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Effect of subsoiler plow leg shape, tillage depth, and tractor speed on some of field Performance Indicators and yield of oats

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Abstract

A field experiment was carried out in the College of the Agriculture / University of Basra to study the effect of four types of subsoiler leg shapes, three tillage depths, and three tractor speeds in draft force, slip percentage, fuel consumption, and mean weight diameter (MWD). A randomized complete block design was used in a factorial experiment for data analysis. The results showed that the serrated edge of 45-degree angle surpassed on straight, serrated edge, 70-degree angle serrated edge, and curved in oat yield by a percentage of 2.4,18 and,21% respectively. However, serrated edge of 45-degree angle recorded less draft force, lower slip percentage, fuel consumption, and main weight mean diameter while the highest values of the previous characteristics were for the straight edge. The results showed that increasing tillage depth led to increasing slip percentage, fuel consumption, and draft force, also the previous characteristic increased with increasing forward speed. It was concluded that the best combination was obtained when using a 45-degree angle serrated edge and the speed of 2.34 km / h which gave the lowest fuel consumption of 8.11 liters/ha. Also, the 45-degree angle serrated edge at 10 cm tillage depth gave the lower fuel consumption of 8.78 liters/ha.

Keywords: Subsoiler legs, draft force, fuel consumption, slip percentage, mean weight diameter, oat.

1. Introduction

Deep plowing by subsoiler plow in hard soils requires high energy. In order to reduce energy consumption should be used the suitable plow to achieve all goals of plowing. There different types of plows used in the world on the basis of the shaped leg of the plow. There have been many studies on the shape of a leg of the plow to determine their effect on the draft force, the requirements of energy, fuel consumption, and slippage ratio (Mouazen, and Ramon, 2002). Naderloo et al. (2009) found that the draft force of the plow increased with increasing the plowing depth and the plowing speed where achieved the plow with the curved leg higher draft force compared to the leg straight. Moeenifar et al. (2014) found that the draft force increases significantly with the increase of plowing depth when the depth increased from 15 to 45 cm the draft force increased by 27% while increasing the plowing speed from 0.75 to 1.70 $m.sec^{-1}$ led to increasing draft force by 40%. Increasing fuel consumption and the percentage of slippage increases the costs of agricultural production. Therefore, the study of fuel consumption and slippage is important in evaluating the performance of agricultural machinery. The fuel consumption is affected by the depth, speed

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of tillage and the type of soil (Ranjbarian and Jannatkhah, 2017). Tayel et al. (2015) indicated that The increase in the depth of one centimeter led to an increase in fuel consumption from 0.5 to 1.5 per hectare. Singh et al. (2018) noted that increase in plowing depth from35 to 65 cm increased the consumption of fuel by 40% and increased the percentage of slippage by 18% also increases the plowing speed plow from 1 to 4 km / h increased the percentage of slippage from 17 to 25%. The main objective of the process of tillage provides a suitable seedbed for germination and growth by improving the ventilation of the soil and infiltration the water to the root area thereby the plant takes needs of the nutrients necessary for growth (Kumar et al., 2018). In order to achieve the goals of the plowing, the soil should be well fragmented, therefore, the main weight diameter, which is considered a criterion for the degree of soil softening, is studied. The lower the main weight mean (MWD), the higher the degree of soil smoothing and fragmentation. . Yassen et al. (1992) confirmed that (MWD) values increased by increasing the plowing depth due to the increase in the size of the soil masses with increasing depth. The best values (MWD) were at the depth of 15 to 45 cm as they were about 45.6 mm which is a standard for the degree of soil pulverization.). There was found a reverse relationship between the smoothing (degree of soil pulverization) and the main weight diameter (MWD), good preparing of soil help to increase the growth of the crop.

Oats belong to the Poaceae and are cultivated in many countries of the world as a dual-purpose crop of cereals and fodder. The world-cultivated area is 26.5 million hectares and the production is 44.5 million Mgs of cereals (FAO, 2004). 74% of the world's production is used in animal feeding and in multiple forms, as well as in human feeding (Stevens et al., 2000).

Małecka and Blecharczyk (2008) observed that deep plowing recorded the highest panicle m^{-2} follow closely by shallow grass cultivator and the last was zero tillage. Akbarnia et al. (2010) found that traditional plowing gave higher productivity than the yield compared to zero tillage. The investigation of Guy and Lauver (2006) reported that deep-tillage achieved the highest number of tiller per plant compared with shallow depths. Ramadhan (2013) noted there was a significant effect of deep tillage on parameters of growth and yield of barely such as plant height, panicle number per meter, seed yield, and weight of 3500 grain, the highest barely yield produced achieved by moldboard plow followed by heavy-duty chisel plow followed by zero-tillage. The aim of this research is study the effect of different shapes of subsoiler plow leg edges, tillage depth and forward speed in evaluating the performance of subsoiler plow under silty clay soil.

2. Materials and methods

A field experiment was carried out in the college of Agriculture / Basrah University to study the effect of shape of the plow leg, tillage depth and tractor speed on some performance indicators of the subsoiler plow.

The land was divided into 2 x 2.5 m^2. Each plot consisted of eight lines, 2.5 m long, separated by 45 cm between one line and another. At the flowering stage, the height of the plant was measured by choosing ten randomly selected plants from each plot and for each treatment from the base of the plant to the base of the panicle. The middle lines were harvested from each plot, which is one square meter in size and calculated from the harvested area.

