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EVALUATION OF THE PERFORMANCE OF NEW ROTARY PLOW BLADES (T-SHAPE) UNDER DIFFERENT LEVELS OF SOIL MOISTURE AND PLOWING DEPTHS AT SOME FIELD INDICATORS

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ABSTRACT

The study evaluates the performance of a new design of blades (T-shape) rotary plow. The field experiment was carried out on the farm of Al-Quba village, Nineveh, Iraq. In the present research, draft force (Df), energy requirement (RE), fuel consumption (FC), soil disturbed volume (SDV), and percentage of the soil clods which have a diameter of less than 5 cm (PSCD) were tested during three soil moisture content levels (10-12, 13-15, and 16-18) %, and two tillage depth levels (5-10, and 10-20) cm. and three rotation speeds of the blade's axis (140, 180, and 220) rpm. The results showed the superiority of soil moisture content (16-18) % with a rotation speed of (140) rpm and tillage depth (5-10) cm were recorded less Df (5.11) kN. The soil moisture content (16-18) % with a rotation speed of (140) rpm and tillage depth of (5-10) cm has recorded less ER (10.20) kw. hr. /ha. The soil moisture content (16-18) % with a rotation speed of (220) rpm and tillage depth of (5-10) cm has recorded less FC (4.10) L/ha. The soil moisture content (16-18) % with a rotation speed of (220) rpm and tillage depth of (10-20) cm has recorded the highest SDV (1237.77) m3/hr. The soil moisture content (10-12) % with a rotation speed of (220) rpm and tillage depth of (5-10) cm has recorded less PSCD (67.30) %.

INTRODUCTION

In Iraq, energy requirements and climate change have become more influential issues in crop production due to the increasing demand for the food requirements of the population. Besides, a gap in yield production. In addition, increasing the farm's operating costs (Central Statistical Organization CSO, 2019).

Generally, agricultural machinery is one of the largest energy consumers on a farm. Therefore, the efficiency of using energy sources for tillage tools must be more studied (Dahham, 2018).

Recently, soil preparation machines with rotating blades have gained more importance compared to drawn machines. Due to the possibility of transferring power with high efficiency by a power take-off, and control over the degree of pulverization (Kumar *et al*., 2023). On the other hand, the rotary plow is fundamentally different from the rest of the plows for design and soil-moving. As well as, its ability to prepare the seedbed in one pass eliminates the use of several machines in sequential operations such as plowing, smoothing, and leveling (Al-Azzawi and Zeinaldeen, 2023; Pacheco *et al*., 2023).

Moreover, rotary plow blade design depends on three basic factors: soil conditions, the shape of the blade, and the method of moving the soil. Therefore, the shape of the blade is the only factor that the designer is free to control, In addition, the angle of inclination of the blade in relation to the direction of movement. (Zhang *et al*., 2023., Wu *et al*., 2023) have designed and analyzed type (C- shape) rotary blades of rotary plows using finite element analysis software, where they found the cohesion of soil particles has the largest action on the rotation speed of the blade holder. (Ismailov, 2022) indicated the relationship between soil and the rotary plow blades depends on the rotation speed of the shaft bearing the blades, the curvature of the blade, and the size of the blade. Hendrick *et al*., (1971) found that to reduce draft force and power requirements, the rotary plows must operate at a slower speed on the tractor and high rotational speed on the blades. Kheiralla *et al*., (2017) concluded in a study conducted in Malaysia in sandy clay soil that the power required for the rotary plow increases as a result of increasing the forward speed of plowing, where the results indicated the highest draft force was (8.53) kN. at the rotation speed (200) rpm. Alavi and Hojati, (2012) studied the effect of the forward speed of the tractor, the blade rotation speed, and the soil moisture content in the soil cross-sectional area, and found that the soil cross-sectional area increased when the forward speed increased, Results show the forward speed of (2.23) km/h with a rotation speed of (183) rpm recorded less soil cross-sectional area (107.94) cm2, while the soil cross-sectional area was (163.14) cm2 at the forward speed of (3.41) km/h with a rotation speed (183) rpm. Sharda and Singh, (2004) found that the degree of fragmentation of soil is directly proportional to the speed of rotation of the rotary plow blades, and they concluded that the degree of fragmentation of soil is relatively better when using plow blades (L- shape) compared to the blades (C- shape), which gave a fragmentation of (1.7 and 2.7) mm at the speed of rotation of the shaft carrying the plow blades (185 and 210) rpm, respectively.

