

A Comparative Study of Conventional and Modified Tine Types of Subsoiler and Their Effect on Some Performance Characteristics

Hussain Th. TAHIR^{1*}, Nazat H. JEEJO², Tariq H. KARIM³

¹College of Agriculture, Kirkuk University, Kirkuk, Iraq

²Ministry of Agriculture and Water Resources. Erbil, Iraq

³College of Agriculture, Salahaddin University, Erbil, Iraq

*Corresponding author e-mail: hussein.tahir2@gmail.com

Geliş Tarihi (Received): 22.07.2018

Kabul Tarihi (Accepted): 03.10.2018

Abstract: The current study was conducted at the experimental field, College of Agriculture, University of Salahaddin in Erbil at Gardarasha. Corn was selected as a sensitive plant to soil compaction that was grown on a silty clay loam soil texture during the summer and autumn. In this study a new design of tine was provided, then machinery indicators and crop indices were evaluated and compared to conventional one manufactured in Massey Ferguson Corporation. A factorial experiment was conducted by using completely randomized block design with split plot and three replications and Duncan test were used to compare the means of treatment at 5%. The first factor was subsoil tillage depth at three deepness of (20 – 25), (30 – 35), and (40 – 45) cm. The second factor included type of tine (conventional and modified with wings).

The summarized important points were: Draft force, effective field capacity and, soil volume disturbance, they increased by depth increment. Furthermore, using modified tine type illustrated greater records in contrast to conventional one. Moreover, field efficiency was considerably affected by tine type. Better results were considered by applying modified tine type. Meanwhile slippage percentage was only affected by tillage depth that increased by depth increment. Briefly, by comparison between two tine types, it was observed that all plant indicators showed greater values by equipping the subsoiler with modified tine, although, this superiority was not significant in some indices.

Key words: Subsoiler tine, draft force, soil volume disturbance

INTRODUCTION

The intensifying pressure of population and development has diminished the soil resources of our small planet and has led to their unsustainable use and degradation in too many parts of the world. Soil compaction by heavy agricultural equipment is among the most important soil degradation agents on many farms around the world (Kasisira, 2005). It is well known that several types of continuous soil hard-pans restrict crop root growth, limiting access to nutrients and moisture in the subsoil (Birkás et al., 2010). These hard-pans are created by field traffic and tillage operations as well as by natural forces (ASAE, 2000). These hard pans reduce crop yields (Raza et al., 2007) and plant growth (Lebert et al., 2004), slow water infiltration and cause soil erosion (Dias Junior, 2003), decrease aeration and make plant susceptible to temporal drought stress (Raper and MacKirby, 2006).

Besides that subsoilers as a primary tillage equipment work in very arduous conditions, so they bear heavy dynamic loads. Therefore, proper design

of these machines is necessary in order to increase their working life and reduce the farming costs due to high energy consumption (Kadam and Chhapkhane, 2017). Accomplishment of this aim encourages research people to conduct relevant investigations. The success depends on the initial soil conditions, operational aspects (Cholaky et al., 2010), type of selected equipment, and its configuration (Kees, 2008). Therefore, subsoilers of different designs have been developed and used in attempts to reduce compaction. The subsoiler system is composed of many important components, but the point assembly is the first element to contact the soil and can largely determine the draft requirement and soil disruption of the subsoiler (Al-Tahan and Al-Irhayim, 2010). Therefore, subsoiler and shank tip equipment manufacturers have invested lots of money and time for developing the most efficient subsoiler tips. They should be able to help define the best tip available for specific conditions in the field. There is a great improvement in the subsoiler field performance when wings are used on its foot (Aday and Hilal, 2001).

Researches over the past 20 years have shown significant yield increases as a result of deep tillage when hardpans exist (Wiatrak and Camberato, 2013). Moreover, corn is sensitive to the presence of hardpans and responds well to subsoiling (Leskiw and Laycock, 1990).

Croitoru et al. (2016) reported the reduction of traction force by decreasing the tillage depth. Hilal (2007) reported 11% increase in draft force by double tines subsoiler compared to single tine. According to Al – Saadi (2011), and Hamid (2012) increasing the plowing depth resulted to increase in the slippage percentage. Abdullah and Dham (2012) found that by tillage depth increment from (10-20) cm to (20-30), the effective field capacity decreased from 0.261 ha/h to 0.247 ha/h. Furthermore Abdullah and Dham (2012) found that increase in the tillage depth from (10-20) cm to (20-30), rose the soil disturbed volume from 437.84 m³/h to 608.02 m³/h due to increasing the soil disturbed area. Leskiw and Laycock (1990) studied the effects of subsoiling on corn fields in Canada. They found that there was a good yield response (10 percent increase) to deep subsoiling on the severely compacted sites. Wang et al. (2009) reported that subsoiling increased the speed of crop emergence, plant density and biomass, as well as crop yield.

