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Field comparison between two rotary plows under different speed and number of shares

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Tangential force, Blades, Kinematic ratio, Specific Energy

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ABSTRACT

For aim of comparing two rotary plow factorial experiment conducted in silt clay loam. L and C shape of the blade in two rotary plows, tractor speed 4.6 and 8.7 km.h^{-1} and depth of tillage 8 and 15 cm were used as experiment factors. L blade rotary plow obtained on the best effective field capacity 0.9835 ha.h^{-1}, shortest distance between two beats blade 0.1653 m, pulverization rate (soil clods < 25 mm) and fuel consumption 24.33 L.h^{-1}. C blade rotary plow recorded least maximum tangential force1518.97 kg, specific energy 87.951 MJ.ha^{-1} and soil force acting on sharpened edge of each blade 303.80 kg. Speed of the tractor 8.7 km. h^{-1} gave least fuel consumption 23.44 L.ha^{-1}, higher effective field capacity 1.2941 ha.h^{-1}. Tractor speed 4.6 km.h^{-1} gave short distance beats of the blades 0.1420 m and high pulverization rate 0.63 %. Depth of tillage 8 cm gave least fuel consumption 23.53 L.ha^{-1}, maximum tangential force 1937.36 kg, specific energy 62.459 MJ.ha^{-1}, higher effective field capacity and pulverization rate 0.9965 ha.h^{-1} and 0.72 % respectively. Direct and inverse significantly correlations, addition non-significant founded among studied characteristics. Concluded the most influential factors in the experiment traits was speed then depth and both of them more than influent from L and C shape of the blades.

مقارنة حقلية بين محراثين دورانيين تحت سرع وعدد اسلحة مختلفة

أحمد عبد علي حامد

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الخلاصة

بهدف مقارنة محراثين دورانيين أجريت تجربة عاملية في تربة مزيجية طينية غريني. ثلاثة عوامل استخدمت في التجربة هي محراثين دورانيين ذوا شكلين للأسلحة هما حرف L وحرف C وسرعتين اماميتين للجرار 4.6 و 8.7 كم/ساعة وعمقين للحراثة 8 و 15 سم . سلاح المحراث شكل L حصل على أفضل سعة حقلية فعلية للحراثة 0.9835 هكتار/ ساعة وأقل مسافة بين ضربتين للأسلحة 0.1653 متر وأفضل نسبة تفتيت (كتل ترابية اقل من 25 ملم) وأقل استهلاك للوقود 24.33 لتر/هكتار. شكل سلاح المحراث C سجل أقل أقصى قوة مماسية للسلاح 1518.97 كغم وطاقة نوعية 87.951 ميكا جول/هكتار وأقل قوة على حافة كل سلاح 303.80 كغم. سرعة الجرار 8.7 كم/ساعة أعطت أقل استهلاك للوقود 23.44 لتر/هكتار وأعلى سعة فعلية حقلية للحراثة 1.2941 هكتار/ساعة. سرعة الجرار 4.6 كم/ساعة أعطت أقصر مسافة بين ضربتين للأسلحة 0.1420 متر وأعلى نسبة تفكيك 0.63%. عمق الحراثة 8 سم أعطت أقل استهلاك للوقود 23.53 لتر/هكتار وأعلى قوة مماسية 1937.36 هكتار/ساعة وأقل طاقة نوعية 62.459 ميكا جول/هكتار وأعلى سعة حقلية فعلية ونسبة تفكيك 0.9965 هكتار/ساعة و 0.72% على التوالي. الارتباط بين الصفات المدروسة في التجربة الحقلية كان معنوي وغير معنوي. أُسْتُنتِجَ أن أكثر عاملين أثرا في صفات التجربة الحقلية هما سُرع الجرار وأعماق الحراثة مقارنة مع شكلي اسلحة المحراثين الدورانيين L و C.

كلمات مفتاحية: القوة المماسية، أسلحة، النسبة الحركية، الطاقة النوعية.

INTRODUCTION

A rotary plow (plough) , also now as a rototiller, rotavator, rotary hoe, power tiller, is agricultural implement that work for plowing and pulverization the soil by rotating tines or blades like L-shaped, C-shaped and J-shaped mounted on flanges, attached by means of a three-point hitch behind the tractor and driven by tractor power take-off (P.T.O) shaft. Rotary plow blade design depends on three basic factors: soil conditions, the shape of the blade, and the method of moving the soil. Iraqi farmers usually using moldboard, chisel and disk plows for primary tillage (Abdul- Munaim, 2013; Abdul-Munaim *et al*., 2020; Al Nuaimi and Al Rijabo 2020; Hamid and Alsabaag, 2023), also many researchers use theses common plows to conduct field research (Alrijabo and Kashmola 2013;Jasim and Alhashimy, 2015; Himoud, 2018; Nafawaah and Mageed, 2019; Jebur *et al*., 2020; Jebur and Al-Halfi, 2022; Alwash and Al-Aani, 2023; Azawi *et al*., 2024), yet, a large of farmers use rotary plow for primary tillage because it achieves the objectives of primary and secondary tillage and for prepare the land for planting various types of vegetables and crops where the time for seedbed preparation is very short or limited, pulverization, and mixing manure with the soil. A rotary is agricultural plow smash (break) and pulverization of soil by blades (knives) rotary, it is different from other plows in design, soil moving, degree of pulverization and prepare the seed bed in one pass (Jithender et al., 2017;Kumare *et al*., 2023; Al-Azzawi and Zeinaldeen, 2023; and Pacheco *et al*.,2023). Grisso et al (2004) predicted in Nebraska test indicated that fuel consumption for a 115.96 hp (86.74 kW) tractor was 25.82 $L.h^{-1}$ (6.82 $gal.h^{-1}$). Firouzi and Alizadeh (2012) founded the maximum soil pulverization was achieved at lowest forward speed, while maximum productivity at higher speed. Abdullah and Abdul Rahman (2019) founded increasing speed tractor leads to increased field effective capacity. Tangential force acting at the tip of the blade and force acts perpendicular to the cutting edge of the blade are main forces when used rotary in the tillage (Bernacki *et al*., 1972). Zareiforoush et al (2010) funded the bigger tangential and soil force acting on each of the blades was 551.50 and 367.67 kg respectively, when rotary tiller 13 hp, width 50 cm and forward speed 1.8 $km.h^{-1}$. Mandal (2015) funded when used width rotary plow 1.6 m, depth 10 cm, contain 11 flanges, 66 blades, tractor speed 0.7 $m.s^{-1}$ and rotor shaft 206 rpm founded the maximum tangential force occurs at the minimum of blade tangential speed and soil force acting on each of the blades were 2083 and 387 kg, respectively. Abdulla and Yahya (2013) founded the effective field capacity and distance between beat blades increasing 0.39 - 0.59 $ha.h^{-1}$ and 12.26 to 18.89 cm, respectively, when tractor speed increase from 3.95 to 6.03 km. h^{-1}, also concluded increase the drawbar power. Diesel fuel consumption in a tractor 109.53 hp (81.67 kW) with crank shaft speed 2100 rpm and standard P.T.O shaft 540 rpm was 23.27 $L.h^{-1}$ (6.15 $gal.h^{-1}$),(Nebraska Tractor Test Laboratory NTTL, 2018). Abou Zaid and Al-ashry (2006) founded the fuel consumption was 10.12 $L.fed^{-1}$ (24.08 $L.ha^{-1}$) when used width rotary plow 1.75 m and tractor power 62 hp. Jethender et al (2017) founded the actual field capacity was 0.18 $ha.h^{-1}$ when a rotary plow with a width of 120 cm and depth 16 cm was used and speed tractor 2.5 km. h^{-1}. Abisuwa *et al* (2023) concluded the highest effective field capacity at depth 9 cm and reduced when depth increasing, also concluded increase the value when tractor speed increased. Al- Hashimy (2012) and Madlol *et al* (2013) concluded that fuel consumption and power requirement increases when plowing depth increases. Al-abaidy *et al* (2016), Taha 2018 and Mankhi and Juber (2022) concluded that effective field capacity decreases when increase the plowing depth.

