0.57	0.88	1.12
Helical	10.23	29	36	41	49
	16.47	35	44	49	57
	24.68	25	33	37	42
General-purpose	10.23	47	55	61	65
	16.47	54	58	70	75
	24.68	50	56	67	62
Semi digger	10.23	39	48	53	58
	16.47	46	59	66	74
	24.68	35	44	51	63

L.S.D.(0.05 plow type× M.C× tractor speed = 0.52

Table (8): The effect of interaction among plow type, soil moisture content and tractor speed on penetration resistance of soil (kN m^{-2})

Plows type	M.C (%)	Tractor speed m sec^{-1} 0.41	0.57	0.88	1.12
Helical	10.23	1200.25	1110.58	985.95	884.46
	16.47	1123.87	914.58	845.73	749.58
	24.68	1224.3	1176.58	1004.69	968.81
General-purpose	10.23	1079.35	991.27	863.89	775.85
	16.47	964.25	814.53	700.54	623.47
	24.68	1109.68	1096.58	945.21	804.28
Semi digger	10.23	1125.87	1053.14	904.59	816.59
	16.47	1010.25	870.36	786.58	725.43
	24.68	1200.25	1110.58	985.95	884.46

L.S.D.(0.05 plow type× M.C× tractor speed = 22.36

The effect of the tractor speed on penetration resistance of soil is presented in table (4). The results indicated a significant differences among tractor speeds, whereas the high speed of 1.12 m sec^{-1} recorded the lowest values of penetration resistance of soil was 800.59 kN m^{-2} while low tracer speed of .41m sec^{-1} caused the highest values of penetration resistance of 1115.15 kN m^{-2}. The results clearly showed that the relationship between tractor speed and penetration resistance of soil was negative. In general the plowing operating led to reduce penetration resistance of soil compared to unplowed soil. Also increasing tractor speed reduce penetration resistance of soil which referred to increasing the soil loosening with increasing tractor speed where soil blocks become lower cohesion thereby penetration resistance of soil decreased with the operating of plowing especially at high tractor speeds. Similar results were also reported by Rashidi *et al.* (2007).

The interaction among plow type, soil moisture content and tractor speed had a significant effect ($p \leq 0.05$) on the penetration resistance of soil (table 8). The general plow type recorded lower value of penetration resistance of soil. Its reached to 884.46 kN m^{-2} at soil moisture content of 16.47% and tractor speed of 1.12 m sec^{-1} . While helical and semi digger recorded higher values of penetration resistance of soil of 1224.3 and 1200.25 kN m^{-2} ,respectively at soil moisture content of 24.68% and tractor speed of 0.41 m sec^{-1}. This was because that high tractor speed and moderate soil moisture (soil in friable state) make the soil more ability to loosen and pulverization led to decreasing in penetration resistance of soil.

Conclusions

The research revealed that high tractor speed of 1.12 m sec^{-1} and soil moisture content of 16.47% gave the best performance with all moldboard plows types used. However, the general-purpose plow type achieved performance better than that of helical and semi digger plow types at the same tillage operating circumstance, where soil physical properties were improved considerably when using general-purpose plow type. Soil physical properties weren't improved highly at soil moisture content of 24.68 or 10.23% when plowing with any type of moldboard plow, especially at slow tractor speed of 0.41 or 0.56 m sec^{-1}.

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