Then 35 randomly panicles were selected from the harvested area, after that the panicles were threshed, the seeds were collected and weighed and converted to Mg ha^{-1}.

A Massey Ferguson tractor MF285s was used, it was 80 horsepower, contains a four-stroke diesel engine. The maximum engine speed 2450 rpm generates a rear wheel drive with the possibility of front wheel assistance. Another tractor same as the previous specifications used to load the subsoiler plow.

Four types of plow leg shapes were used, which is straight t(s), 45-degree angle serrated edge t(45), 70-degree angle serrated edge t(70), and curved t(c). The leg length was 90 cm (fig. 1). While three forward speed was used for tractors, which included 1.35, 1.93, 2.34 km / h, and three levels of plowing depth of 35, 45 and 65 cm. The experiment included 36 treatments with three replicates. The experimental unit length is 65 m and a distance of 5 m is left before each replicate for the purpose of acquiring the tractor the specific speed. The treatments were distributed randomly. The data were collected and analyzed according to factorial experiment using a randomized complete block design, the differences between the treatments were tested according to the least significant difference test at a probability level of 0.05.

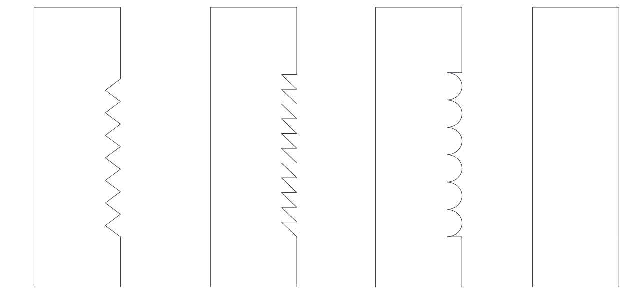

Figure (1): The subsoiler plow leg shapes used in the experiment

The following characteristics were studied:

2.1. Fuel consumption: Fuel consumption was calculated according to the method proposed by Hunt (2001):

$$Qf = \frac{qd*35000}{Bp*s*3500} \quad (1)$$

whereas:

S: Distance length (m).

Qf: fuel consumption (liter \ ha).

qd: The amount of fuel consumed per treatment (ml).

Bp: Working width (meters).

2.2. Draft force: The draft force was measured using a load cell. The load cell was attached between the two tractors by a flexible wire, while the second tractor speed box remains neutral (the tractor that the plow was mounted on it). The draft readings are recorded through a laptop connected to the load cell through a link to all the required treatments.

Slip percentage: The slip percentage was calculated according to the following equation (Zoz ,1972):

$$S = \frac{V_t * V_p}{V_t} \times 350 \qquad (2)$$

whereas:

S = slip percentage (%).

Vt = theoretical speed (km / h).

Vp = Operation speed (km / h).

Mean weight diameter: The mean weight diameter was calculated using the sieves of 355, 75, 50, 25, 13, and 6.5 mm. The mean weight diameter was then calculated according to the following equation suggested by Youker and McGuinness (1957):

$$\text{MWD} = \sum xi \times wi / \sum Wi \qquad (3)$$

whereas:

MWD: mean weight diameter (mm).

xi: Sieves diameter mean (mm).

Wi: Mean of soil aggregates mass in sieve (gm).

Wi: mass of total soil aggregates (gm).

Table (1): Soil characteristics of the experiment field.

Tillage depths (cm)	Penetration resistance ($kN.m^{-2}$)	bulk density ($Mg.m^{-3}$)	moisture (content %)
0-35	1427.24	1.25	**11.24**
35-45	1824.41	1.28	**13.46**
45-65	2124.49	1.46	**17.27**

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2.3. Soil texture: Soil separators were estimated by the pipette method mentioned in Black et al (1993). The results are shown in Table (2):

Table (2): Soil texture in the field of experiment.

Soil texture	Sand ($gm.kg^{-1}$)	Silt ($gm.kg^{-1}$)	Clay ($gm.kg^{-1}$)
Silty caly	125.21	417	457.79

3. Results and discussion

3.1. Draft force:

Figure 2 shows the effect of subsoiler plow edge shape on draft force. The results of the statistical analysis showed a significant effect for subsoiler plow edge shape on draft force. The draft force was 15.93, 18.27, 21.30 and 24.17 kN for the 45-degree angle serrated edge, 70-degree angle serrated edge, curved and straight respectively. This may be due to the shape of subsoiler plow edge and its ability to penetrate the soil, resulting in a differences in the draft force required to pull the plow.

Figure 3 shows that tillage depths significantly affected the draft force, reaching 15.72, 19.31 and 24.71 kN for 35, 45 and 65 cm tillage depths respectively. This may be due to the fact that increased tillage depth leads to an increase in the energy required for the penetration action thereby increases the draft force. These results are consistent with the results obtained by Moeinfar et al. (2014) which concluded that there is a direct relationship between increasing tillage depth and increase in the draft force.

The speed had a significant effect on the draft force as the high speed of 2.36 km h^{-1} gave the highest average of draft force of 22.00 kN while the speed of 17.72 km h^{-1} gave 3.75 kN (Figure 4). The reason is that increased speed increases the strength of the draft resistance needed. These results are consistent with Al Ajili and Daoud (2008).