The aim of this research is comparison between two rotary plows under different speed and number of shares and shapes during primary tillage in silt clay loam under two depth of tillage for determine maximum tangential force, soil force acting on sharpened edge of each blades, effective field capacity, distance between beat blades, fuel consumption, pulverization rate (Soil clods < 25 mm) and specific energy.

MATERIAL AND METHODS

Experimental site, Tractor and two rotary plows

The experiment was carried out in Al-Mahmoudia region 31 km south of Baghdad, the capital of Iraq, within coordinates Latitude 33.06871° N, Longitude 44.36403° E. According to Köppen climate classification, Iraq is located within the arid climate. The field aria was 14850 m^2 (135 m length and 110 m width). The height of the experiment field above sea level was 31.8 m. Ten random soil samples were taken from soil field which collected from 20 cm upper soil layer, used a cylindrical core sampler 5 × 5 cm and dried at 105° C for 24 hour in oven (Black, 1965), moisture of soil was 15-18 % when soil tilled and bulk density was 1.34 $g.cm^{-3}$. Field was silt clay loam (465, 425 and 110 $g.kg^{-1}$).

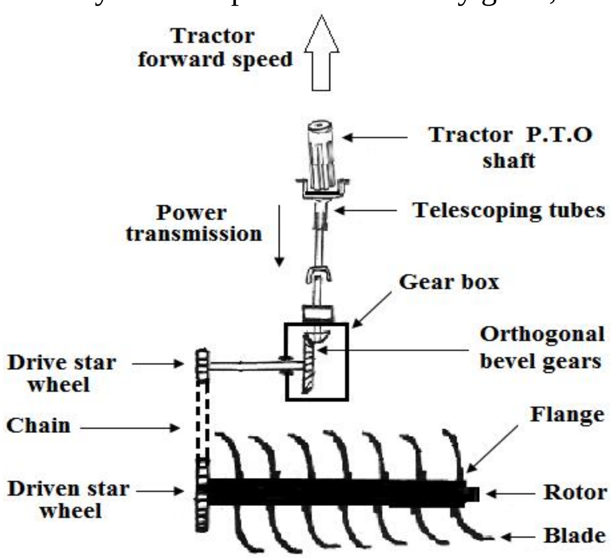
The tractor and two rotary plows were selected to meet manufacturing specifications and avoid defects and shortages. A professional tractor driver was also selected and the tractor was set to the required speeds and engine revolutions 2000 rpm for all treatment, the most technical specifications of the tractor and rotary plows in table 1.

Table (1): The most technical specifications of the tractor and rotary plows

Tractor	Rotary plow type	
	Khalsa	Koylu
Model: Fiat 110 - 90 4WD	Rotary working width: 1920 mm	Rotary working width: 2000 mm
Engine power:110 hp (82.0 kW)	Maximum working depth: 180 mm	Maximum working depth: 200 mm
Max. power P.T.O shaft:91.3 hp	Rotor rpm: 210 rpm at 540 P.T.O shaft	Rotor rpm: 215 rpm at 540 P.T.O shaft
Number of cylinders: 6 – Diesel	Number of flanges: 8	Number of flanges: 8
P.T.O shaft: 540 / 1000 rpm	Distance between the flanges: 240 mm	Distance between the flanges: 250 mm
Cylinder diameter: 100 mm	Total number of blades: 32	Total number of blades: 48
Stroke length: 127 mm	Blades on the flange: 4	Blades on the flange: 6
Compression ratio: 1:16	Shape of blades: C	Shape of blades: L
Cooling system: Water	No. of blades per side flange: 2	No. of blades per side flange: 3
Front tire: 12.4/11-28	No. of blade action jointly with soil: 8	No. of blades action jointly with soil: 8
Rear tire: 16.9/14-38	Span blade : 100 mm	Span blade : 100 mm
Fuel tank: 132.9 L (35.1 gal)	Blade vertical length effective: 200 mm	Blade vertical length effective: 220 mm
Gear box: 15 front & 4 Rear	Thickness of blade: 8 mm	Thickness of blade: 8 mm
Total weight: 4670 kg	Required power: 30 - 50 hp	Required power: 35 - 55 hp
Steering wheel : Hydraulic	Diameter rotor shaft plus blades:500 mm	Diameter rotor shaft plus blades:500 mm
Country of manufacture: Italy	Country of manufacture: India	Country of manufacture: Turkey

Kinematic blades of the rotary plow

According to the agricultural companies that manufacture rotary plow blades found most three important types of the blades: L, C and J shapes, which are suitable for variable operating conditions. Power efficiency is transmitted from the tractor to the rotary plow usually higher, in the other hand, rotary plow directly transmit power to blades by gears, shaft, stars wheel and chain (fig. 1).



