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DETERMINATION OF POWER AND ENERGY REQUIREMENTS OF SUBSOILER PLOW WITH DIFFERENT SHAPES OF LOCALLY MANUFACTURED SHANKS

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Abstract

The experiment was conducted at the season of 2019-2020 in an agricultural field located within Wana area in a mixture of silty loam soil. The study included three factors ; the moisture content at two levels (10.35 and 16.75%), forward speed (2.11, 3.11 and 4.90 km/h) and three shapes of shanks of the subsoiler plow were used of (straight, curved and arcuate type). The impact on drawbar power, fuel consumption, slipping percentage, specific resistance and specific energy were studied. The study was carried out according to the complete random blocks design within a split plots system of three replicates. The results were tested by multi-range Dunkin method $P < 0.05$ in order to evaluate the significance of the differences between the means. The results showed that two traits; drawbar power and the percentage of slippage, impacted by moisture content. Whereas all studied criteria were significantly affected by the forward speed and shape of the shanks.whereby the curved shank excelled in recording the lowest values in the drawbar power and slippage and specific resistance and specific energy. Whereas the moisture content 16.75% exceeded in recording the lowest values for the previously mentioned criteria. The speed of 4.90 km/h recorded the lowest values for fuel consumption. The speed of 2.11 km/h recorded the lowest values for the remaining criteria.

Key words: Power, energy requirements, subsoiler plow, manufactured shanks

Introduction

One of the most important factors for the advancement of the agricultural sector is to increase productivity per unit of area, improve the quality of production, and reduce its cost. to achieve these goals collectively, the means of production must be exploited according to the studied scientific principles , thus choosing the most appropriate ones among them that is appropriate to the conditions of the region. One of the most important means among agricultural production, is agricultural machinery which is considered as the spine. The goal of using a subsoiler plow is to break the solid layer in order to ease water permeability and root penetration (Gill and Vanden Berg 1968). The design and manufacture of tillage equipment, and energy requirements during operation are a major concern for engineers and farmers, because this has a very important impact on efficient plowing operations. Studies have been useful in using equipmen to measure and evaluate forces, energy requirements, along with the impact of the design on tillage and soil characteristics (odey and manuwa 2016; odey 2018), Talabani and Saad (2018) stated that the moisture content has an influence in the percentage of slippage when using the triple disc plow whereby The moisture content 13%, recorded a slippage rate of 15.9%, whereas the moisture content 17% recorded slippage, 9.9% and the moisture content 21%, recorded the highest value which was 19.7%.

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Tupper (1977) stated that the slippage percentage decreased by 43.4% when using a curved shank compared to the straight shank.

Rajab and Al-Hilal (2017), while studying a two-blade subsoiler, explained that the percentage of slippage increased with an increase in the forward speed, whereby the speed 3.5 km/h, recorded a slippage value of 32.5%, while the speed 2.37 km/h recorded the lowest value of 17.81%, due to increasing the speed lead to increases the sheer force in the soil, and consequently, it increases the rotational resistance thus the slippage percentage increases. Al-Jarrah (1998) stated that the increase in the practical speed of tractors from 5.68 to 7.71 to 9.15

km/h led to decreases the fuel consumption from 8,13 to 7,08 then to 6,46 liters/ha, and the reason to this, is that the increase in practical speed optimizes the utilization of the engine capacity, and reduces the time required to complete the process. Tahir and Jawad (2017) illustrated In a study that the effect of forward speed on fuel consumption and energy requirements for different types of tractors in loamy soil, that the increase in front speed of the tractor from 3.42 to 6.24 km/h led to a decrease in the average of fuel consumption from 20.83 l/ha to 17.68 l/ha.