This paper considers the first study that lookup designed and manufactured blades (T-shaped) of the rotary plow in Iraq, and evaluates the performance of these blades (T-shaped) under moisture levels, rotation speed, and different tillage depths. Besides, these results could also facilitate future research into the improvement performance of the rotary plow.

MATERIALS AND METHODS

Field experiment and soil test

The field tests were conducted at the farm of Al-Quba village (34º72 N/36º22 E), Mosul City, Iraq. There were planted vegetables in the previous season before carrying out the test. The soil texture at the field test was silty loam. The measurement of the soil penetration index, soil bulk density, and soil moisture content was based on (Dane and Topp, 2020) as shown in Table (1).

Test Rotary plow

In this experiment, the rotary plow used was produced by Rama Company for the manufacture of agricultural equipment, the total number of blades (28), number of blades per disc (4), designed working width (138) cm, and plow mass (232) kg.

Tractor Massey Ferguson (75 HP) was used to draw and operate the plow in all treatments. These treatments were conducted at fixed forward speed of 3.95 Km/hr.

Table (1): Soil characteristics:

Soil depths (cm)	Soil moisture content (%)	Soil penetration index (kpa)	Bulk density ($mg.m^{-3}$)
0-5	10.17	1077.90	1.28
5-10	12.26	1227.40	1.31
10-15	16.35	1427.70	1.37
15-20	18.41	1732.60	1.42
Soil texture	Sand (%)	Silt (%)	Clay (%)
	27.25	52.50	20.25

The rotary plow blades were manufactured with the alloy metal 1340 Manganese steel in the form of (T-shape) by the researcher in the factory of Al-Shamal Company for mechanical industries in Mosul, Iraq. Figure.1 shows the dimensions of the manufactured blade.

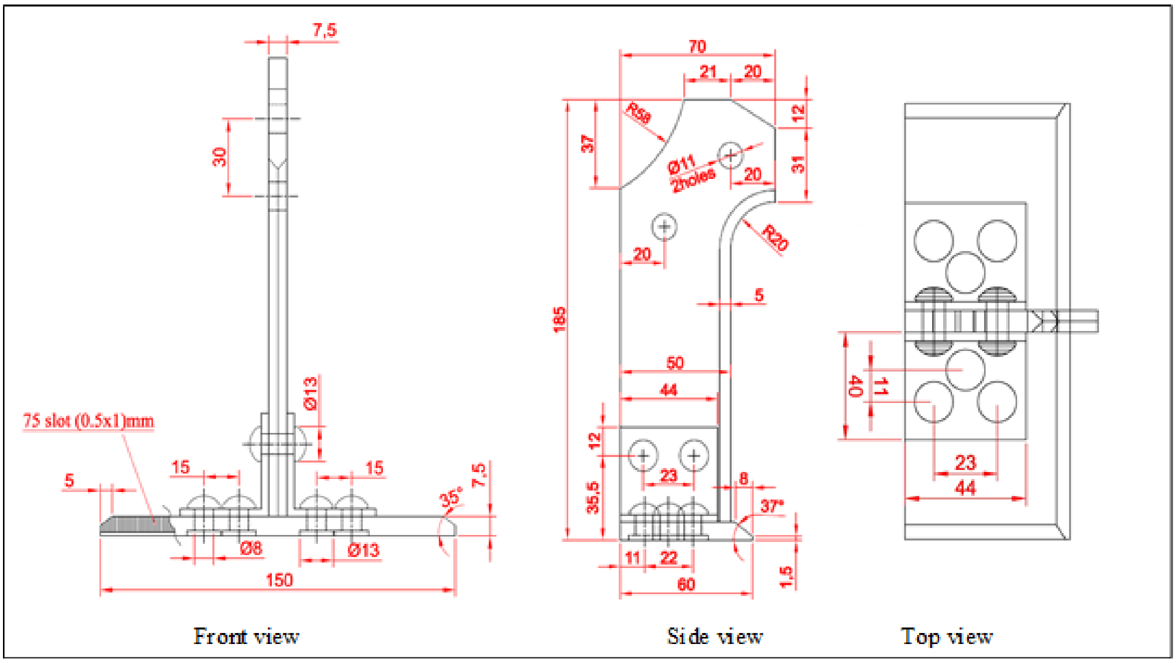

Figure (1): The dimensions of the rotary plow blade (T-shape).