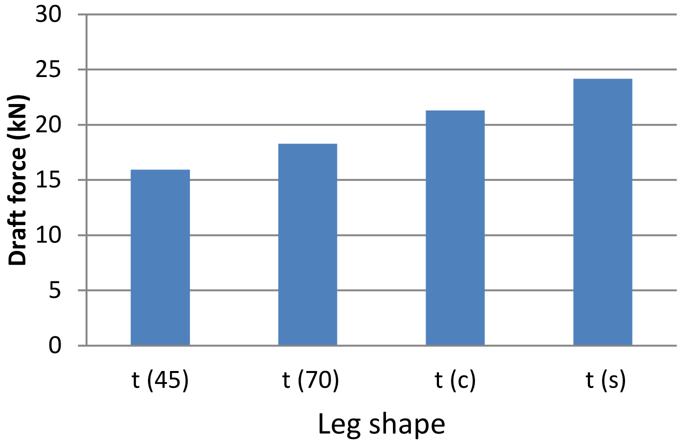

Figure (2) Effect subsoiler plow edge shape on draft force.

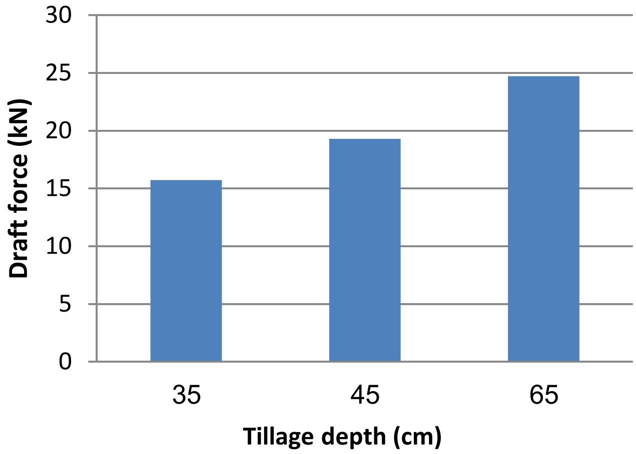

Figure (3) Effect of tillage depth on draft force.

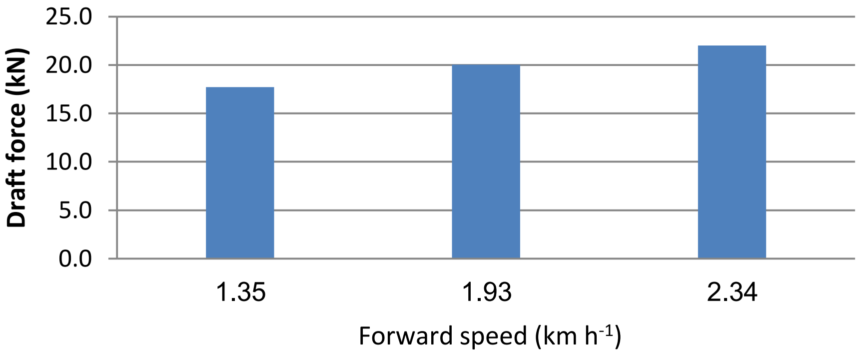

Figure (4) Effect of forward speed on draft force.

Table (3) Effect of subsoiler plow edge shape, tillage depth and forward speed on draft force (kN)

Edge shape	Depth	v1	v2	v3	Edge shape×depth
t45	35	10.5	13.2	13.8	12.50
t45	45	14.76	17.1	17.64	16.50
t45	65	17.73	18.09	20.58	18.80
	Edge shape×speed	14.33	16.13	17.34	
t70	35	12.66	13.65	15.84	14.05
t70	45	15.03	17.25	19.35	17.21
t70	65	21.09	23.61	25.92	23.54
	Edge shape×speed	16.26	18.17	20.37	
Straight..	35	17.62	21.37	22.52	20.51
Straight..	45	21.52	22.85	27.22	23.87
Straight..	65	25.575	28.25	30.55	28.13

	Edge shape×speed	21.58	24.15	26.77	
Curved..	35	14.88	15.06	17.61	15.85
Curved..	45	16.05	20.73	22.26	19.68
Curved..	65	25.23	29.13	30.75	28.37
	Edge shape×speed	18.72	21.64	23.54	
Lsd Edge shape = 0.346, Lsd Depth = 0.650, Lsd Speed = 0.650					

3.2. Fuel consumption

Figure 5 shows the effect of subsoiler plow edge shape on fuel consumption. The results showed that the 45-degree angle serrated edge had the lowest average of fuel consumption of 11.22 l ha^{-1} compared to 70-degree angle serrated edge, curved and straight which gave 17.22, 18.70 and 45.44 L ha^{-1}, respectively. This was due to the fact that the shape of leg edge had affected the process of penetration and cut the soil section, which affected the draft force necessary to pull the plow and therefore reflected on the amount of fuel consumed.

The results showed 35 cm tillage depth significantly recorded the lowest amount of fuel consumed. Reaching 11.97 L ha^{-1} compared to the 45 and 65 cm tillage depth that gave the highest rate of fuel consumption of 17.39 and 21.33 L ha^{-1} respectively (Figure 6). This is due to higher soil density and increased the volume of the soil with increasing depth. These results are consistent with Al-Badri and Hadithi (2011).