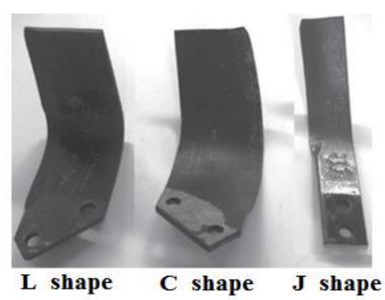


Figure (1): Schematic of power transmission in rotary plow and most three shape of the blades

As show in fig. 1 the tractor engine power transmitted to power take- off (P.T.O) shaft then to gear box of the rotary plow, then the power is transmitted by shaft to the star wheels and a chain to rotating shaft which carrying flanges (discs), that means transmitted power to the blades directly, hence, the rotary plow has higher efficiency transmitted power. Each flange carries usually 4 or 6 blades (half of blades are on the right side and the other half on the left side), (fig. 2). The sharpness and angles of the blades are verified according th the manufacturer's specifications.

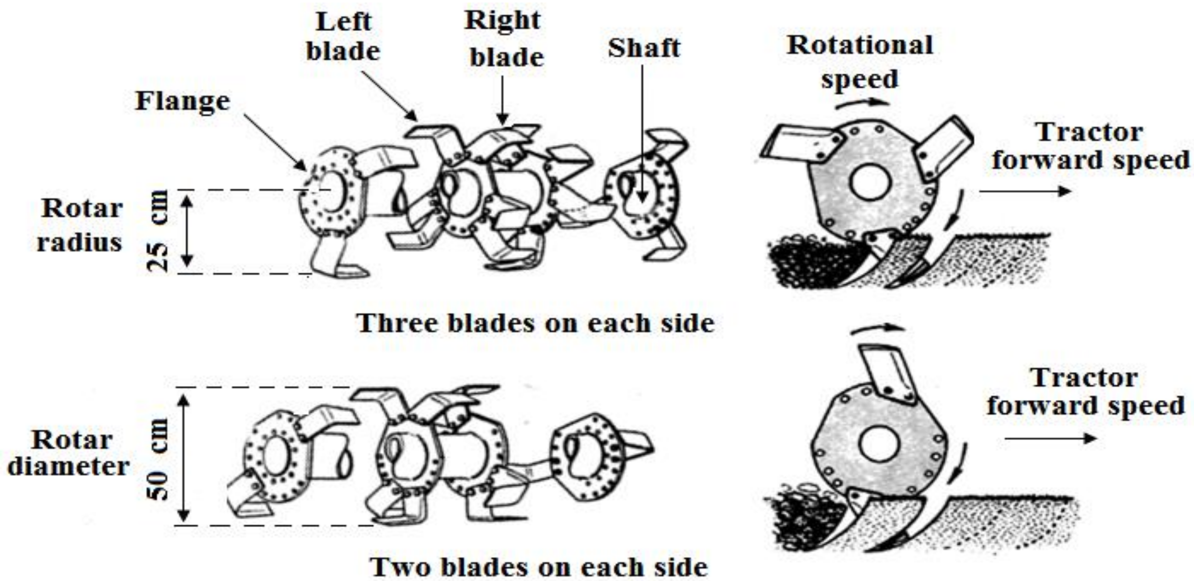


Figure (2): Distribution of blades on both sides of the flange and method of the penetration

Kinematic ratio *λ* (dimensionless) is the ratio between velocities in each of tangential blades (*U*) and the practical forward tractor (*V*), the kinematic ratio *λ* depend of the number of revolutions of the rotor shaft (rpm), the radius of rotor (shaft and blades as one piece), the speed of the tractor during the operation tillage. Each blade cuts a segment of soil as it moves downward and toward the rear as shown in figure 3, the letter C is the center of the rotor, X is the distance between two beats or the length of slice cutting by the blade which depend of the number of blades on the peripheral flange, rotational flange and the forward speed tractor, ω is angular velocity of the blade, R is radius of rotor (shaft, flange and blade as on piece), D is depth of tillage, Y is the distance between the rotor and depth of tillage, B is width of slice (span) and L is vertical slice. The shift rotates with the same direction tractor forward travel, moreover, blades is located at 90° to the line travel. As long as the shaft rotates at a speed greater than the tractor speed, the tillage and break soil is accomplished.

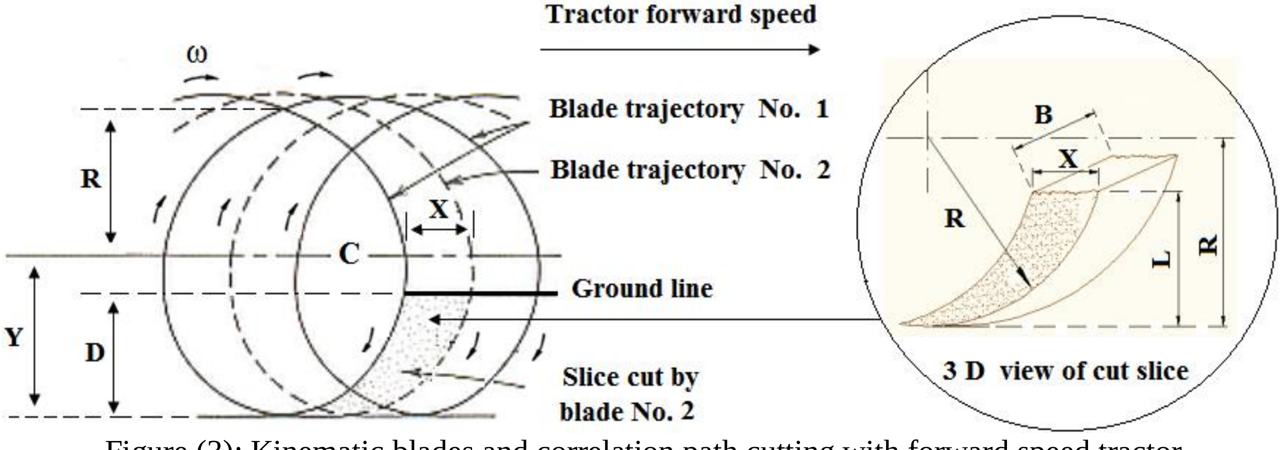


Figure (3): Kinematic blades and correlation path cutting with forward speed tractor

Experiment Design

Factorial experiment under randomized complete block design (RCBD) using least significant designs (L.S.D) 5 and 1 %. Statistical Analysis System (SAS) was used (SAS, 2010). In this experiment three factors used: two rotary plows, tractor speed 4.6 and 8.7 $km.h^{-1}$, and depths of tillage 8 and 15 cm. Experiment included 8 treatments with three replications, therefore, all treatments were 24 (2 × 2 × 2 × 3 Replication = 24), the treatment area was 90 m^2 (30 m length and 3 m width). The field was divided according to the design used, addition, experiment factors and replicates distribution and sings were placed in the field, moreover, the factorial experiment allowed transparent and fair of the two rotary plow through a right division of the experimental factors in the field.