Nichols and Reaves, (1958) said in a study conducted on the shape of the subsoiler shanks at the National Tillage Machines laboratory that the specific energy of drawing with curved shank was 7 to 20 percent less than straight shank. Raper and Sharma (2004) indicated that the effect of moisture content on energy in a silty sandy soil in the USDA-ARS laboratory of two contradictory conditions of soil which are completely saturated and the other is very dry. The study also included the condition of medium moisture and dry soils. The results showed that the very dry soil recorded the highest values of Energy whereas the dry moisture content recorded reducing in energy value by 25%-32% and there moreover no significant differences between them and the rest of the moisture contents except for very dry moisture. Nassir *et al.,* (2016) stated that the drawbar power in the chisel plow increased with increasing forward speed as the speed of 0.41 m/s recorded the lowest value of drawbar power of 3.43 kW whereas the speed of 0.80 and 1.30 m/s recorded 9.78 and 18.16 kW respectively, Raper (2007) showed when comparing the specific resistance to drawing of three types of shanks which are arcuate, curved and straight. The strait shank at the depth of 40 cm recorded the highest value of 165 kN/m^2, as for the curved and arcuate shank recorded 100.1 and 111.1 kN/m^2 respectively. This study was conducted to evaluate the field performance of a subsoiler plow using Different types of shanks at different moisture content and forward speeds.

Materials and Methods

The experiment was carried out in the agricultural season 2019-2020 in an agricultural field located within wana village in the Kara Kharab district 60 km northern of Mosul. The field was characterized by its flat surface, high values of bulk density and penetration resistance. Furthermore the field was irrigated by axial sprinklers.wheat was planted in the previous season. The total area of the field was 50000 m^2. A texture of silty loam soil. The area used to implement the experiment was 5000 m^2. The study included three factors which is the moisture content (10.35 and 16.75%) achieved within the main plots. Forward speed (2.11, 3.11 and 4.90 km/h) represented the split plots. The shape of the shanks (straight, curved and arcuated) represented sub- split plots. the number of treatments were 18 with three replications per treatment thus 54 experimental units of 30 meters length per experimental unit. The study was carried out according to the design of the randomized complete block Design (RCBD). The results were tested by Duncan multi-range method $P < 0.05$ to test the differences significance among the means (Dawood and Elias 1990).

The soil moisture content was measured in the field by Extech MO750 Soil Moisture Meter at four depths with 6 replications per depth.

The tractor New HOLAND TD95 98 hp was used of power source and A 1998 Massey Ferguson tractor, Iranian made, was used to suspend the subsoiler plow.

a b c

types of shanks used in the study- a: Conventional straight shank. b: arcuated shank, c: curved shank

The pulling force was measured by a dynamometer, which was connected between the front and rear tractor with the help of a flexible wire, due to the lack of a device that measures the pull force between the plow and the tractor directly, the reading was taken while the indicator of the device was in a stable condition. The amount of fuel consumed by the cylinder is calculated and by the addition method.

The studied characteristics were calculated through the following relationships:

Studied traits:

Drawbar Power (kW)

The power required to draw was calculated according to the following equation, Ezzat and Lotfi (1979):

DP = PF * VP

whereas:

DP: drawbar power (KW)

PF: Pulling force (kN)

VP: practical speed (m/sec)

Fuel Consumption (L/h)

The following equation was adopted to calculate the fuel consumption for each stage of the experiment per each unit. Ayat (1998):

Fc = (Fca / Tp) * 3.6

Whereas:

Fc: amount of fuel consumed per unit time (liter/hour).

Fca: The amount of fuel consumed (ml).

Tp: actual time completion for a treatment (sec).

Slippage Percentage (%):

S% = ((Vt - Vp) / Vt) * 100

whereas:

S: slippage percentage (%).

Vt: theoretical speed (km / h).

Vp: practical speed (km / h).

Specific Resistance :

It was calculated from the following equations Gill and Vanden Berg (1968):

S.R. = F / A

whereas :

SR: specific resistance (kN /m^2)

F: drawing force (kN)

A: disrupted area (m^2)

Specific Energy :

It was calculated from the following equation Khader (2008).

SEV = DP / V

Whereby.

SEV: specific energy (kJ / m^3)

DP: drawbar power (kW).