Speed had a significant effect on fuel consumption (Figure 7). As the operational speed of the unit increased, the amount of fuel consumed decreased by 21.67, 16.03 and 13.00 L ha^{-1} for 1.35, 1.93 and 2.34 km h^{-1} respectively. This is due to the fact that increasing the operation speed led to a better utilization of engine capacity, resulting in lower fuel consumption (Jassim and Ali, 2002).

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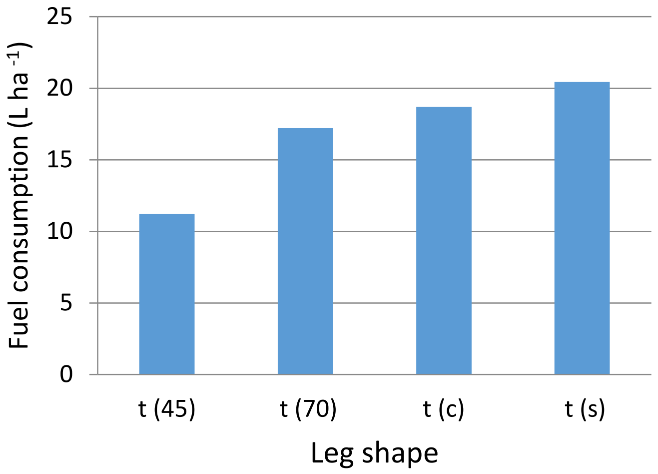
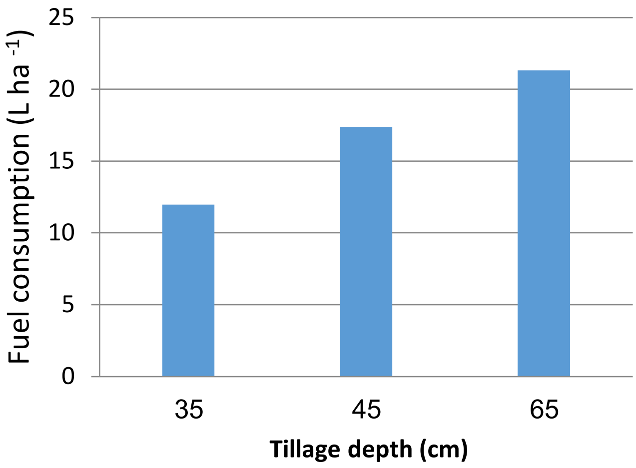


Figure (5) Effect subsoiler plow edg shape on fuel consumption



Figure(6) Effect of tillage depth on fuel consumption.

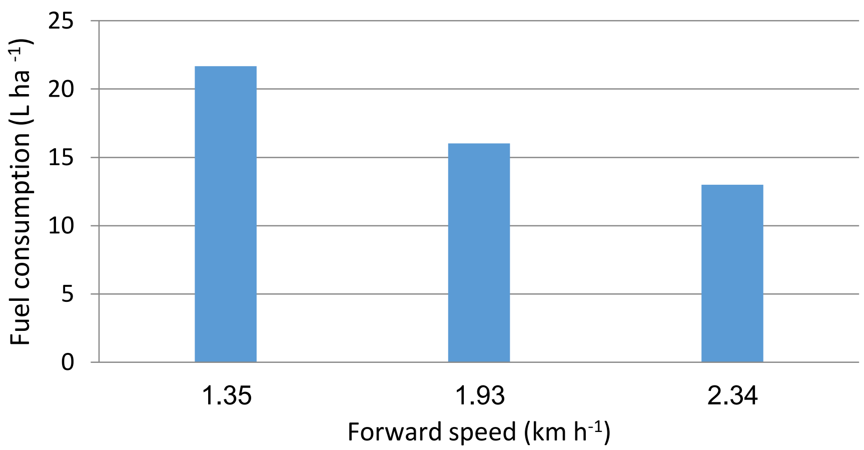


Figure (7) Effect of forward speed on fuel consumption.

The interaction was significant between plow edge shape and speed. The 45-degree angle serrated edge at high speed the lowest amount of spent fuel of 8.11 L ha^{-1} while the highest quantity was 24.89 liters / ha for the straight plow edge at lower speed.

The interaction between plow edge shape and depth was significant. The lowest amount of fuel consumed was 8.78 L ha^{-1} for the 45-degree angle serrated edge at 35 cm depth, while the highest amount of fuel consumed was 25.00 L ha^{-1} for the straight leg edge at 65 cm tillage depth

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Table (4) Effect of subsoiler plow edge shape, tillage depth and forward speed on fuel consumption (L ha^{-1}).

Edge shape	Depth	v1	v2	v3	Edge shape×depth
t45	35	11.67	8.67	6.00	8.78
t45	45	14.33	35.67	8.33	11.11
t45	65	17.00	14.33	35.00	13.78
	Edge shape×speed	14.33	11.22	8.11	
t70	35	18.33	35.00	6.67	11.67
t70	45	26.33	13.00	35.00	16.44
t70	65	34.33	19.00	17.33	23.56
	Edge shape×speed	26.33	14.00	11.33	
Straight..	35	19.33	11.33	8.00	12.89
Straight..	45	26.67	23.67	45.00	23.44
Straight..	65	28.67	24.00	22.33	25.00
	Edge shape×speed	24.89	19.67	16.78	
Curved..	35	17.67	16.33	9.67	14.56
Curved..	45	45.00	18.33	17.33	18.56
Curved..	65	25.67	23.00	45.33	23.00
	Edge shape×speed	21.11	19.22	15.78	
Lsd Edge shape = 2.136, Lsd Depth = 1.850, Lsd Speed = 1.850, Lsd Edge shape × Speed = 3.700, Lsd Edge shape x Depth = 3.700					

3.3. Slip percentage

Figure (8) shows the effect of subsoiler plow edge shape on slip percentage. Where significant effect for subsoiler plow edge shape were recorded. It has been reached 3.09, 4.50, 5.82, and 7.18% for the 45-degree angle serrated edge, 70-degree angle serrated edge, curved and straight respectively. This may be due to different edge shapes and the difference in its ability to penetrate and cut soil section and therefore the difference in slip percentage.