Measuring Indicators

Maximum tangential force

It is occurs at the minimum of blades tangential velocity, showed in (fig. 4), calculated by following equations (Bernacki *et al*., 1972):

$$K_s = C_s \; 75 \; T_e \; \eta_t \; \eta_r \; / \; U_{min} \qquad (1)$$

To obtain U_{min} following the equations:

$$U_{min} = V \; \lambda_{min} \qquad (2)$$

$$\lambda_{min} = 2 \pi R \; / \; Z \; L_{max} \qquad (3)$$

$$L_{max} = R \; \pi \; / \; \lambda \qquad (4)$$

$$\lambda = U \; / \; V \qquad (5)$$

$$U = 2 \pi N R \; / \; 60 \qquad (6)$$

Where K_s is maximum tangential force (kg), C_s is reliability factor 1.5 and 2 for non-rocky and rocky soils, respectively, in this experiment was 1.5, T_e is tractor engine power (115 hp), η_t is the traction efficiency 0.9 its value of shaft forward rotation (because the rotor shaft and tractor forward speed are the same direction), η_r is reservation coefficient for tractor power which is between (0.7 – 0.8) and it takes an average of 0.75 in this experiment, U_{min} is minimum peripheral velocity taken ($m . s^{-1}$), V is the practical forward speed of the tractor during the plowing process ($m.s^{-1}$), R is the rotor radius (25 cm rotor shaft with blades as one part), Z is the number of blades on each side of the rotor flanges, L_{max} the maximum length of sliced soil (cm), U is the tangential velocity of the blades ($m.s^{-1}$), λ is the ratio between tangential speed of the blades (U) and the practical forward speed of the tractor (V), N is rotor rotate velocity (210 and 2015 rpm for Czech and Turkey rotary plows, respectively). λ and λ_{min} are kinematic ratio (dimensionless).

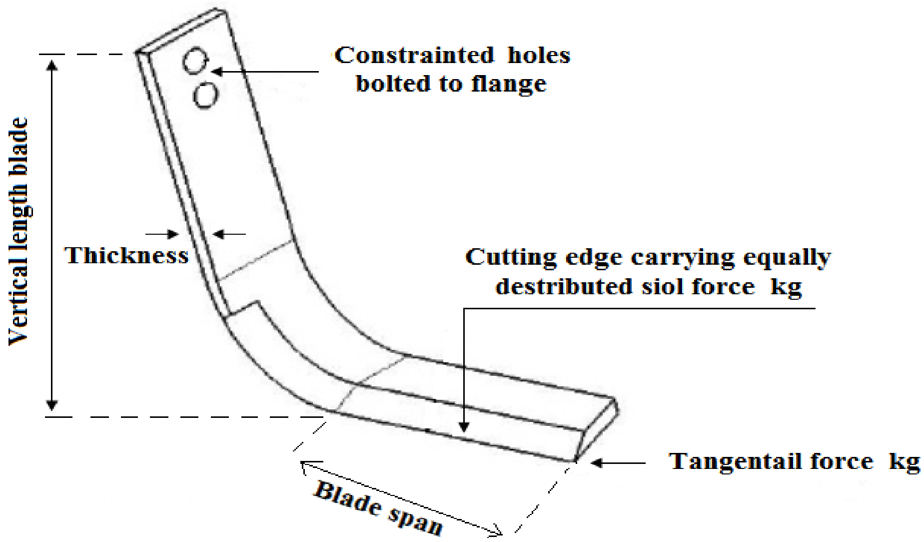


Figure (4): Three dimention vewe of blade showing the forces

Soil force acting on sharpened edge of each blades

It is calculated by the following the equation (Bernacki et al 1972):

$$K_e = K_s \times C_p / i \times Z_e \times N_e \qquad (7)$$

Where C_p is tangential force coefficient (0.80), i is the number of flanges (8), Z_e is the number of blades on each side of the flanges, and N_e is obtained through division the number of blades which action jointly on the soil (one blade from each flange jointly on the soil in the same time during rotation of the shaft) on the total number of the blades (8 ÷ 32 for blade C and 8 ÷ 48 for Blade L).

Effective field capacity

The actual plowing of the rotary plow performed in the field during a limited time, calculated from the following equation (Kepner, 1972; Hamid, 2012).

$$E_{FC} = 0.1\ B_p V_p f_t \qquad (8)$$

Where E_{FC} is practical productivity (ha. h^{-1}), 0.1 is conversion factor, Bb is actual width of the rotary plow (m), Vp is speed of the tractor (km.h^{-1}), and ft is the time utilization factor for the rotary plow is equal to 0.75 – 0.85, and 0.80 is taken as the average in this experiment (ASABE, 2006).

Distance between beat blades

The distance between one beat blade and another in the soil during the plowing, and affected by the speed of the tractor, the speed of rotation of the rotary plow blades and the numbers of blades in the flange (disc), calculated from the following equation (Radomirović, 2005):

$$D = 16.66\ (V_p / K\ N) \qquad (9)$$

Where D is the distance between one beat and another (m), K is the number of pairs of blades installed in the flange (disc), N is the rotational speed of rotary plow blades (rpm), and 16.66 is the conversion factor (1000 ÷ 60 min = 16.66).

Fuel consumption

Fuel consumption was measured by refilling the fuel tank tractor to the brim before and after each treatment, using a 1000 ml graduated cylinder and from where the quantity of fuel used is measured per time of the operation (Igoni et al., 2020; Ahmed and Alsabbgh, 2022) calculated from the following equation:

$F_c = F_{ca} \times 10000 / W_p \times L_p \times 1000$ (10)

Where F_C is fuel consumption (L. ha^{-1}), F_{ca} is the measure fuel quantity for tillage line treatment (ml), T is the time plowing of line treatment (sec), 10000 and 1000 is conversion factor.

Pulverization rate (Soil clods < 25 mm)

Is the percentage of the soil weight fraction composed of soil clods less than 25 mm which passes through the sieve openers 25 mm to the total weight (fig. 5), calculated from the following equation (Khder 2008; Hamid 2024):

$P_r = (C_c / T_w) \times 100$ (11)

Where P_r is the pulverization rate %, C_c clods of the soil < 25 mm which passes from the sieve of 25 mm (fig. 5), T_w is the total weight of all clods produced by plowing.

Pulverization soil depend of moisture soil, rotational velocity blades, forward speed tractor, shape of the blade, number of the blade in the flange and angle of the cover.