V: volume of the disrupted soil (m^3 / sec).

Results and Discussion

Table 1 shows that there were significant differences of the moisture content influence on the character of the drawbar power. The moisture content exceeded 16.75% in recording the lowest value of this character value of 11.68 kW, whereas the moisture content of 10.35% recorded the highest value of 12.67 kW, due to the fact that the pulling force increases according to less moisture content than the ideal limit, due to the increase in the penetration resistance of the soil. Hence a large pulling force is needed to accomplish the action of penetration and breaking the soil, thus because the pulling force is a derivative among the compounds of the drawbar power, hence it is increased by increasing it. Obviously, the effect of the forward speed have a significant differences.whereby the drawbar power increases rapidly due to the increase in the pulling force and the speed of 2.11 km/h exceeded significantly in recording the lowest value of the drawbar power of 7.46 kW. the speed of 3.11 km/h recorded 11.44

Table 1: The effect of the studied factors and their interaction on the drawbar power (kW).

Moisture content (%)	Shank type	Forward speed (km/h)			Interaction between moisture content and shank type	
		2.11	3.11	4.90		
10.35	Straight	9.10	13.29	20.29	14.23	
	Curved	7.28	10.59	16.70	11.52	
	Arcuate	7.20	11.74	17.83	12.26	
16.75	Straight	8.67	12.70	19.64	13.67	
	Curved	5.82	9.84	14.10	9.92	
	Arcuate	670	10.74	17.22	11.46	
Interaction between moisture content and speed	10.35%	7.86	11.88	18.27	Mean of moisture content	12.67a
	16.75%	7.06	11.00	18.98		11.68b
Interaction between speed and shank type	Straight	8.89	13.00	19.96	Mean of shank type	13.95a
	Curved	6.55	10.21	15.40		10.72c
	Arcuate	6.95	11.10	17.53		11.86b
Mean of forward speed		7.46c	11.44b	17.63a		

kW, while the speed of 4.90 Km/h recorded the highest value of 17.63 kW, due to the fact that the increase in the forward speed, leads to an increase in the power required to compensate for the soil blocks, thus this leads to an increase in the force of the pulling, which in turn increases the power of drawbar, (Taha and Taha 2019), (Nasser *et al.,* 2016) And (Khairi *et al.,* 2019). Obviously there is a significant effect of the shape of the shanks on the drawbar power. the curved shank excelled significantly and recorded the lowest value of the drawbar power of 10.72 kW , followed by the arcuate shank that recorded 11.86 kW. then strait shank recorded the highest value of power needed of 13.95 kW, that's may be due to the fact that the horizontal distance between The blade/nose of the plow placed on the foot of the plow and the vertical level of the shank are greater in the design of the curved shank than other types, which causes soil to be broken by the blade/weapon before it reaches the shank. Thus when it reaches the shank, It leads to reducing the force and power of the required to draw. Whereas the straight shank, The plow works to cut and raise the soil due to the sliding movement of the soil particles on the shank, which requires a large drawing capacity. The Interaction between moisture content and speed did not have a significant impact on the power of drawbar a. the moisture content of 16.75% with the speed of 2.11 km/h. recorded The lowest value of the drawbar power of 7.06 kW, while the moisture content 10.35% with the speed of 4.90 km/h recorded the highest value of the drawbar power of 18.27 kW for the same reasons mentioned above. the character of the drawbar power was not affected by the Interaction between the moisture content and the shape of the shank. The curved shank with the moisture content 16.75%, recorded the lowest value of the drawbar power of 9.92 kW, followed by the arcuate shank with the same moisture content of 11.46 kW, while the straight shank with the moisture content of 16.75% and 10.35% recorded the highest values of 13.67 and 14.23 kW, respectively. The interaction between the shape of the shank and the forward speed did not have any significant effect. The curved shank with the speed 2.11 km/h recorded the lowest value of the drawbar power of 6.55 kW, while the straight shank with the speed of 4.90 km/h recorded the highest value of the drawbar power of 19.96 kW for the same reasons Mentioned previously. The triple interaction of the studied factors did not have any significant effect. The straight shank with moisture content of 10.35% and speed 4.90 km/h recorded the highest value of the drawbar power of 20.29 kW.The curved shank with moisture content of 16.75% and speed of 2.11 km/h recorded the lowest value of the drawbar power of 5.82 kW.