The relevant investigation was conducted to highlight the following objectives:

To increase the crop production through improving physical conditions of dense subsoil by introducing a new sub-soil plow shear. This was as the main objective of the study throughout choosing the best shape of tine between conventional and winged tine. That was done by comparing the improvement of subsoil physical condition, and showing the contribution of modified sub-soil plow tine on increasing corn production compared with conventional one.

MATERIAL AND METHODS

The current study was conducted at the experimental field, College of Agriculture, University of Salahaddin in Erbil at Gerdarasha. Corn was selected as a sensitive plant to soil compaction that was grown on a silty clay loam soil texture during the summer and autumn. In this study a new design of tine was provided, then machinery indicators and crop indices were evaluated and compared to conventional one manufactured in Massey Ferguson Corporation.

The field dimensions were 88m X 155 m, while the plot size was 30m X 2 m.

Randomized Complete Block Design (RCBD) with split -plot design was used for this experiment (Dawod and Ilyas, 1990). Main plot of depth of tillage divided to three plots. Each plot was under the sub plot of the type of tine. The experiment was factorial and two factors were: firstly tillage depth with three levels (20 - 25, 0 - 35, and 40 - 45) cm, while the second one was type of tine with two levels (conventional and modified). There were three replications; therefore, the experiment had 3*2*3 (18) treatments and then used Duncan test were used to compare the means of treatment at 5%. The length of refined treatments was 30 m. In order to avoid animal and human disturbance a fence with 1.5 meter height was constructed in all around the experimental field. The distance between two plots was 5 meters to allow tractor with implement maneuver freely.

During this experiment these tractors, equipment, devices, and materials were used:

1. Tractor type of Case with 120 HP.
2. Tractor type of New Holland double axle with 110 HP.
3. Subsoil plow with three shanks that was equipped to conventional tine (Fig. 1).
4. Subsoil plow with three shanks that was equipped with modified tine (Fig. 2).

Table 1. Subsoiler specifications

Number of shanks	Space between shanks	Height From soil surface	Working depth	Manufacturer company	Model
3	75 cm	70 cm	50 cm	Massey Ferguson	349

Table 2. Mechanical properties after heat treatment for modified tine (AISI 1010 classification)

Hardness HB30	Ultimate Tensile Strength
128 (kg / mm ²)	881.25 (MPa)



Fig. 1. Subsoiler with conventional tine



Fig. 2. Subsoiler with modified tine

5. Stage of Cutting and Formation of the Metal

After suitable metal selecting, the cutting stage of metal was started by considering this point that three tines were required for the subsoiler. During this phase the actual wooden sample and dimensions of the design were used to gain an accurate device. Then grinding and polishing of them were done using special instruments that were explained by (Rahmet Allah, 1985). Now the points are ready but some characteristics of them should be improved. These operations were achieved in AL-Tesahul Laboratory of agricultural machinery industry in the Kirkuk city. Then the prepared devices were heat treated to improve their mechanical properties as the table2.

Land Preparation:

In this experiment some plots were under subsoil plowing at different depths of (20-25), (30-35), and (40-45) cm. This was done by conventional and modified tine of subsoiler.

Initial soil conditions of experimental:

Furrow opener was the implement that was used making furrows for the purpose of irrigation. The furrows were later rebuilt by hand to creat the similar conditions of depth, length, and width. Each plot contained two furrows spaced of 0.75 m and 30 m in

length. Correction of sizes was done by using ropes, measuring tape, and shovel.

Soil moisture content:

Soil moisture content from 0 to 50 cm with 5 cm increment and illustrated in fig.3.

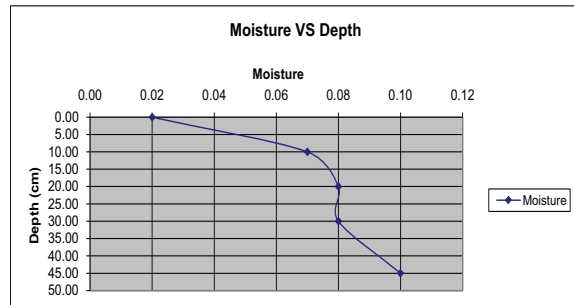


Fig. 3. Soil moisture content

Bulk Density:

Before starting the experiment, a grid system with grid spacing of 25 m * 25 m was established. A soil profile was dug at each grid point. The soil bulk density was measured at different depths by core method as outlined by Blake and Hartage (1986). The depth increments were 0 – 5 cm, 10 – 15 cm, 20 – 25 cm, 30 – 35 cm, 40 – 45 cm, 50 – 55 cm, 60 – 65 cm, 70 – 75 cm, and 80 – 85 cm. The core samples were obtained by carefully driving the core into the soil at each depth horizontally. Then samples were used to determine the soil moisture content and bulk density.