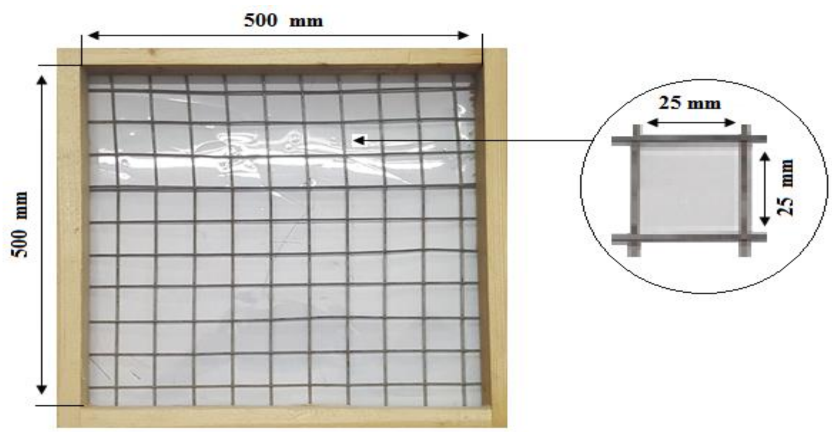


Figure (5): Sieve 25 mm

Specific energy

It is calculate by following the equations (Embaby 1985):

$S_E = (P \times 3.6) / E_{Fc}$ (12)

$P = (D_F \times V_P) / 3.6$ (13)

Where S_E is specific energy (MJ. ha^{-1}), P is drawbar power required for plowing (Kw), E_{FC} is Effective Field Capacity (ha . hr^{-1}), D_F is the draft force of rotary plow (kg), V_P is practical speed of the tractor (km . h^{-1}), and 3.6 is conversation factor.

Unfortunately, at the experiment site, there was no device (load cell) to measure the draft force at the rotary plow, which takes its movement from the power take-off shaft of the tractor, so the draft force was calculated based on American Society of Agricultural and Biological Engineers (ASABE, 2006), by followed the equation:

$D_F = F_i [A + B (V_P) + C (V_P)^2] W \times T \times 0.101972$ (14)

Where F_i is a dimensionless soil texture adjustment parameter (F_i = 1 for fine soil, 2 for medium and 3 for coarse) and in this experiment Fi = 1, A, B and C is Machines specific parameter, A is function of soil strength (A = 600) while the coefficient of speed parameter, B or C are related to soil bulk density (*B* and *C* = 0) for the rotary plow or rotary tiller (ASABE 2006), *W* is rotary plow width (m), *T* is depth of tillage (m), and 0.101972 is Newton to kg conversation factor.

RESULT AND DISCUSSION

Table. 2 showed the types of the blades were significant difference in maximum tangential force, the maximum tangential force for C blade rotary plow was least from L blade rotary plow 1518.97 kg and 2411.15 kg respectively, and that belong to the deference in kinematic ratio λ_{min} for rotational flanges and forward speed tractor for each blades, According to equation (3) the kinematic ratio λ_{min} in L blade rotary plow was least from C blade rotary plow, because flange blades L and C contain 3 and 2 blades in each side, respectively, so that effect on the minimum peripheral velocity of the rotor U_{min} (equation 2 then 1) was clearly. Result showed the L blade rotary plow recorded higher soil force acting on sharpened edge of each blades was 482.22 kg comparing 303.80 kg for C blade rotary plow, that belong to the difference between values of the Maximum tangential force in the two blades L and C. The types of blades had significant difference in effective field capacity, there are slight differences in values which were 0.9778 and 0.9835 $ha.h^{-1}$ for C and L blades rotary plow respectively, and that belong to the difference in the width of the two plows. Also result founded the types of the blades had significant difference in distance between beats blades, the L blade rotary plow obtained the batter distance was 0.1653 m, while C blade rotary plow was 0.2528 m, because of the difference in the number of the blades in L and C blades in each of the flange (disc) which are 6 and 4 respectively, therefore, the design distances between blades on the circumference of the flange was varies. The result fund the types of blades had significant difference in fuel consumption, L blade rotary plow recorded least consumption was 24.33 L. ha^{-1}, while C blade rotary plow was 25.40 $L.ha^{-1}$, and that belong to the difference in the width of rotary plows. Type of the blades were Significant difference in pulverization rate, L blade rotary plow obtained higher rate was 0.73 % comparing 0.62 % for C blade rotary plow, that because the number of L blades on each flange was 6 blades, so there are 6 hits in one revolution of the flange, while C blade was 4 on each flange, for other hand, the type of the blade L was more soil disintegration comparing with C blade. The blades type were significant difference in specific energy, C blade rotary plow was least value 87.951 $MJ.ha^{-1}$, while L blade rotary plow was 91.619 $MJ.ha^{-1}$, and this because the effective field capacity for C blade rotary plow was least from the L blade, from other hand, the difference between width of two rotary plow.

Table (2): The values of the studied attributes of the experimental factors

Experiment factors	Maximum tangential force kg	Soil force acting on sharpened edge of each blades kg	Effective field capacity $ha . h^{-1}$	Distance between beat blades m	Fuel Consumption $L.ha^{-1}$	Pulverization rate %	Specific energy $MJ.ha^{-1}$
Blade C	1518.97	303.80	0.9778	0.2528	25.40	0.62	87.951
Blade L	2411.15	482.22	0.9835	0.1653	24.33	0.73	91.619
Speed 4.6	1987.88 ^{NS}	397.56 ^{NS}	0.6672	0.1420	26.28	0.71	89.786 ^{NS}
Speed 8.7	1942.24 ^{NS}	388.45 ^{NS}	1.2941	0.2757	23.44	0.63	89.784 ^{NS}
Depth 8	1937.36	387.48	0.9965	0.2123	23.53	0.72	62.459
Depth 15	1992.76	398.54	0.9648	0.2055	26.19	0.63	117.111

Table . 3 showed the simple statistics analysis of characteristics of the field experiment, higher standard deviation (Std . Dev) for the maximum tangential force, Soil force acting on sharpened edge of each blades and specific energy, that means the date which obtained in 24 treatments in the field experiment was far away from the mean, therefor, there is a large variance in the results when conducted the experiment factors such as L and C blades rotary plow, speed of the tractor and depth of tillage. The rest of the traits had Standard deviation closely from the mean, therefor, the variance were small, then the dispersion is better. The result showed the least Standard deviation were in the distance between beat blades and Pulverization rate 0.08288 and 0.08327 respectively, while the higher standard deviation 462.260 for maximum tangential force.