Table 2, it's obvious that there were no differences with the effect of moisture content on fuel consumption as the moisture content of 16.75% recorded the lowest value for fuel consumption of 9.80 L/h. The reason for that may be due to the force required to pull, the percentage of slippage and the power required to cause the soil penetration action to be less than the moisture content of 10.35% which recorded 10.56 L/h Rajab (2005).

We also notice a significant effect of forward speed on fuel consumption as the speed of 4.90 km/h significantly exceed in recording less fuel consumption of 8.80 L/h while the speed of 2.11 km/h recorded the highest value of fuel consumption of 11.98 L/h. The speed of 3.11 km/h recorded 9.77 L/h due to the increase in speed lead to an optimal utilization of the engine's power within the permissible limits and reducing the time period to complete the work, Thus the fuel consumption decreases Aljarrah (1998) and Taher and Jawad (2017).

As for the effect of the shank shape on the character of fuel consumption, it's obvious that the significant superiority of the arcuate shank in recording the lowest value for fuel consumption of 9.52 L/h that which was not different from the curved shank that recorded 9.73 L/h, whereas the straight shank recorded the highest value for fuel consumption of 11.31 L/h This is due to the fact that the required pulling force and power is high in the straight shank in comparison with the curved and

Table 2: Effect of the studied factors and their interaction on the fuel consumption (L/h).

Moisture content (%)	**Shank type**	**Forward speed (km/h)**			**Interaction between moisture content and shank type**	
		2.11	3.11	4.90		
10.35	Straight	13.85	12.05	9.65	11.85	
	Curved	12.05	9.16	8.75	9.99	
	Arcuate	11.23	10.01	8.34	9.86	
16.75	Straight	13.16	10.006	9.14	10.77	
	Curved	11.40	8.57	8.43	9.46	
	Arcuate	10.21	8.84	8.49	9.18	
Interaction between moisture content and speed	10.35%	12.38	10.41	8.91	Mean of moisture content	10.56
	16.75%	11.59	9.14	8.69		980
Interaction between speed and shank type	Straight	13.51	11.02	9.40	Mean of shank type	11.31a
	Curved	11.72	8,87	8.59		9.73b
	Arcuate	10.72	9.42	8.41		9.52b
Mean of forward speed		11.98a	9.77b	8.80c		

arcuate shanks.

As for the effect of interaction between the moisture content and the forward speed, there were no significant differences, whereby the speed of 2.11 km/h with the moisture content 10.35% recorded the highest value for fuel consumption of 12.38 L/h, while the moisture content of 16.75% with the speed of 4.90 km/h recorded the lowest value for fuel consumption of 8.69 L/h.

The effect of interaction between the moisture content and the shape of the shank on the fuel consumption, it's clear that there were no significant differences, as the straight shank recorded the highest value of fuel consumption with the moisture contents of (16.75 and 10.35)% reached (10.77 and 11.85) L/h, respectively, while the arcuate shank with moisture content of (16.75)% recorded the lowest value of 9.18 L/h.

There were no significant differences by the effect of interaction between the forward speed and the shape of shanks. The speed of 4.90 km/h recorded the lowest value for fuel consumption with the arcuate shank, of 8.41 L/h, while the speed of 2.11 km/h with the straight shank recorded the highest value for fuel consumption of 13.51 L/h.

The triple interaction for the studied factors did not have a significant effect on the fuel consumption trait , whereby the straight shank with the speed of 2.11 km/h and the moisture content of 10.35% recorded the highest value for fuel consumption of 13.85 L/h while the moisture content of 10.35% with the speed of 4.90 km/h and the arcuate shank recorded the less Value of 8.34 L/h for the same reasons mentioned above.