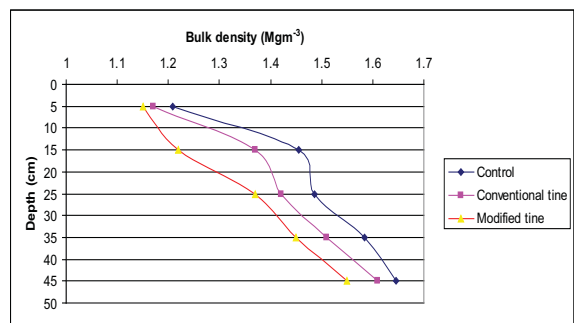


Fig. 4. Distribution of soil bulk density with depth under some selected treatments (control, subsoiled with conventional tine, and subsoiled with modified tine).

Fig.4. displays the effect of subsoiling using both conventional and modified tines to a depth of 45 cm on distribution of soil bulk density with depth. As can be noticed from Fig. 4. both curves of subsoiling go approximately parallel to the curve of the control treatment. It is also evident from Fig. 4. that at any depth, there was a significant reduction in soil bulk density due to subsoiling either by conventional or modified tines. This finding is in concord with the

results of Baumhardt and Jones (2005), who observed that the soil bulk density was positively affected by subsoiling. Additionally, Holmkvist (2008) attributed the reduction in soil bulk density as a result of subsoiling to an increase in the amount of larger pores with radius over 36 μ m. It is also apparent from Fig. 4. That the modified tine was superior to the conventional tine in reducing soil bulk density. A larger reduction due to subsoiling by modified tine occurred in between the depths of 15 and 25 cm compared with the other depths. Moreover, it can be observed that under the modified tine the depth at which growth-limiting bulk density occurs, shifted from a depth of 15 cm as mentioned earlier to a depth of about 35 cm, where most of the corn roots were concentrated. This is the main reason for the highest corn yield under this treatment.

Soil cone index:

The field was planted by barley in spring season but due to the low rainfall was not harvested although, then was grazed by sheep, the plant unharvest from the field was barley. The conducting time of experiment was summer and fall of 2013 Silty clay loam soil texture.

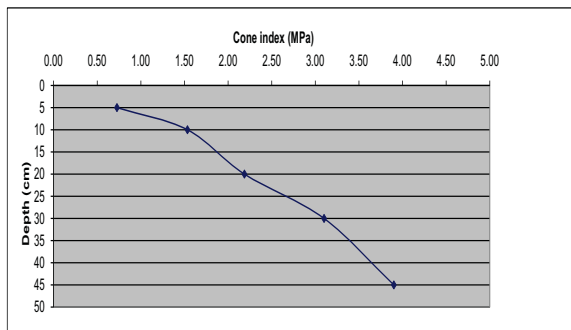


Fig. 5. Soil cone index from 0 to 50 cm with 5 cm increment

7. Plant and Planting Depth:

Corn seeds (var. Motrolla) that were imported from Spain were sowed. Wiatrak and Camberato (2013) recommended that corn seed should be generally planted by hand between 4 - 5 cm deep. Depth of seed planting was 5 cm.

The Study Factors

1. Plowing Depth

Plowing depth, which had three levels; (20 – 25) cm, (30 – 35) cm, (40 – 45) cm.

2. Subsoil Plow Tine

Subsoiler tine, which had two levels; Conventional tine at the right and Modified tine at the left, (Fig.6)



Fig. 6. Modified tine at left (with wings and angels) and Conventional tine at right of the image.

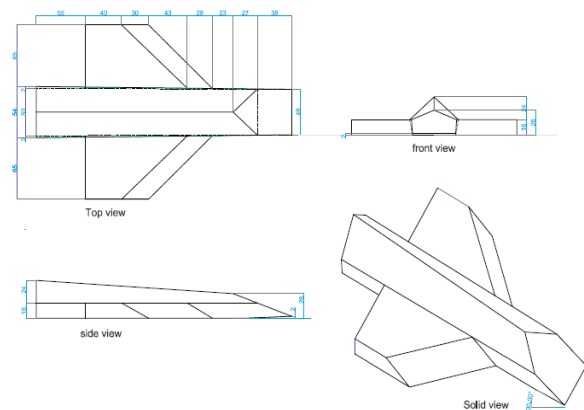


Fig. 7. The scheme of Modified tine.

Each treatment was replicated three times in design. Thus, the total number of experimental units was 3 * 2 * 3 = 18.

Study Indicators:

Plant Parameters

1. Plant height (cm).
2. Cob length (cm).
3. Plant dry matter (g).
4. Oven dry weight of root (g).
5. 1000 grain dry weight (g).