Table (3): Simple statistics analysis of the characteristics of field experiment

Study traits	N*	Mean	Std. Dev	Sum	Min**	Max**
Maximum tangential force kg	24	1965	462.260	47161	1405	2527
Soil force acting on sharpened edge of each blades kg	24	393.01	92.4478	9432	281.00	505.40
Effective field capacity ha . h^{-1}	24	0.9807	0.32067	23.536	0.6451	1.3148
Distance between beat blades m	24	0.2089	0.08288	5.0142	0.1090	0.3391
Fuel consumption $L.ha^{-1}$	24	24.865	2.11408	596.76	21.180	28.470
Pulverization rate %	24	0.6770	0.08327	16.250	0.5200	0.8400
Specific energy MJ. ha^{-1}	24	89.785	27.9826	2155	61.182	119.51

* **N are treatments (2 × 2 × 2 × 3 replication = 24).**

** **Minimum and Maximum values which obtained in the field experiment.**

Interaction of blades shape, speed tractor and plowing depth on maximum tangential force was significant difference (fig. 6), interaction L blade rotary plow, speed tractor 4.6 $km.h^{-1}$ and tillage depth recorded 2431.83 kg, while interaction C blade, speed tractor 8.7 $km.h^{-1}$ plowing depth 8 cm recorded 1457.43 kg, according to equation (1) by Bernacki *et al*., (1972) the minimum peripheral velocity of the rotor U_{min}, kinematic ratio λ_{min} and the number of blades in the flange effect and limited values, which mean if the flange contain 6 blade that lead to high of maximum tangential force. Interaction of blades shape, speed tractor and plowing depth on Soil force acting on sharpened edge of each blades was significant difference (fig.7), deference values on L and C blades rotary plows when using the same speed tractor and depth of tillage, L blade recorded higher value 486.36 kg when speed and depth were 4.6 $km.h^{-1}$ and 15 cm respectively, while C blade obtained least value 291.56 kg when speed and depth 8.7 $km.h^{-1}$ and 8 cm, and this because the effect of maximum tangential force (according to equation 7), the number of blades in flanges, contact aria between sharp edge of blade and soil, which was more in L blade comparing with C blade. Significant effect of interaction the shape of blade, speed tractor and depth of tillage on effective field capacity (fig.8), result showed the speed effect more than depth, also noticed the shape of blades was not effect on the effective field capacity in the same speed and tillage, but the difference come from the width of two rotary plows.

The L blade rotary plow, speed tractor 8.7 $km.h^{-1}$ and depth of tillage 8 cm obtained higher effective field capacity was 1.3117 ha . h^{-1}, while the C blade rotary plow, speed 4.6 $km.h^{-1}$ with depth 15 cm recorded 0.6486 $ha.h^{-1}$, and that belong to increasing the speed tractor lead to increase the effective field capacity, while increasing the depth of tillage lead to decreasing the effective field capacity. Result showed the most effect on the distance between beat blades were the number of blades in the flange, speed of the tractor and the rotational blades (rpm). Interaction L blade, speed tractor 4.6 $km.h^{-1}$ and depth of tillage 15 cm recorded least distance between beat blades 0.1101 m that because the number of blades was 6 on each flange, while the blade C, speed 8.7 km.h^{-1} with depth 8 cm recorded higher distance between beat blades was 0.3381 m, and that because the number of blades was 4 on each flange (fig.9). From resulting noticed increase the speed tractor lead to increase the distance between two beat of the blades, while the increased the depth of tillage lead to reduce the distance between two beat of the blades. Interaction shape blade, speed tractor and depth of tillage was significant difference fuel consumption (fig.10), L blade rotary plow, speed tractor 8.7 km.h^{-1} and depth of tillage 8 cm gave best fuel consumption 21.66 L.ha^{-1}, that belong to increase the speed of the tractor result to decrease the fuel consumption at the expense of the unit area. While C blade rotary plow, speed 4.6 and depth of tillage 15 cm recorded higher value 28.12 ha.h^{-1}, because the width of rotary plow was least from L blade rotary plow. It was noted from the results that the effect of the experimental factors, tractor speed and plowing depth, had more influence on fuel consumption than the blade shape factor. Interaction shape of the blades, speed tractor and depth of tillage was significant differences on Pulverization rate (soil clods less than 25 mm) (fig.11), interaction L blade, speed tractor 4.6 km.h^{-1} with depth 8 cm obtained higher Pulverization rate was 0.82 %, this because the number of the L blades on each flange was 6 blades which lead to small distance between two beats of the blades, from other hand, the reduce the speed of the tractor also lead to minimize of the distance between the beats of blades, so this two reasons make more clods of the soil less than 25 mm which mean increase the pulverization rate.

While C blade, speed tractor 8.7 km. h^{-1} and depth of tillage 15 cm was 0.53 %, this was belong to two reasons: the number of C blades in the flange and the increase in the speed of the tractor, which works to increase the distance between the beats of the blades, and this means reducing the rate of pulverization (soil clods less than 25 mm). Interaction shape of the blades, speed tractor and depth of tillage was significant differences on specific energy (fig.12), According to equations 12, 13 and 14 the effective field capacity, speed of the tractor, depth of the tillage and width the two rotary plows plays an important role in the specific energy value. The higher specific energy was when interaction L blade, speed tractor 4.8 km.h^{-1} and depth of the tillage 15 cm was 119.501 MJ. ha^{-1}, while the interaction C blade rotary tractor, speed tractor 8.7 km.h^{-1} and depth of the tillage 8 cm was 61.183 MJ.ha^{-1}. Also result showed the L blades rotary plow which contains 6 blades in each flange need specific energy more than C blades rotary plow which contain 4 blades in each flange.

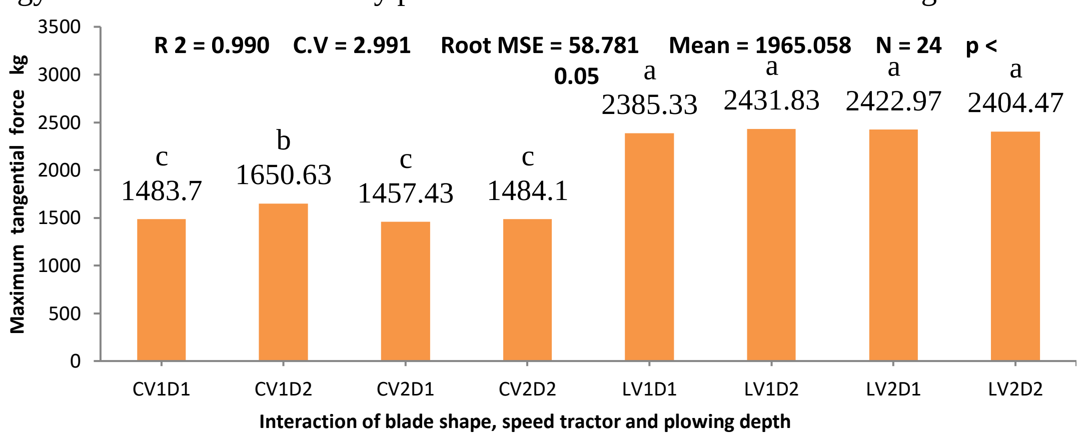


Figure (6): Interaction among blade shape, speed tractor and plowing depth in maximum tangential force. (Means with the same letter are not significantly different), L blade shape L, S blade shape S, V1 speed tractor 4.6 km.h^{-1}, V2 speed tractor 8.7 km.h^{-1}, D1 plowing depth 8 cm, D2 plowing depth 15 cm