Table 3 shows that there was a significant effect of the moisture content on the slippage percentage , whereby the moisture content of 10.35% and recorded the highest slippage percentage, of 15.57%, while the moisture content of 16.75%, recorded the lowest slippage of 10.58%, due to the reason that the soil in the moisture content 10.35% becomes of great hardness and cohesion, which increases the soil resistance to penetration, cracking and cutting, so the pulling force increases, which in turn increases the slippage (Al-Talabani and Saad 2018).

Moreover there is a significant effect of forward speed on the slippage as the first speed recorded the lowest slippage value of 7.93%, while the speed of 4.90 km/h recorded the highest slippage value of 17.86%. the reason of increasing the slippage is due to the increasing in speed results in rotation resistance thus the slippage increases because of the positive relation between them in addition to the less time period for the wheels to come into contact with the soil that leads to slippage increases, (Abdul Karim 2017).

The shape of the shanks had a significant effect, as the curved shank recorded the lowest rate of slippage of 11.20%, whereas the straight shank recorded the highest rate of slippage of 14.84%, which did not differ significantly from the arcuate shank that which recorded 13.17%. The reason is due to the dependability of slippage on the force and power of pulling which recorded the least value with the curved shank (Tupper, 1977).

Obviously the effect of interaction between the moisture content and the speed had a significant differences effect. The moisture content of 16.75%, recorded the lowest slippage values of (6.05, 9.55 and 16.10)% for all speeds respectively, whereas the second moisture content recorded (9.81, 17.31 and 19.62)% respectively for all the speeds.

There was no significant effect of interaction between the moisture content and the shape of the shank. The moisture content of 16.75% recorded the lowest slippage values for all the shanks straight, curved and arcuate of (11.68, 9.36 and 10.67)% respectively, whereas the moisture content of 10.35% recorded the highest values of (18.00, 13.05 and 15.68)% respectively, for the same reasons mentioned above.

The slippage was not affected significantly by the interaction between the forward speed and the shape of the shank. The curved shank recorded the lowest value of slippage of 6.72%, at the speed of 2.11 km/h. While the speed of 4.9 km/h with the straight shank

Table 3: The effect of the studied factors and their interaction on the slippage percentage (%).

Moisture content (%)	Shank type	Forward speed (km/h)			Interaction between moisture content and shank type	
		2.11	3.11	4.90		
10.35	Straight	12.62	19.64	21.76	18.00	
	Curved	7.76	14.36	17.02	13.05	
	Arcuate	9.04	17.93	20.07	15.68	
16.75	Straight	7.06	11.21	16.77	11.68	
	Curved	5.67	7.53	14.87	9.36	
	Arcuate	5.43	9.91	16.67	10.67	
Interaction between moisture content and speed	10.35%	9.81c	17.31b	19.62a	Mean of moisture content	15.57a
	16.75%	6.05d	9.55c	16.10b		10.58b
Interaction between speed and shank type	Straight	9.84	15.42	19.27	Mean of shank type	14.84a
	Curved	6.72	10.95	15.95		11.20b
	Arcuate	7.23	13.92	18.37		13.17b
Mean of forward speed		1.93c	13.43b	17.86a		

recorded the highest value of 19.27%.

The triple interaction of the studied factors did not have a significant effect on the slippage. The straight shank with the moisture content of 10.35% at the speed of 4.90 km/h recorded The highest slippage value of 21.76%. Whereas the arcuate shank recorded the lowest value of slippage of 5.43% with the moisture content of 16.75% and at the speed of 2.11 km/h.

Table 4 shows that there were no significant differences in the effect of the moisture content factor on the specific resistance of pulling. The moisture content of 16.75%, recorded the lowest value of specific resistance of 126.55 kN/m^2, while the moisture content of 10.35% recorded the highest value of 130.19 kN/m^2, This is due to the fact that the pulling force increases with the decrease in the moisture content, so the specific resistance of pulling increases (Rajab 2005).