Description of experiment factors

The experiment included three factors, which are the soil moisture content (10-12, 13-15, and 16-18) %, tillage depths (5-10, and 10-20) cm, and rotation speed (140, 180, and 220) rpm. According to the randomized complete block design (RCBD) for the split-split plot design. According to mathematical equations of the ASAE standard (American Society of Agricultural Engineers), the draft force was calculated, the following:(ASAE, 2000).

$$FT = F_i\ (A + B(V_p) + C(V_P)^2 \times B_P \times D_p$$

where FT: draft force(N); Vp: tillage speed (km/hr); Dp: tillage depth(cm); Bp: plow width (m); A, B, C: machine specific parameter; i: 1 for fine textural soil.

Soil disturbed volume: (Bukhari *et al*., 1988)

$$S.D.V = EFC \times d \times 100$$

where S.D.V: soil disturbed volume(m3/hr.); EFC: effective field capacity (ha/hr.); d: tillage depth (cm). The energy requirement (kW.hr. /ha): calculated according to the following equation:(Al-Janobi *et al*., 2020).

$$ER = \frac{F_t \times S}{3.6 \times \mathrm{EFC}}$$

where ER: energy requirement (kW.hr. /ha); Ft: draft force (kN); S: speed tillage (km/hr); EFC: effective field capacity (ha/hr.)

Fuel consumption (L/h)

The fuel consumption was measured using a graduated cylinder of 1000 ml with a base connected to the fuel tank of the tractor on the one hand and the filter of the tractor engine on the other. The fuel consumption was measured according to the following equation (Dahham, 2018):

$$FC = \frac{F_a \times 10000}{W \times L \times 1000}$$

where FC: fuel consumption (L/ha); Fa: The fuel consumed (tractor +plow) (ml); L: the treatment line Length (m); W: actual tillage width (m).

Percentage of the soil clods which have a diameter of less than (5 cm) of plowed soil (PSCB) was calculated at the depth of treatment, using the following equation (Dane and Topp,2020):

$$M(\%) = ((W_1 - W_2) \div W_1) \times 100$$

where M: Percentage of the soil clods which have a diameter of less than (5 cm) %; W1: Total sample weight (kg); W2: The weight of the sample whose diameter is greater than (5) cm.

RESULTS AND DISCUSSION:

There is a significant effect on each of the soil moisture content, plowing depths, and rotation speed of all the attributes in Table (2). P-values less than 0.05 indicate model terms are significant. In this case, A, B, C, AB, AC, BC, and ABC are significant model terms.

Table (2): Analysis of variances (ANOVA) statistic for the effect of soil moisture content, plowing depths, and rotation speed on all attributes.

Source	Term df	Error df	F-value	p-value	
Whole-plot	2	14.69	30320.06	< 0.0001	significant at 5%
C-Rotation speed	2	14.69	30320.06	< 0.0001	
Subplot	15	17.05	20928.29	< 0.0001	Significant at 5%
A-Soil moisture content	2	20.34	13036.46	< 0.0001	
B-Tillage depth	1	21.17	2.657E+05	< 0.0001	
AB	2	20.12	73.26	< 0.0001	
AC	4	19.95	70.70	< 0.0001	
BC	2	20.93	25.85	< 0.0001	
ABC	4	19.14	23.47	< 0.0001	

Draft force (Df)

As shown in Figures (2-A and 2-B), increasing the soil moisture content from (10 to 18) % resulted in a drop in draft force from (7.98 to 5.11) kN when the rotation speed is constant and a decrease from (7.91 to 6.87) kN when the tillage depths are constant. That is, the draft force follows an inverse relationship with soil moisture content levels; the greater the degree of soil drying, the larger the draft force required to plow that soil, leading to an increase in soil specific resistance (Ramadhan, 2014)**.**