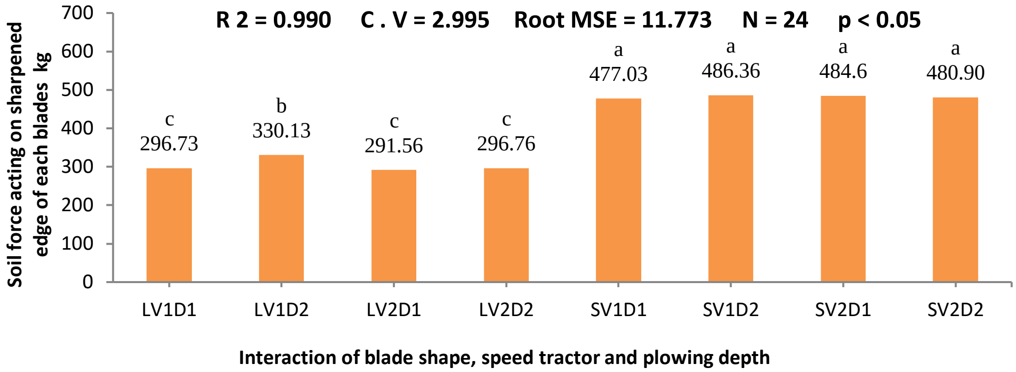


Figure (7):Interaction among blade shape, speed tractor and plowing depth in Soil force acting on sharpened edge of each blades

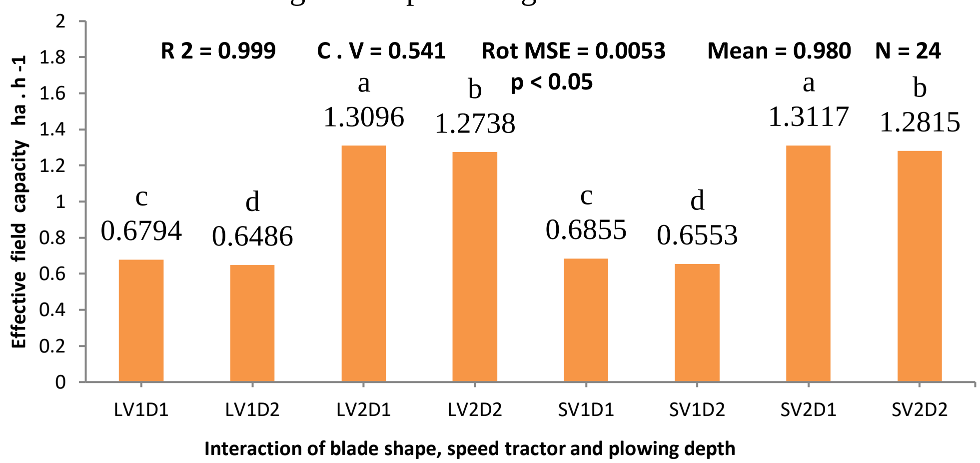


Figure (8): Interaction among blade shape, speed tractor and plowing depth in effective field capacity

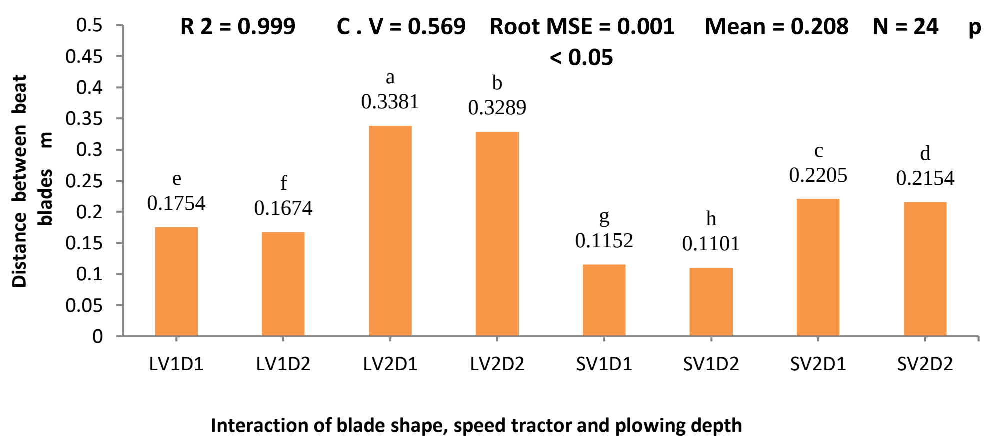


Figure (9): Interaction blade shape, speed tractor and plowing depth in distance between beat blades

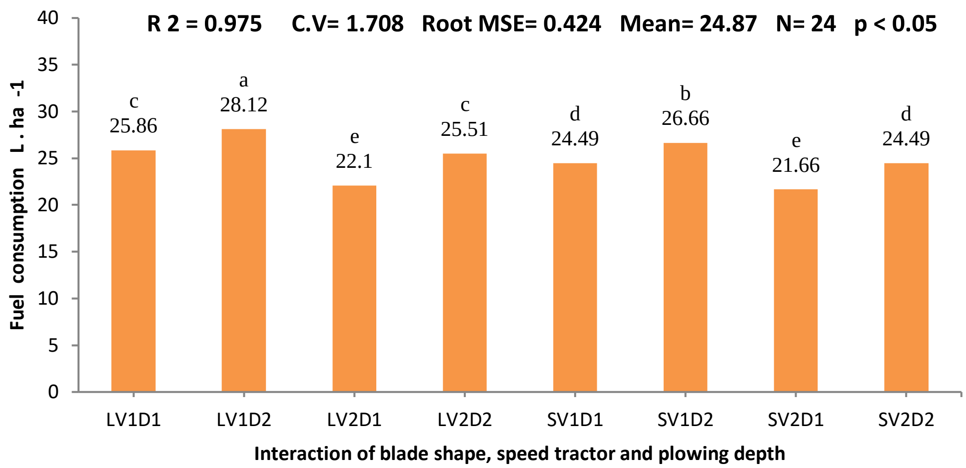


Figure (10): Interaction blade shape, speed tractor and plowing depth in fuel consumption