Machinery (Mechanical) Parameters;

1. Draft Force

According to Kepner et al. (2000) draft force is calculated as below:

$$Ft = Fpm - Frm \text{ (kg)} \dots \dots \dots (1)$$

where:

Ft = required pulling or draft force that is expressed by (kg)

Fpm = Actual draft force that is required to pull the tractor equipped with subsoil plow during work and is gained by dynamometer (Dillon with 10000 kg capacity).

Frm = Rolling resistance (kg) that is read through pulling tractor without applying subsoil plow and directly can be obtained by reading the dynamometer gauge.

2. Slippage Percentage

The following equation was applied to compute the slippage percentage that was described by Tahir (2004).

$$S = (1 - (Vp/Vt)) \times 100 \text{ (%) ... (2)}$$

Vt = Theoretical forward speed (km.h⁻¹)

Vp = Practical forward speed (km.h⁻¹)

3. Tractive Efficiency (T.E)

The tractive efficiency of tractor in every plot for both subsoil plow tines, three depth levels, and two soil cases according following equation was calculated that was described by Zoz and Grisso (2003).

$$T.E = \{ Ft \times (1 - S) / Ft + Frm \} \times 100 \text{ (%) ... (3)}$$

4. Effective Field Capacity

This parameter was determined by applying the following equation that was described by Kepner et al. (2000).

$$Cp = 0.10 \times Wp \times Vp \times fp \text{ ... (4)}$$

where:

Cp = Effective field capacity (ha.h⁻¹)

Wp = Practical or actual width of machine (m)

fp = Modulus of time consumption with a value between (0.56-0.75). In this study the value of 0.70 was applied to *fp* as recommended by Hamid (2012), Taha (2011).

5. Soil Volume Disturbance (S.V.D)

The volume of disturbed soil was calculated according to formula described by Abdul-Jabbar (2011).

$$S.V.D. = A \times Vp \text{ ... (5)}$$

A=disturbed area (cm³).

The disturbed area was obtained by measuring the cross section dimensions forming due to subsoiling and using the following formula which was described by Spoor and Godwin (1978). Cross section properties can be determined by hand excavation perpendicular to the plow line.

A= Disturbed soil area (cm²) that can be calculated from below equation:

$$A = (s \times dc) + (w \times d) \text{ cm}^2 \text{ ... (6)}$$

where:

d= Subsoil plow depth. (cm)

dc= critical depth from the surface. (cm)

w= Width of the tilled soil at the critical depth. (cm)

s= Disturbed distance on one side (cm)

RESULTS AND DISCUSSION

Effect of Tillage Depth on Indicators

Plant Indicators

Table 3 reveals that all studied plant indicators are considerably affected by changing in tillage depth. They increased by increasing the depth of subsoiling and totally gained to their highest values at the depth of (40 – 45) cm whereas the lowest rates were scored at the shallowest depth (Table 4; Table 5). Al-Tahan and Al-Alikhan Baq (2008) confirmed the increase in plant indicators by increasing tillage depth, and related to improvement in soil physical conditions such as better soil porosity and higher water content. Furthermore, Akhtar et al. (2005) explained that better plant response to deep plowing may be due to softer soil condition which facilitated needles to easily penetrate into the soil. Wasaya et al. (2012) confirmed that biomass yield of maize improved due to good soil conditions provided to crop for better growth and development by loosening the soil with deep tillage. Besides that Hussain et al. (2007) showed that depth increment resulted increasing in corn height, cob length, number of grain per cob, 1000 grain weight, and grain yield per hectare (Table 4; Table 5).

Table 3. Effect of tillage depth on indicators

Indicator	Mean value		
	Tillage depth (cm)		
	20 – 25	30 – 35	40 – 45
Plant height (cm)	184.0308 b	187.0862 ab	193.0438 a
Cob length (cm)	23.1006 b	23.0402 b	24.0270 a
Plant dry matter (g)	370.970 b	398.340 a	421.070 a
Oven dry weight of root (g)	27.183 c	34.272 b	40.017 a
1000 grain dry weight (g)	288.077 b	291.640 ab	295.398 a
Tractive efficiency (%)	68.757 a	67.924 ab	67.039 b
* Draft force (kg)	2625.000 c	3550.00 b	4250.000 a
* Slippage percentage (%)	12.002 c	14.034 b	17.827 a
Effective field capacity (ha.h ⁻¹)	0.322 a	0.319 a	0.307 b
Soil volume disturbance (m ³ .h ⁻¹)	627.750 c	988.180 b	1269.970 a

- Same letters in front of numbers at any row mean there is no significant difference but different letters mean significant difference.
- The sign of (*) Before indicators means the lower value is better. For remaining indices higher values are better.