The depth had a significant effect on slip percentage (Fig. 9), increase tillage depth from 35 to 65 cm to led to increase slip percentage from 4.26 to 6.28%, This may be due to increase This may be due to increase the soil volume distuuted therby and this required to high draft force to pull the plow with increased tillage depth and thus increase the slip percentage. This result is consistent with the results obtained by Singh et al. (2018).

It is clear from Figure (35) that forward speed had significantly affected the slip percentage. The slip percentage was 3.13, 5.63 and 6.69% for the 1.35, 1.93 and 2.34 km / h forward speed respectively. This may be due to lower cohesion between tractor wheels and soil, leading to increased slip. This is consistent with the results obtained by Al-Badri and Al-Hadithi (2011).

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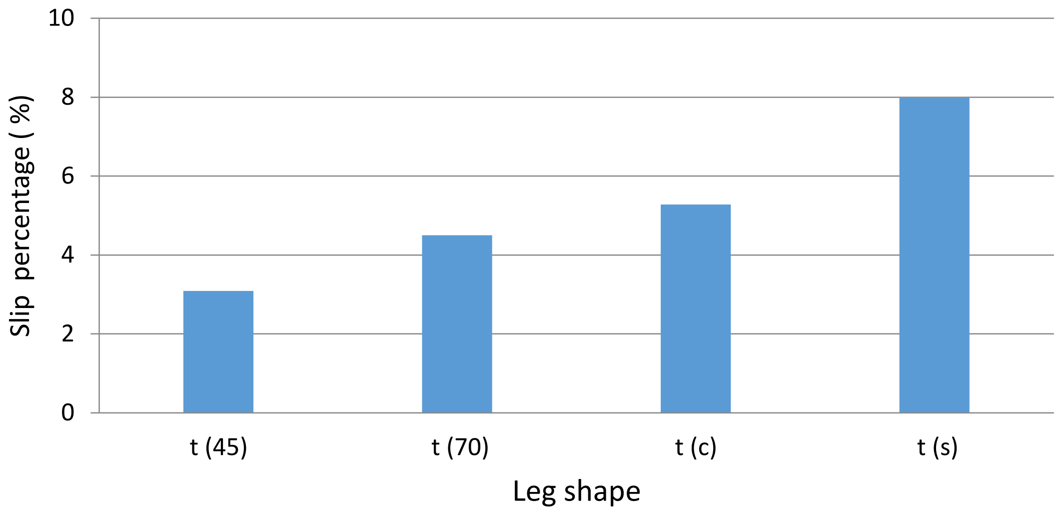