Figures (2-A, and 2-C) show increasing tillage depths from (5 to 20) cm, leading to an increase in the draft force from (5.23 to 9.81) kN, when the rotation speed is fixed, while an increase from (4.67 to 7.93) kN when the soil moisture content is fixed. The reason for this is the increase in the specific resistance of the soil, as the draft force is directly proportional to the tillage depths (Campos-Magaña *et al.*, 2015) **.**

Furthermore, Figures (2-B, and 2-C) show increasing rotation speed from (140 to 220) rpm led to an increase in the draft force from (6.31 to 8.72) kN, when tillage depths are fixed, while an increase from (4.43 to 9.33) kN when the soil moisture content is fixed. Due to given high acceleration of the soil particles during their replacement (Naderloo *et al.*, 2009)**.**

Figure (2-A, 2-B, and 2-C) results indicate, the interaction of soil moisture content (16-18) % with a rotation speed of (140) rpm and tillage depth (5-10) cm has registered less draft force of (5.11) kN, while the highest draft force (10.15) kN, was recorded at interaction soil moisture content (10-12) % with a rotation speed of (220) rpm and tillage depth (10-20) cm.

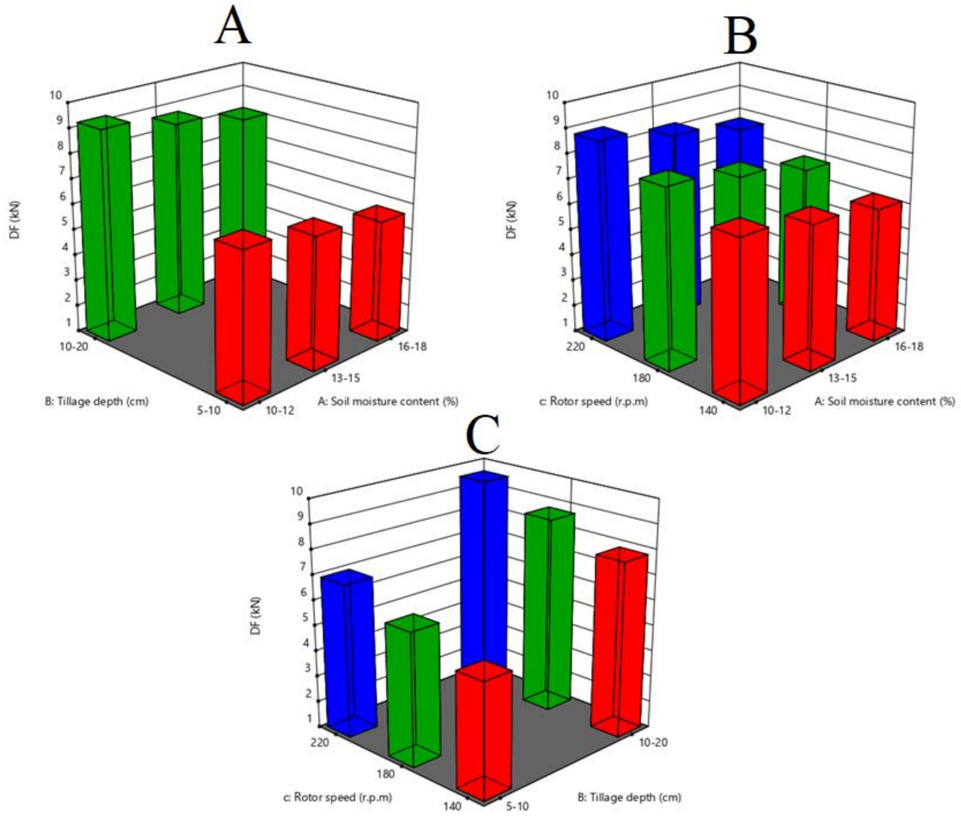

Figure 2: The soil moisture content, tillage depths, and rotation speed of the attribute of draft force (Df).