Table 4. Effect of subsoiler tine type on indicators

Indicator	Mean value	
	Type of tine	
	Conventional	Modified
Plant height (cm)	185.990 b	191.082 a
Cob length (cm)	23.0814 b	23.6971 a
Plant dry matter (g)	391.320 a	402.270 a
Oven dry weight of root (g)	29.194 b	38.453 a
Tractive efficiency (%)	66.819 b	68.995 a
* Draft force (kg)	3408.330 b	3541.670 a
* Slippage percentage (%)	14.335 a	14.908 a
Effective field capacity (ha.h ⁻¹)	0.312 b	0.320 a
Soil volume disturbance (m ³ .h ⁻¹)	854.780 b	1069.200 a

- Same letters in front of numbers at any row mean there is no significant difference but different letters mean significant difference.
- The sign of (*) Before indicators means the lower value is better. For remaining indices higher values are better.

Tractive Efficiency

Tillage depth was superior in tractive efficiency at the depth of (20 – 25) cm to depths of (30 - 35) and (40 – 45). Their values were 68.725%, 67.924%, and 67.812% respectively. There was a trend to reduction by depth increment. The results (Table 4) were in agreement with Tahir (2004).

Draft Force

Increasing the tillage depth from (20 – 25) to (30 – 35) then (40 – 45) cm, considerably increased the draft force 35.24% and 61.90% respectively (Table 4; Table 5). Therefore, depth increment caused

increasing the draft force. The reason is that raising in depth means increasing the area of plow which faced to soil and subsequently disturbing more soil volume that finally results to more draft force requirement, This is verified by Abdul-Jabbar (2011).

Slippage Percentage

Increasing the tillage depth from (20–25) to (30–35) then (40–45) cm, considerably increased the slippage percentage 16.93% and 48.53%, respectively. Increasing the depth results to more contact area between plow and soil particles that causing further disturbed volume of soil and finally raises the draft force (Jabr, 2009); therefore, the tractor and plow practical speed decreases which leads to increase the slippage percentage (Inchebron et al., 2012). This was also confirmed by Taha and Abdul-Jabbar (2011).

Effective Field Capacity

Raising the tillage depth led to significant reduction in effective field capacity. So that at the shallowest depth it was 0.322 ha / h and at the deepest depth 0.307 ha / h. The results were verified by Taha (2011); Abdul-Jabbar, Al – Saadi (2011) and Al- Sharifi (2009) who explained that increasing the depth, raises the draft force resulting to reduction in practical speed (due to more slippage percentage) that is a factor to reduction in effective field capacity value. The reason verified by Jabr (2009), and Al-Taie (1999).

Table 5. Effect of interaction between tillage depth and type of tine on indicators

Tillage depth (cm)	Type of tine	Plant height (cm)	Cob length (cm)	Plant dry matter (g)	Root oven dry weight (g)	1000 grain dry weight (g)	Tractive efficiency (%)	* Draft force (kg)	* Slippage percentage (%)	Effective field capacity (ha.h ⁻¹)	Soil volume disturbance (m ³ .h ⁻¹)
20 - 25	Co	181.230 c	22.7275 b	360.150 b	24.093 e	287.543 b	67.615 abc	2575 c	11.640 c	0.318 ab	544.000 f
	Mo	187.387 bc	23.4737 ab	381.800 ab	30.273 d	288.610 ab	69.900 a	2675 c	12.365 c	0.325 a	711.500 e
30 - 35	Co	186.445 bc	22.8095 b	396.700 ab	29.697 d	291.003 ab	66.975 bc	3475 b	13.860 b	0.315 ab	889.010 d
	Mo	189.278 b	23.2708 b	399.990 ab	38.847 b	292.277 ab	68.873 ab	3625 b	14.208 b	0.323 a	1087.350 c
40 - 45	Co	190.295 ab	23.7072 ab	417.120 a	33.793 c	293.845 ab	65.867 c	4175 a	17.505 a	0.302 c	1131.200 b
	Mo	196.580 a	24.3468 a	425.020 a	46.240 a	296.952 a	68.212 abc	4325 a	18.150 a	0.312 bc	1408.740 a

- Same letters in front of numbers at the any row mean there is no significant difference but different letters mean significant difference.
- The sign of (*) Before indicators means the lower value is better. For remaining indices higher values are better.
- Co; Conventional tine, Mo; Modified tine.

Soil Volume Disturbance

Increasing the tillage depth from (20 – 25) to (30 – 35) then (40 – 45) cm, significantly raised the soil volume disturbance 57.42% and 100.02%, respectively. This is in agreement with the findings of Al- Sharifi (2009).

Effect of Subsoiler Tine type on Indicators Plant Indicators

Table 4. revealed that subsoiler tine type significantly affected the plant height, cob length, and oven dry weight of roots. Ramazan et al. (2012) confirmed that the soil with low bulk density has more porosity, good hydraulic conductivity, thus has favorable condition for plant growth.

Rahman et al. (2005) clarified that the increase in plant growth associated with soil decompaction may be related to the combination of decreased root penetration resistance and the development of a rhizosphere environment that influences plant nutrient availability.