The effect of speed on the specific resistance of pulling shows that there were significant differences, whereby the specific resistance increased with increasing speed, and its highest value was 148.19 kN/m^2, recorded at the speed of 4.90 km/h. Where as the speed of 2.11 km/h, recorded the lowest value of the specific resistance, which was 115.98 KN/m^2, which did not differ significantly from the speed of 3.11 km/h, that recorded 120.94 kN/m^2. Hence when the speed increases, the shear forces of the soil increase, as a result the requirements for pulling and specific resistance increases, and (Rajab and Hilal 2017).

The table also indicates that the effect of the shank shape on the specific resistance was significant. The curved shank was superior in recording the lowest value of the specific drawing resistance of 116.57 kN/m^2, followed by the arcuate shank which recorded 125.32 kN/m^2. Whereas the straight stalk achieved the highest value of the specific resistance of 143.22 kN/m^2, This is due to the fact that the curved shank design requires the lowest value of the drawing requirements and gives a large disrupted area, so the specific resistance decreases, (Raper 2007).

The interaction between the moisture content and the forward speed, there were significant differences. The speed of 2.11 km/h with the moisture content of 16.75%, recorded the lowest value of 107.94 kN/m^2, the highest value of specific resistance was 141.18 kN/m^2 recorded with the moisture content of 10.35% and the speed of 4.90 km/h, that which was lowest in value in comparison with the speed of 4.90 km/h and the moisture content of 16.75%, which recorded 155.21 kN/m^2. The reason for this is that the effect of the disrupted soil area is greater than the effect of the pulling force.

The interaction between the moisture content and the shape of the shank did not have any significant effect. The curved shank with the moisture of 16.75% recorded the lowest value of the specific resistance of 111.58 kN/m^2 whereas the straight shank recorded the highest value of the specific resistance of (143.24 and 143.20) kN/m^2 with the moisture contents of (10.35% and 16.75%) respectively.

It is also noticed that there is no significant effect of speed interaction with the shape of the shank. The curved shank with the speed of 2.11 km/h recorded The lowest value of specific resistance of 105.71 kN/m. The straight shank with the speed of 4.90 km/h recorded The highest value of specific resistance of 163.55 kN/m^2 The reason for this is due to the fact that the pulling force in the curved shank is less and the area of the disrupted soil section is larger compared to the straight shank.

Table 4: The effect of the studied factors and their interaction on the specific resistance (kN / m^2).

Moisture content (%)	Shank type	Forward speed (km/h)			Interaction between moisture content and shank type	
		2.11	3.11	4.90		
10.35	Straight	132.89	136.86	159.97	143.24	
	Curved	115.79	117.95	130.96	121.56	
	Arcuate	123.42	121.27	132.63	125.77	
16.75	Straight	129.05	133.42	167.13	143.20	
	Curved	95.63	103.74	135.38	111.58	
	Arcuate	99.13	112.40	163.11	124.88	
Interaction between moisture content and speed	10.35%	124.03 bc	125.36 bc	141.18 ab	Mean of moisture content	
	16.75%	107.94c	116.52c	155.21a		
Interaction between speed and shank type	Straight	130.97	135.14	163,55	Mean of shank type	143.22a
	Curved	105.71	110.84	133.17		116.57c
	Arcuate	111.27	116.83	147.87		125.32b
Mean of forward speed		115.98b	120.94b	148.19a		

The table indicates that there was no significant effect of the triple interaction among the studied factors in the specific resistance. The moisture content treatment of 16.75% at the first speed of 2.11 km/h with the curved shank recorded the lowest value of the specific resistance of 95.63 kN/m^2 whereas the moisture content treatment of 16.75% at the third speed of 4.70 Km/h with the straight shank recorded the largest value of specific resistance of 167.13 kN/m^2.

Table 5 indicates that the specific energy was not significantly affected by the moisture

Table 5: Effect of the studied factors and their interaction on the_specific energy (kJ/m^3).