Energy Requirement (ER)

Figure (3-A, and 3-B) indicates, increasing the soil moisture content from (10 to 18) % led to a decrease in the energy requirement from (18.16 to 10.43) kW. hr. /ha, when the rotation speed is fixed, while a decrease from (17.81 to 12.11) kW. hr. /ha when tillage depths are fixed. This is due to the decrease in specific resistance soil with an increase in the soil moisture content, this leads to a decrease in the amount of fuel consumed, thus a decrease in energy requirements (Abbaspour-Gilandeh *et al*., 2006).

Figure (3-C) shows, increasing both tillage depths from (5 to 20) cm and rotation speed from (140 to 220) rpm led to an increase in the energy requirement from (7.89 to 15.83) kW.hr. /ha, and from (8.12 to 14.92) kW.hr. /ha respectively. The reason for this is the increase in both tillage depths and rotation speed is accompanied by an increase in the specific resistance of the soil, which leads to an increase in the amount of fuel consumed as a result of an increase in the percentage of slippage, thus an increase in energy requirement.

Figures (3-A, 3-B, and 3-C) results indicate, the interaction of soil moisture content (16-18) % with a rotation speed of (140) rpm and tillage depth of (5-10) cm has registered less energy requirement of (10.20) kW. hr. /ha, while the highest energy requirement (20.43) kW. hr. /ha was recorded at interaction soil moisture content (10-12) % with a rotation speed of (220) rpm and tillage depth (10-20) cm.

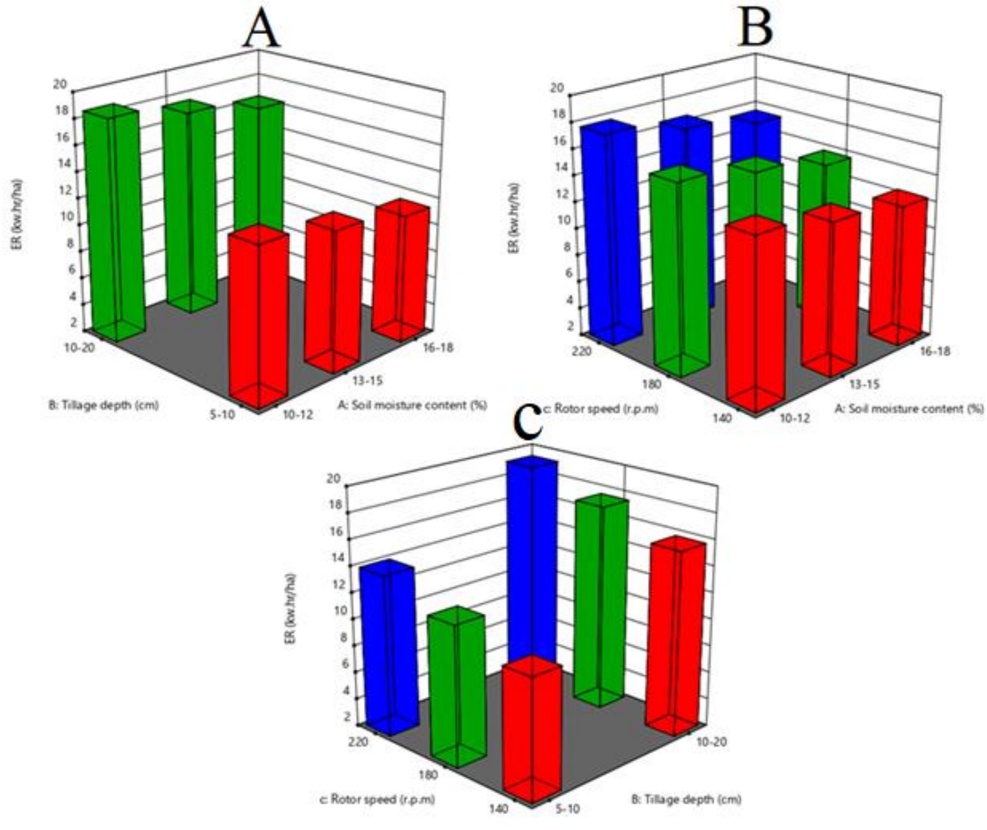

Figure 3: The soil moisture content, tillage depths, and rotation speed of the attribute of energy requirement (ER).