Tractive Efficiency

Modified tine of subsoiler was superior to conventional one in tractive efficiency. They illustrated 68.995% and 66.819% respectively. This indicator is highly affected by slippage percentage as described by Zoz and Grisso (2003) also draft force controls that. Influencing the latter factor is much greater than slippage percentage for modified tine type which is the determining factor for superior value of this indicator.

Draft Force

Subsoiler equipped with modified tine significantly required 3.91% more draft force than conventional one. The results were in agreement with findings of Aday and Hilal (2001). This was due to added wings and thicker base (growing from the nose to the back) which enhanced the facing plow area to the soil resulting more needed draft force. The results were also verified by Kumar and Thakur (2007).

Effective Field Capacity

Modified tine was superior to conventional one in effective field capacity. They demonstrated 0.320 ha.h⁻¹ and 0.312 ha.h⁻¹ respectively. Al – Saadi (2011) and Tahir (2004) explained that higher working width is an affecting factor to increase the effective field capacity which for modified tine was greater as mentioned before.

Soil Volume Disturbance

Subsoiler equipped with modified tine showed a considerable 25.08% more soil volume disturbance

than that one with conventional tine. Because of wings modified tine had greater actual working width which increased the soil volume disturbance. The reason was confirmed by Hamel (2012) and Al- Sharifi (2009).

Effect of Interaction Between Tillage Depth and Type of Tine on Indicators Plant Indicators

Interaction between tillage depth and type of tine significantly affected all plant indexes (Table 5). They totally illustrated their highest values at the depth of (40 – 45) cm of subsoiling when utilizing the modified tine. The reason maybe was due to the highest disturbed area in this treatment which helped the plant to find nutrients and water easier due to better root proliferation. At the same time entire indicators showed their lowest values when the plow worked at the depth of (20 – 25 cm) and was equipped with conventional tine. Total indicators showed continuous increasing by increasing the tillage depth that was greater for modified tine rather than conventional one for each depth. Solhjoui and Mohammadi (2007) gave detail proving that subsoiling helps plant to persist against water crisis. This was maybe a reason to explain plant indicators demonstrations especially for this study that was performed in summer. Furthermore, lower soil bulk density verified by, Holmkvist (2008) and penetration resistance, as well as better water infiltration that are discussed here after were important influencing factors on plant production.

Tractive Efficiency

Treatment combination of modified tine at depth of (20 – 25) cm was superior in tractive efficiency to the treatment of conventional tine at the third depth (69.900% 65.868% respectively). Tractive Efficiency decreased by depth growing that verified by Zoz and Grisso (2003).

Draft Force

Treatment combination of modified tine and depth of (40 – 45) cm was superior to conventional tine at the depth of (20 – 25) cm in draft force requirement (4325 kg and 2575 kg respectively). The results were verified by Croitoru et al (2016) depth increment significantly increased the draft force.

Slippage Percentage

Treatment combination of the (40 – 45) cm depth and applying modified tine was superior in slippage percentage comparing to the depth of (20 – 25) cm and using conventional tine (18.150% and 11.640% respectively). By increasing the depth this indicator

significantly increased that was verified by Inchebron et al., (2012). Also for each depth modified tine indicated greater slippage percentage that was discussed here before.

Effective Field Capacity

Subsoil plow equipped with modified tine was superior in effective field capacity compared to conventional tine at the deepest tillage (0.323 and 0.302 respectively). This indicator considerably decreased with depth growing, also, for each depth modified point significantly showed greater value in contrast to conventional one. According to Al – Saadi (2011), practical speed for shallower depth is higher due to less slippage which influence on effective field capacity; furthermore working width of winged tine is higher than conventional one that is another control factor, therefore the designed width of modified tine with wings is wider than conventional tine which is covered the differences of slippage percentage between two tines in favor of modified tine. The results were verified by yaye (1998), the designed working width has a significant effect on the effective field capacity.

REFERENCES

- Abdul-Jabbar, M. A. S. 2011. The effect of cutting angle, depth and tractor speed on some technical performance parameters for the mole plow. A master thesis in Agricultural machine and equipment, College of Agriculture, University of Baghdad. (In Arabic).
- Abdullah A. A., G. A. Dham. 2012. Study effect of moldboard plow shares shape design locally made on some performance parameter and soil physical properties. Kirkuk University Agric Sci. 3(2): 36-51. (in Arabic).
- Aday, S. H., and Y. Y. Hilal. 2001a. The effect of wings width on the field performance of the subsoiler in heavy soil the specific resistance and energy utilization. Basrah Journal of agricultural Science. 14 (2): 51-66.
- Akhtar, J., S.M. Mehdi, O. Rehman, K. Mahmood, AND M. Sarfraz. 2005. Effect of deep tillage practices on moisture preservation and yield of groundnut under rainfed conditions. Journal of Agric and Social Sci. 1(2): 98-101.
- Al – Saadi, A. K. J. 2011. Evaluation of the performance efficiency of locally modified plow and compared with other plows. A master thesis submitted to the council of the college of Agriculture at the University of Baghdad, agricultural machines and equipment. (In Arabic).
- Al- Sharifi, S.K. A. 2009. Evaluation the effect two plows on some machine mints performance parameters and soil physic properties. Pure and applied Science. 17 (1): 182-205. (In Arabic).
- Al-Tahan, Y. H. and A. M.A. Al-Alikhan Baq. 2008. The effect of some plow types on growing and yield properties of corn (Zea mays) under sprinkler irrigation systems. Mesopotamia Agriculture. 36 (2). (In Arabic).