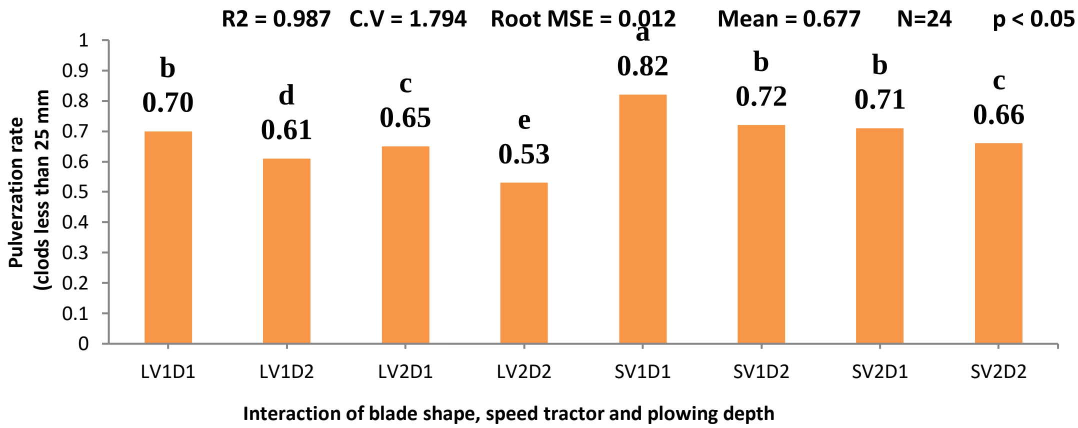


Figure (11): Interaction blade shape, speed tractor and plowing depth in pulverization rate.

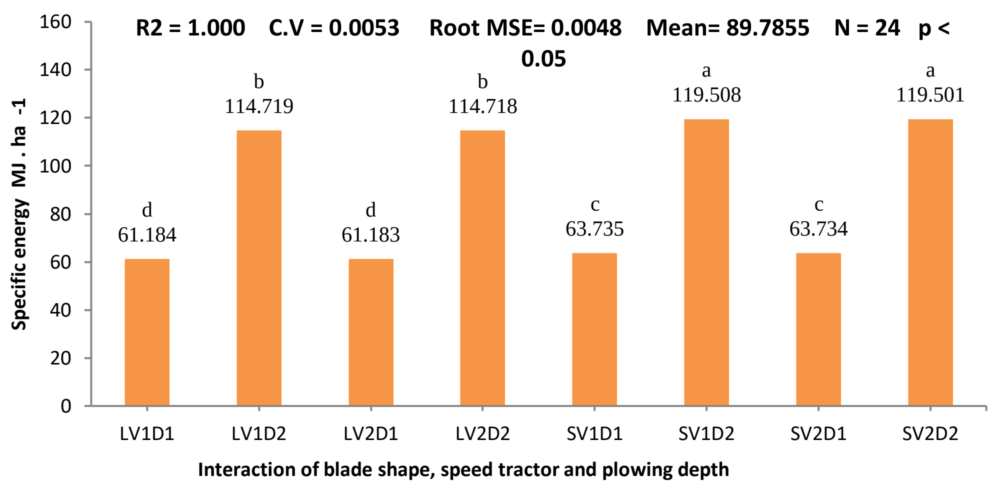


Figure (12): Interaction blade shape, speed tractor and plowing depth in specific energy

Correlation

Statistical analysis system SAS funded the correlation among the characteristics of the field experiment was significant and non-significant, as well as the presence of a direct (positive) and an inverse (negative) correlation as show in table 4. Highest significant direct correlation was between soil force acting on sharpened edge of each blades and maximum tangential force which was 1.0000 at L.S.D 0.01, and this explain the strong correlation which mean if the maximum tangential force increases, the soil force acting on sharpened edge of each blade also increases, because the maximum tangential force used in calculated soil force acting on sharpened edge of each blades according to equation (7), so the correlation is very strong between both of theme. Least significant inverse correlation was between the effective field capacity and pulverization rate was - 0.4302 at L.S.D 0.05. Non-significant correlations between fuel consumption and each of the pulverization rate, soil force acting on sharpened edge of each blades and maximum tangential force. Also non-significant correlation between the effective field capacity with the specific energy and maximum tangential force. Non-significant correlation between the specific energy and distance between beats blades.

Table (4): Correlation among indicator studied in the field experiment

	X1	X2	X3	X4	X5	X6	X7
X1	1.0000						
X2	-0.7213**	1.0000					
X3	0.6249*	-0.0498	1.0000				
X4	-0.1775	-0.0451	0.1261	1.0000			
X5	-0.4695*	0.8204**	-0.0777	-0.5841*	1.0000		
X6	-0.2040	**-0.4302***	-0.5100*	0.6286*	-0.6992**	1.0000	
X7	-0.1777	-0.0450	0.1260	**1.0000****	-0.5840*	0.6287*	1.0000

X1 Fuel consumption, X2 Effective field capacity, X3 Specific energy, X4 Maximum tangential force, X5 Distance between beat blades, X6 Pulverization rate, X7 Soil force acting on sharpened edge of each blades.

* Significant in L.S.D 0.05

** Significant in L.S.D 0.01

CONCLUSION

In light of this findings, concluded L blade rotary plow gave best pulverization and this related to the number of L blades in the flange, because of this, the distance between the blades was reduced. C blade rotary plow gave least values of maximum tangential force and soil force acting on sharpened edge of each blade. L blades rotary plow which contain 6 blades in each flange need specific energy more than C blades rotary plow which contain 4 blades in each flange. Increasing the tractor speed contributed to reducing fuel consumption and increasing the effective field capacity. Reducing the tractor speed making the distance between beat blades shortest, therefore the pulverization rat was increased. Moreover, concluded when used the depth of tillage 8 cm contributed to increase the effective field capacity, maximum tangential force, pulverization rate, Soil force acting on sharpened edge of each blades and specific energy. Depth of tillage 15 cm gave high fuel consumption. Kinematic ratio λ_{min} (rate of rotational flanges and forward speed tractor) and peripheral velocity of the rotor U_{min} has a role in determining maximum tangential force. Blade L was more soil disintegration comparing with C blade. Six blades in the flanges on the rotary plow has higher maximum tangential force, pulverization rate, short distances between the beats of the blades, soil force acting on sharpened edge of each blades and specific energy. The speed and depth had more influence on all indicators, than the blade shape factor. Finally, the correlation of the studied traits were significant and non-significant.

CONFLICTS OF INTEREST

The authors declare no conflicts of interest associated with this manuscript.

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