Fuel consumption (FC)

Figure (4-A, and 4-B) shows, increasing both soil moisture content from (10 to 18) % and rotation speed from (140 to 220) rpm led to a decrease in fuel consumption from (5.81 to 4.26) L/ha, and from (5.10 to 4.78) L/ha respectively. The reason is that the increase in both the soil moisture content and rotation speed leads to optimal exploitation of the tractor capacity, then a reduction in the time required to complete the agricultural process, thus a decrease in the amount of fuel consumed**.**

Figure (4-A, and 4-C) shows increasing tillage depths from (5 to 20) cm led to an increase in the fuel consumption from (4.47 to 5.75) L/ha, when the rotation speed is fixed, while an increase from (4.10 to 5.50) L/ha when the soil moisture content is fixed. The reason for this is the increase in the specific resistance, and an increase in the percentage of slippage, which led to an increase in fuel consumption.

Figures (4-A, 4-B, and 4-C) results indicate, the interaction of soil moisture content (16-18) % with a rotation speed of (220) rpm and tillage depth of (5-10) cm has registered less fuel consumption of (4.10) L/ha, while the highest fuel consumption (6.25) L/ha, was recorded at interaction soil moisture content (10-12) % with a rotation speed of (140) rpm and tillage depth (10-20) cm.

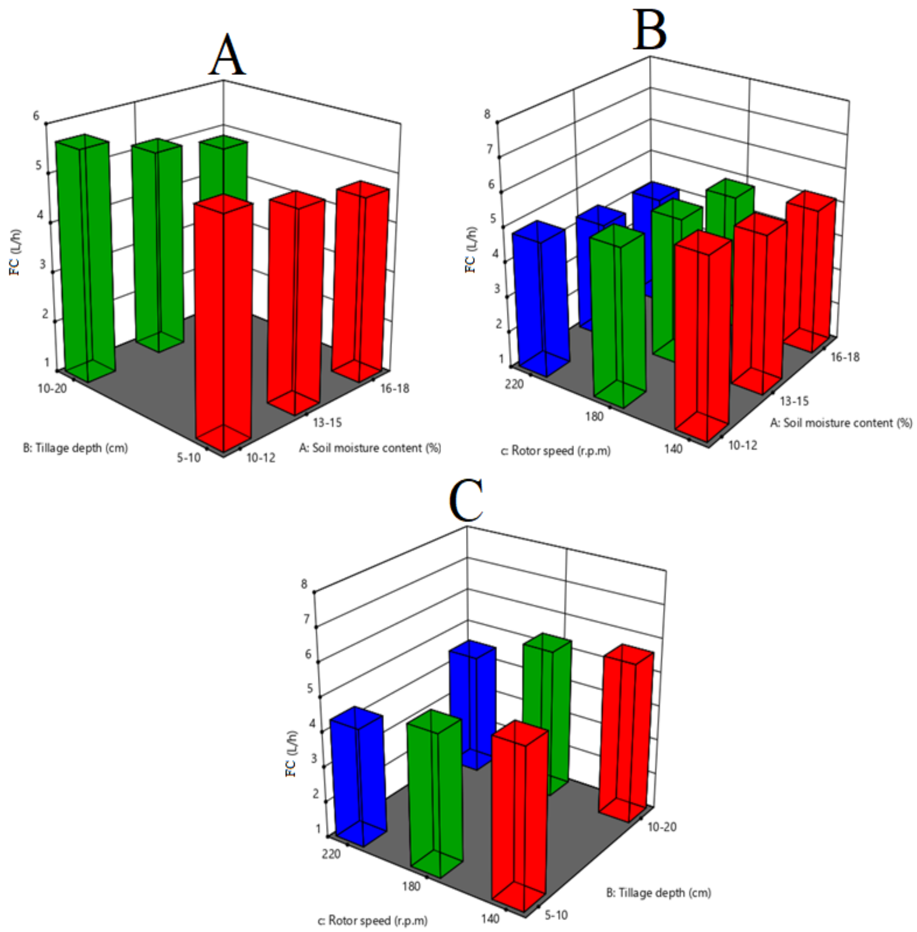

Figure 4: The soil moisture content, tillage depths, and rotation speed of the attribute of Fuel consumption (FC).