Soil Volume Disturbance

low with modified tine at the depth of (40 – 45) cm, disturbed 1408.740 m³.h⁻¹ as the highest value of this indicator; whereas using conventional tine at the depth of (20 – 25) cm indicated 544 m³.h⁻¹ as its lowest rate. It considerably increased by depth increment and modified tine at each depth illustrated the greater value in contrast to conventional one. Hamel (2012) verified that due to wings modified tine had greater disturbed area.

CONCLUSIONS

- At a given depth, significant higher tractive efficiency, and soil volume disturbance were observed by utilizing modified tine.
- The majority of the studied plant indicators exhibited their highest values at the depth of (40 – 45) cm of subsoiling done on uncultivated soil using the modified tine type.
- Apply the tillage depth of (40 – 45) cm for corn crop using modified tine.
- Evaluate the performance of wings with different widths to find the optimum size.
- Study the performance of modified tine under other crops.
- Examine the persistence of plant and soil indicators by testing them during several years of experiments.

- Al-Tahan, Y. H., M. N. Al-Irhayim. 2010. Manufacturing different tine shapes for subsoiler and their field performance effect in the soil physical properties. Al-Rafidain Engineering Journal. (In Arabic).
- Al-Taie, M. S. 1999. Performance efficiency of plowing systems in removing plow sole under dry-land conditions. Master thesis in agricultural mechanization, college of Agriculture and forestry, University of Mosul.
- ASAE Standards. S414.1. 2000. Terminology and definitions for agricultural tillage implements. 47th Ed. Joseph, Mich:ASAE.
- Birkás, M., I. Kisić, D. Jug, M. Jolánkai, Z. Kakuszi. 2010. Tillage induced soil compaction consequences in the pannonian region. pp:9 – 16.
- Blake, G. R., and K. H. Hartage. 1986. Bulk density. In C. A. Black (eds.). Methods of soil analysis. Mono. P1; Pp: 363 – 375. 2nd Agron. Mono. Am. Soc. Agro. Madison. WI.
- Cholaky, C., J. M. Cisneros, and R. Balbuena. 2010. Field performance of a winged scarifier as a function of soil compaction and water content. Chillen Journal of Agriculture research. 70 (1): 150 - 158.
- Croitoru, S., Valentin V., Eugen M., Mihai M., and Ilie D., 2016. Determination of Subsoiler Traction Force Influenced by Different Working Depth and Velocity. Engineering for rural development, Jelgava, 25-27.05.2016.
- Dawod, K. M., and Z. A. Ilyas. 1990. Analysis ways of Agricultural researches. Ministry of higher education and scientific research, University of Mosul, book publishing administration.
- Dias Junior, M. S. 2003. A soil mechanics approach to study soil compaction and traffic effect on the pre-consolidation pressure of tropical soils. Soil Science Department, Federal University of Lavras, Brazil