Moisture content (%)	Shank type	Forward speed (km/h)			Interaction between moisture content and shank type	
		2.11	3.11	4.90		
10.35	Straight	138.56	138.83	146.87	141.43	
	Curved	93.51	103.97	105.68	101.06	
	Arcuate	108.39	133.41	127.43	123.08	
16.75	Straight	132.15	135.18	153.66	140.33	
	Curved	90.56	99.77	105.67	98.68	
	Arcuate	97.16	102.91	138.27	112.78	
Interaction between moisture content and speed	10.35%	113.50	125.40	126.66	Mean of moisture content	121.85
	16.75%	106.63	112.62	132.53		117.26
Interaction between speed and shank type	Straight	135.37	137.00	150.26	Mean of shank type	140.88a
	Curved	92.05	101.87	105.68		99.87c
	Arcuate	102.78	118.16	132.85		117.93b
Mean of forward speed		110.07b	119.01b	129.60a		

content of the soil. Moisture content of 16.75%, recorded the lowest value of specific energy of 117.26 kJ/m^3, whereas the moisture content of 10.35% recorded the highest value of 121.85 kJ/m^3, the reason is due to that The energy required to penetrate and break down blocks of soil is increased by decreasing the moisture content of the soil (Raper and Sharma 2004).

Obviously there are significant differences in terms of the effect of forward speed, whereby the speed of 4.90 km/h exceeded significantly in recording the highest value of specific energy of 129.60 kJ/m^3, whereas the speed of 2.11 km/h recorded the lowest value of 110.07 kJ/m^3 that which did not differ significantly from the speed of 3.11 km/h, which recorded 119.01 kJ/m^3. The reason for increasing the specific energy increasing the speed is due to the increase in the drawbar power (Sadiq K. Muhsin, 2017) and (Khader, 2008).

The effect of the shank shape, recorded significant differences in the specific energy whereby the curved shank exceeded significantly in recording the lowest significant value of specific energy of 99.87 kJ/m^3, followed by the arcuate that which recorded 117.93 kJ/m^3, while the straight shank recorded the highest value of 140.88 kJ/m^3. The reason for this is that the curved shank design requires the lowest drawbar power in comparison with the rest of the types of the shanks, moreover it achieves the highest value of the disrupted soil area, which increases the disrupted soil volume, thereby results in reducing the specific energy. (Nichols and Reaves, 1958).

The interaction between the moisture content and the forward speed did not have any significant effect. The treatment of the moisture content of 16.75% with the speed of 2.11 km/h, recorded the lowest value of specific energy of 106.63 kJ/m^3, whereas the highest specific energy recorded at the same moisture content with the speed of 4.70 km/h. The reason for this is that the disrupted area was the least valuable according to this speed. Therefore the volume of the disrupted soil decreased, and the drawbar power increases with increasing speed, thus led to increasing the specific energy value.

There were no differences in the effect of interaction between the moisture content and the shape of the shank, as the straight, curved and arcuate shank at the moisture content of 10.35% recorded a specific energy of (141.43, 101.06 and 123.08) kJ/m^3, respectively, whereas the shanks at the moisture content of 16.75% recorded (140.33, 98.68 and 112.78) kJ/m^3, respectively, whereby the effect of shanks were greater than the effect of moisture content.

The effect of speed interaction and the shape of the shank, the curved shank recorded its lowest values compared to the rest of the shanks and for all speeds (92.05, 101.87 and 105.68) kJ/m^3 respectively, whereas the straight shank recorded the highest value of (135.37, 137.00 and 150.26) kJ/m^3. Due to the same reasons mentioned above.

As for the triple interaction of the studied factors, it did not have any significant effect on the specific energy trait. The treatment of the straight shank and the moisture content of 16.75% and speed of 4.70 km/h recorded the largest value of specific energy of 153.66 kj/m^3, whereas the curved treatment and the moisture content of 16.75% with speed 2.11 km/h recorded the minimum value of 90.59 kj/m^3.

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