Soil Disturbed Volume (SDV)

Figure (5-A, and 5-B) shows, increasing the soil moisture content from (10 to 18) % led to an increase in the soil disturbed volume from (567 to 910) m3/hr, when the rotation speed is fixed, while increases from (356 to 893) m3/hr when tillage depths are fixed. Due to a decrease in the percentage of slippage, this led to an increase in the soil disturbed volume**.**

Figure (3-C) shows, increasing both tillage depths from (5 to 20) cm and rotation speed from (140 to 220) rpm led to an increase in the soil disturbed volume from (376 to 600) m3/hr, and from (550 to 1150) m3/hr respectively. The reason for this is both tillage depth and rotation speed are components of the disturbed volume**.**

Figures (5-A, 5-B, and 5-C) results indicate, the interaction of soil moisture content (16-18)% with a rotation speed of 220 rpm and tillage depth of (10-20) cm has registered the highest soil disturbed volume of (1237.77) m3/h, while the less the soil disturbed volume (342.79) m3/h, was recorded at interaction soil moisture content (10-12)% with a rotation speed of (140) rpm and tillage depth (5-10) cm.

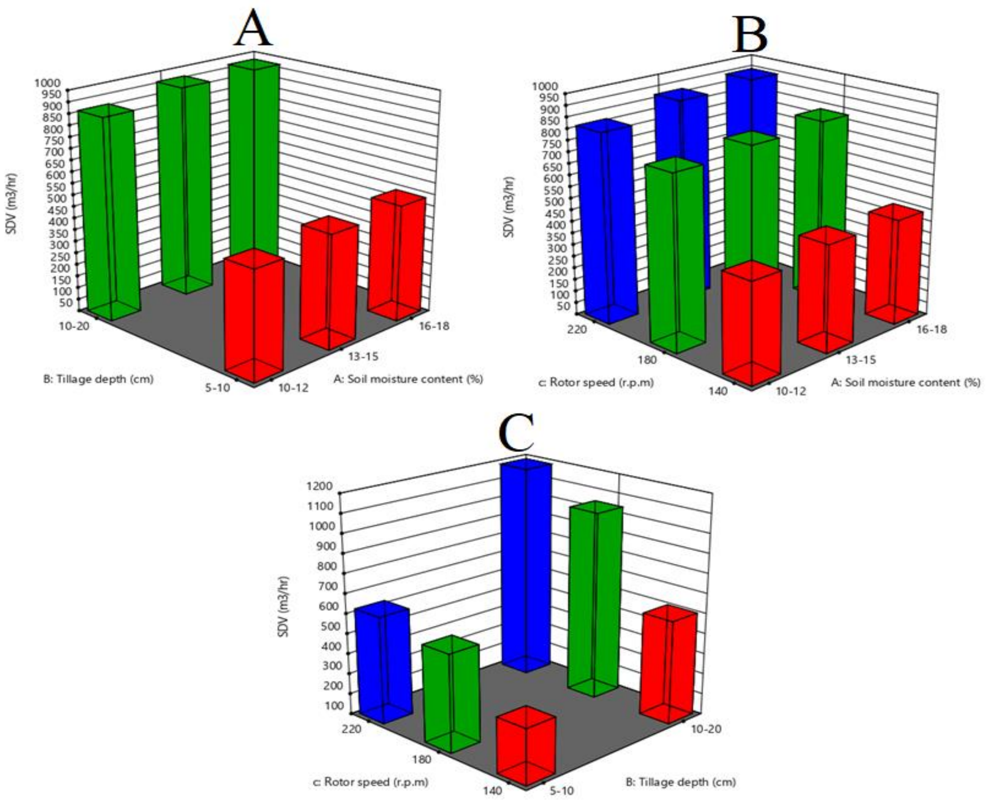

Figure 5: The soil moisture content, tillage depths, and rotation speed of the attribute of soil disturbed volume (SDV).