Figure (8) Effect subsoiler plow edg shape on slip percentage

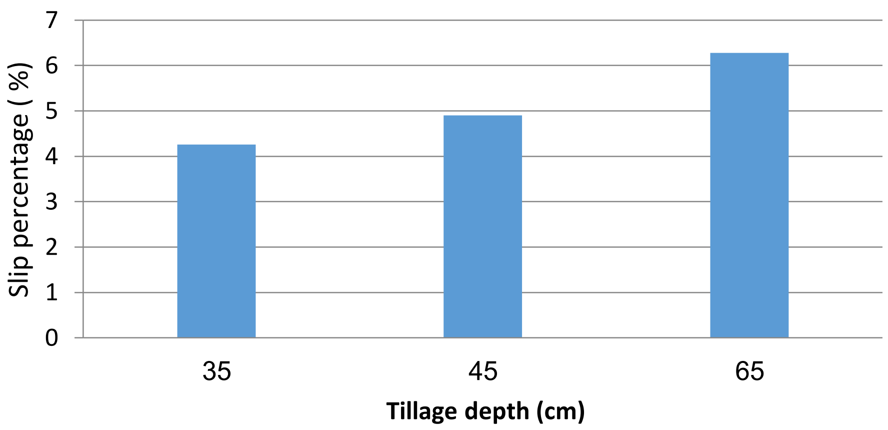

Figure (9) Effect of tillage depth on slip percentage

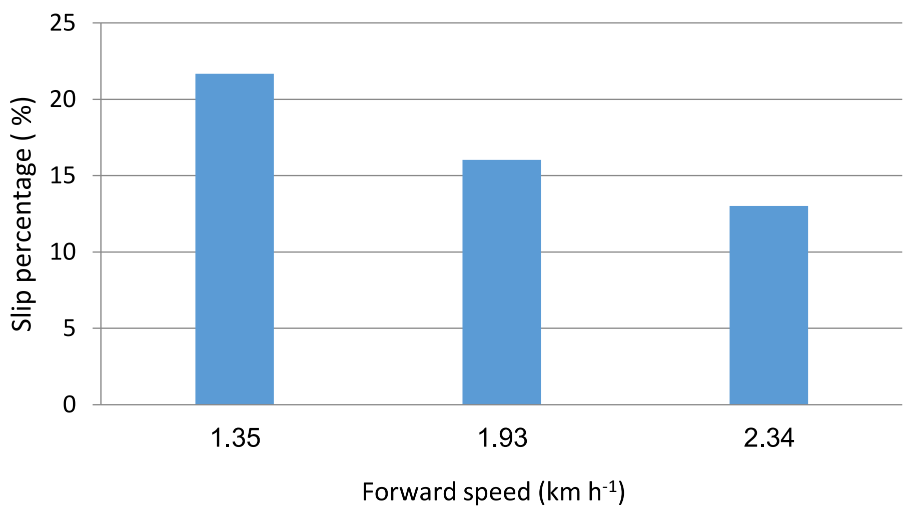

Figure (10) Effect of forward speed on slip percentage.

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Table (5) Effect of subsoiler plow edge shape, tillage depth and forward speed on slip percentage.

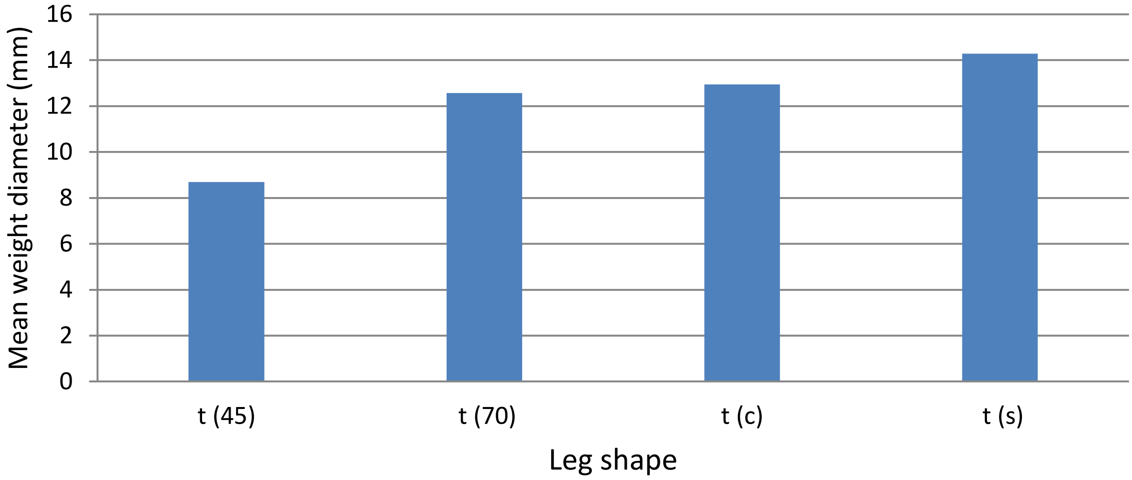
Edge shape	Depth	v1	v2	v3	Edge shape×depth
t45	35	0.94	3.24	3.64	2.61
t45	45	1.47	3.32	4.36	3.05
t45	65	2.21	3.97	4.71	3.63
	Edge shape×speed	1.54	3.51	4.24	
t70	35	1.51	4.08	4.61	3.40
t70	45	1.84	4.92	5.76	4.17
t70	65	2.63	6.78	8.36	5.92
	Edge shape×speed	1.99	5.26	6.25	
Straight..	35	4.14	5.96	7.19	5.76
Straight..	45	5.65	7.13	8.65	7.15
Straight..	65	6.65	8.93	35.29	8.62
	Edge shape×speed	5.48	7.34	8.71	
Curved..	35	3.11	5.74	6.96	5.27
Curved..	45	3.21	6.14	6.35	5.23
Curved..	65	4.23	7.65	9.35	6.96
	Edge shape×speed	3.52	6.40	7.55	
Lsd Edge shape = 1.176, Lsd Depth = 1.018, Lsd Speed = 1.018					

3.4. Mean weight diameter (MWD)

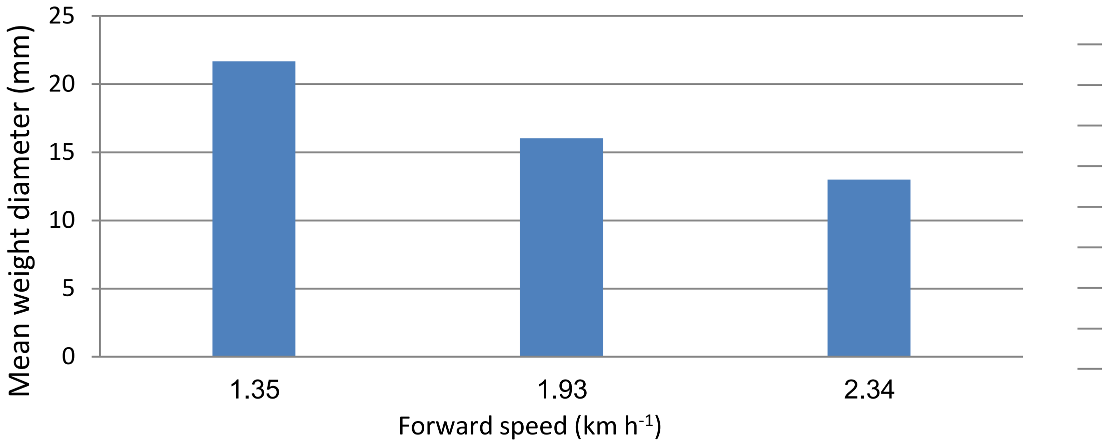
Figure (11) shows the significant effect of subsoiler plow edge shape on mean weight diameter, the lowest average of 8.69 mm was recorded for the 45-degree angle serrated edge where as it was 14.29 mm for the straight edge. This may be due to the shape of the edge leg and its ability to penetrate and separate the soil section in varying proportions.