- Hamid, A. A. 2012. Evaluation and performance comparison of mold board and disc plow in soil of central Iraq. *The Iraqi Journal of Agricultural Science*, 43(5): 110-121. (In Arabic).
- Hamel, G. 2012. Influence of a winged tine subsoiler combined on the performance of the work. Available at: <http://www.akimoo.com/business/architecture-and-interior-design/>. Last view on 6/10/13.
- Hilal, Y. Y. 2007. Evaluation of some parameters of subsoiler (double tine) plow performance in clay silty soil. *Mesopotamia Agric.Journal*. 35 (3).
- Hunt, D. 1980. Farm power and machine management. Iowa State. University of Iowa. U.S.A.
- Holmkvist, A. 2008. Potato yield and soil physical properties as affected by subsoiling. Bachelor project in the horticultural Science program. SLU, Alnarp.
- Hussain, A. S., A. S. Mahdi., R. A. Idan., and A. Aliwi. 2007. Effect of irrigation intervals, plowing depth, and planting date on growth and yield of corn. *Scientific Journal of Karbala University*. 5 (4): 87- 98. (In Arabic).
- Inchebron, K, S.R. Mousavi Seyedi, R. Tabatabaekoloor. 2012. Performance evaluation of a light tractor during plowing at different levels of depth and soil moisture content. *International Research Journal of Applied and Basic Sciences*. 3 (3), 626-631.
- Jabr, H. A. 2009. Studying of effect and interference soil moisture and plowing depth on the drag force resistance and total economical costs for machinery unit. (In Arabic).
- Kadam, Arjum, Chhaphane N. K., 2017. Design and Analysis of Subsoiler. *International Jour. Of Modren Trends in Eng. And Sc.*, 4(1),pp:11-14.
- Kasisira, L. L. 2005. Force modeling and energy optimization for subsoilers in tandem. University of Pretoria. PhD Thesis. Submitted in partial fulfillment of the requirement for the degree of Philosophiae Doctor in the faculty of engineering, built environment and information technology University of Pretoria, South Africa.
- Kees, G. 2008. Using subsoiling to reduce soil compaction. USDA, Forest service technology and development program, Missoula, MT, 5E52F74 Soil tilth restorer.
- Kepner, R. A., R. Bainer, and E . L. Barger. 2000. Principles of farm machinery , Implement types, field capacities, and costs. Third Edition , CBS Publishers & distributors. PP:23-47.
- Kumar, A., and T.C. Thakur. 2007. An experimental investigation into the performance of conventional and winged type subsoilers. 44. No. 2.
- Lebert, M., H. Böken, F. Glante. 2004. Soil compaction - indicators for the assessment of harmful changes to the soil in the context of the German federal soil protection. This Article was originally presented as a German contribution at the OECD Expert Meeting on 'Farm Management Indicators for Agriculture and the Environment', in Palmerston North, New Zealand.
- Leskiw, L.A., and A. Laycock. 1990. Effects of subsoiling on corn yields and soil conditions in southwestern Ontario.
- Rahman, M. H., M. Hara, and S. Hoque. 2005. Growth and nutrient uptake of grain legumes as affected by induced compaction in Andisols. *International Journal of Agriculture and biology*. 7 (5): 740 – 743.
- Rahmet-Allah, H. B. 1985. Fundamentals of metals and materials. Ministry of higher education and scientific research, University of Mosul, book publishing administration. (In Arabic).
- Ramazan, M., G. D. Khan, M. Hanif, and S. Ali. 2012. Impact of soil compaction on root length and yield of corn (*Zea mays*) under irrigated Condition. *Middle-East Journal of scientific research*. 11 (3): 382 - 385.
- Raper, R. L. and J. MacKirby. 2006. Soil compaction: How to do it, undo it, or avoid doing it. ASAE distinguished lecture. Number 30. Agric. equipment technology conference, Louisville, Kentucky, USA. pp: 1-14
- Raza, W., S. Yousaf, Y. Nadeem, and A. John. 2007. Compaction and subsoiling effects on soil properties, plant nutrient concentration, and yield of cotton. *American-Eurasian Jour. of Agric. & Environ. Sci*.2 (4):375–381.
- Solhjoui, A. A. and D. Mohammadi. 2007. Technical and economical comparison of subsoiling and conventional tillage in different irrigation frequency on sugarbeet production. *Pajouhesh & Sazandegi*.77 :182-191.
- Spoor, G. and R. J. Godwin. 1978. An experimental investigation into the deep loosening of soil by rigid tines. *Journal of Agricultural engineering Research*, 23: 243 – 258.
- Taha, F. J. 2011. Performance of chisel plow under tillage depths and tractor speed. 2011. *The Iraqi Journal of Agric. Sc*. 42 (5): 67-76. (In Arabic).
- Tahir, H. Th. 2004. Mechanical design of moldboard plow bottom through stress analysis and performance measurements. A Ph. D. Thesis in Agricultural mechanization, college of Agric. and forestry, University of Mosul. (in Arabic).
- Wang, Y., Y. Chen., S. Rahman., and J. Froese. 2009. Tillage effects on soil penetration resistance and early crop growth for Red River clay.
- Wasaya, A., M. Tahir, A. Tanveer, and M. Yaseen. 2012. Response of maize to tillage and nitrogen management. *The Journal of Animal & Plant Sciences*, 22(2): 452-456.
- Wiatrak, P., and J. Camberato. 2013. Planting Considerations. CU. Available at: http://www.clemson.edu/extension/rowcrops/corn/guide/planting_considerations.html. last visited on 2/7/2013.
- Yaye, A. M. 1998. Tractor loading by moldboard and disk plows with measuring some performance indicators under semi-arid conditions. A Ph. D. Thesis in Agricultural mechanization, college of Agric. and forestry, University of Mosul. (in Arabic).
- Zoz, F. M., and R. D. Grisso. 2003. Traction and tractor performance. ASAE distinguished lecture series. Pp: 1–4.