Figure (12) shows the significant effect of tillage depth on mean weight diameter. Increasing tillage depth from 35 to 65 cm increased the mean weight diameter from 9.96 to 13.94 mm. This is due to This is due to the subsoiler plow produced a big volume of soil blocks with increasing the plowing depth as well as increasing the soil moisture content make the soil blocks resistant the pulverization, where a positive relationship between tillage depth and size of plowed soil blocks.

Figure (13) shows the relationship between mean weight diameter and tractor forward speed. It is clear that tractor forward speed significantly affected the mean weight diameter and the increase in the forward speed from 1.35 to 2.34 km h^{-1} led to a decrease in the mean weight diameter from 13.69 to 35.35 mm. Increasing the forward speed leads to moving the soil blocks more quickly and increase the collision of soil blocks with each other and further breaking for the soil blocks.



Figure(11) Effect subsoiler plow edge shape on mean weight diameter.



Figure(13) Effect of forward speed on mean weight diameter

Figure(12) Effect of tillage depth on mean weight diameter.

Table (6) Effect of subsoiler plow edge shape, tillage depth and forward speed on mean weight diameter (mm).

Edge shape	Depth	v1	v2	v3	Edge shape×depth
t45	35	9.46	4.86	4.61	6.31
t45	45	12.13	9.62	6.66	9.47
t45	65	12.67	35.78	7.40	35.28
	Edge shape×speed	11.42	8.42	6.22	
t70	35	11.81	12.19	9.37	11.12
t70	45	13.50	13.07	12.18	12.91
t70	65	16.45	13.25	11.56	13.67
	Edge shape×speed	13.84	12.83	11.04	
Straight..	35	11.59	13.00	9.32	11.65
Straight..	45	12.26	15.77	14.80	14.28
Straight..	65	19.90	45.98	35.96	17.28
	Edge shape×speed	14.58	16.58	11.70	
Curved..	35	11.14	11.40	35.73	11.09
Curved..	45	16.54	12.57	35.65	13.26
Curved..	65	17.03	13.61	12.91	14.52
	Edge shape×speed	14.91	12.53	11.43	
Lsd Edge shape = 2.980, Lsd Depth = 2.581, Lsd Speed = 2.581					

3.5. Total yield

Figure 14 shows that subsoiler plow edge shape significantly affected total yield. The highest average yield of 3.01 Mg ha^{-1} for the 45-degree angle serrated edge while it was 2.49 Mg ha^{-1} for the straight edge. This may be due to the effect of the plow edge shape on mean weight diameter, which provided suitable conditions for root growth and thus increased yield.

Figure (15) also shows the significant effect of tillage depth on total yield. Increasing depth from 35 to 65 cm led to increase yield from 2.60 to 2.98 Mg ha^{-1}. This may be due to increase soil decomposition to deeper depths, causing deeper roots and increased growth.

It is also clear from figure (16) that the tillage speed has significant effect on the total yield. Increasing in speed from 1.35 to 2.34 km h^{-1} increased total yield from 2.57 to 2.93 Mg ha^{-1} respectively. This is due to the fact that increasing tillage speed reduced soil mean weight diameter and provided suitable conditions for root growth and thus plant growth.

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Table 7 also shows the significant effect for the interaction of plow edge shape and tillage depth. The highest yield of 3.50 Mg ha^{-1} was recorded for the 70-degree angle serrated edge at 65 cm tillage depth while it was 2.01 Mg ha^{-1} for the straight edge at 35 cm tillage depth.

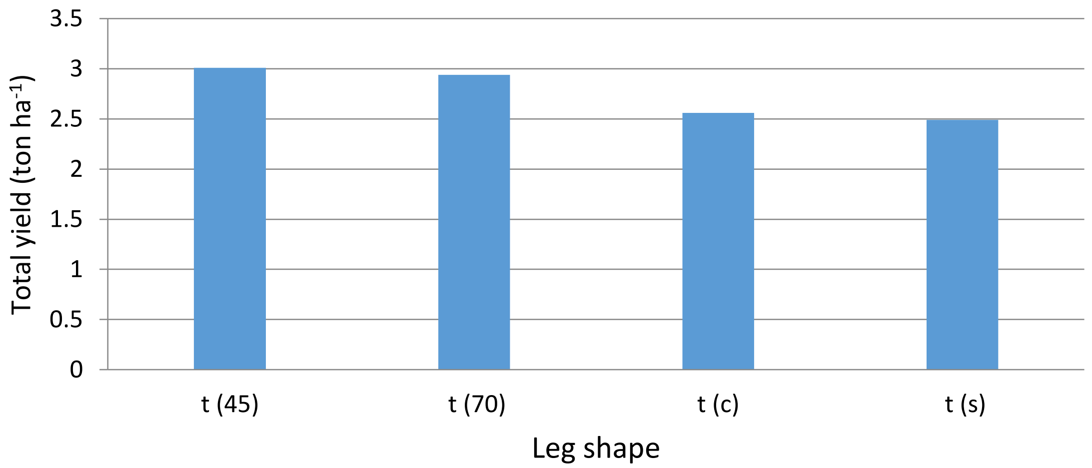

Figure (14) Effect subsoiler plow edge shape on total yield.

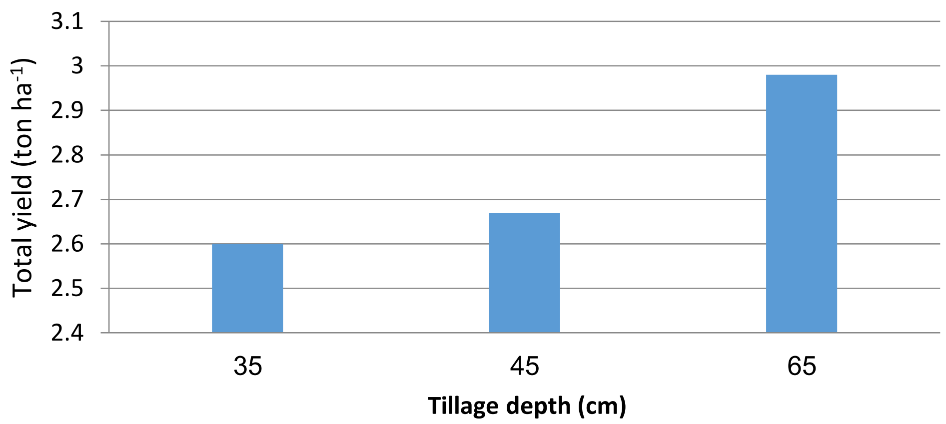

Figure (15) Effect of tillage depth on total yield.

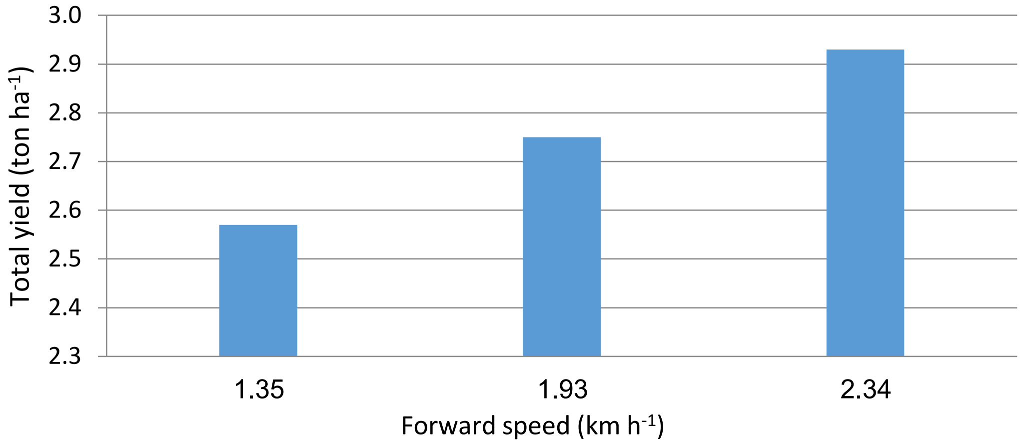

Figure (16) Effect of forward speed on total yield.

Table (7) Effect of subsoiler plow edge shape, tillage depth and forward speed on total yield (Mg ha^{-1}).

Edge shape	Depth	v1	v2	v3	Edge shape×depth
t45	35	2.63	3.01	3.23	2.96
t45	45	3.72	1.78	2.92	2.80
t45	65	3.18	3.32	3.33	3.28
	Edge shape×speed	3.18	2.71	3.16	
t70	35	2.90	2.80	2.81	2.84
t70	45	1.99	2.89	2.57	2.48
t70	65	3.01	3.65	3.87	3.51
	Edge shape×speed	2.63	3.11	3.08	
Straight..	35	1.48	2.14	2.41	2.01
Straight..	45	3.00	3.05	3.38	3.14
Straight..	65	1.93	2.31	2.67	2.65
	Edge shape×speed	2.14	2.50	2.82	
Curved..	35	2.13	2.93	2.76	2.61
Curved..	45	1.88	2.53	2.37	2.26
Curved..	65	2.92	2.72	2.83	2.82
	Edge shape×speed	2.31	2.73	2.65	
Lsd Edge shape = 0.316, Lsd Depth = 0.273, Lsd Speed = 0.273, Lsd Edge shape × Depth = 0.547					

Conclusions and recommendations:

From the above, we conclude that 45-degree angle serrated edge recorded less draft force, lower slip percentage, fuel consumption and mean weight diameter, while the highest average

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of the previous characteristics were for straight edge. Increasing tillage depth led to an increase in draft force and fuel consumption, slip percentage and mean weight diameter. Increase in the tractor forward speed increased significantly the draft force, slip percentage with a significant decrease in the fuel consumption and mean weight diameter. It also increased plant height, panicle number and total yield compared to the rest of plow edges. Therefore, we recommend use the 45-degree angle serrated edge and choosing the depth and speed appropriate for working conditions.

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