Percentage of the soil clods which have a diameter of less than (5 cm) (PSCD)

Figure (6-A, and 6-B) shows, increasing both soil moisture content from (10 to 18) % and tillage depths from (5 to 20) cm led to an increase in the percentage of the soil clods which have a diameter of less than (5 cm) from (62 to 91) %, and from (68 to 96) % respectively. The reason tillage depth led to increased soil moisture, and thus the cohesion of the soil particles increased, which led to an increase in the percentage of the soil clods which have a diameter of less than (5 cm).

Figure (6-C) shows, increasing the rotation speed from (140 to 220) rpm led to a decrease in the percentage of the soil clods which have a diameter of less than 5cm from (90 to 70) %. Because of the increase in the rotation speed, led to an increase in the impact of the plow blades on the dirt blocks, thus increasing the dismantling of the dirt blocks, and decrease in the percentage of the soil clods which have a diameter of less than 5cm.

Figures (6-A, 6-B, and 6-C) results indicate, the interaction of soil moisture content (16-18)% with a rotation speed of (140) rpm and tillage depth of (10-20) cm has registered the highest percentage of the soil clods which have a diameter of less than 5 cm (97.45)%, while the less the percentage of the soil clods which have a diameter of less than 5 cm (67.30)%, was recorded at interaction soil moisture content (10-12)% with a rotation speed of (220) rpm and tillage depth (5-10) cm.

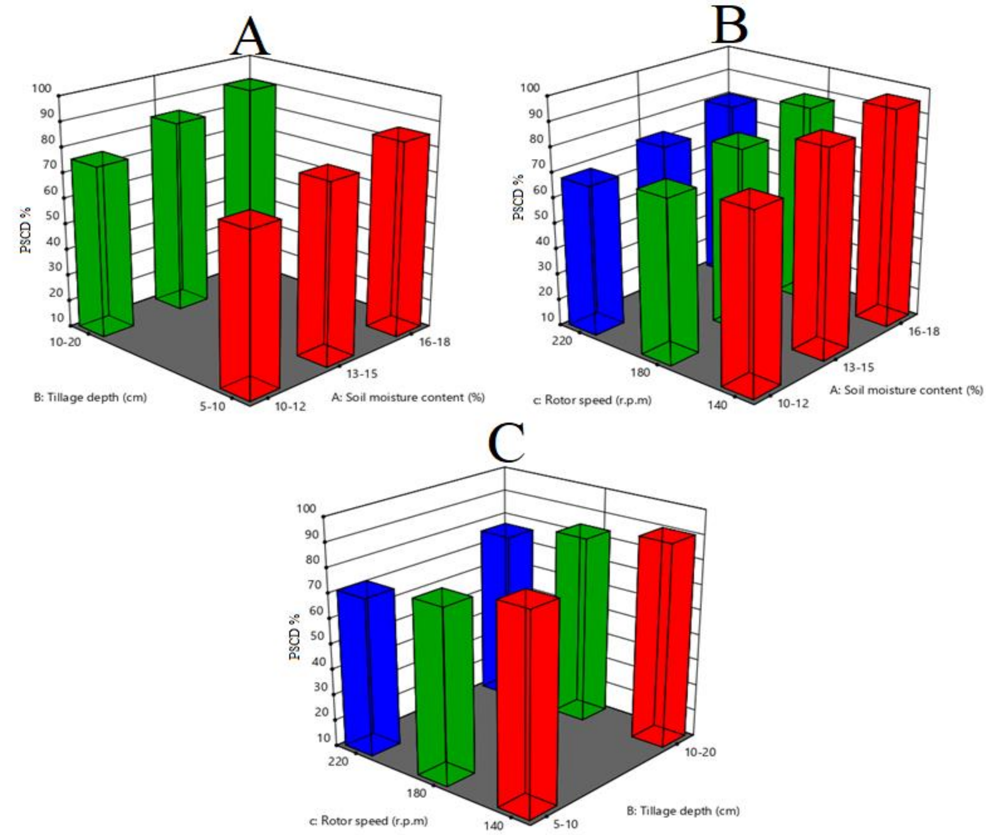

Figure 6: The soil moisture content, tillage depths, and rotation speed of the attribute of percentage of the soil clods which have a diameter of less than 5cm (PSCD).

CONCLUSIONS

The study was conducted under field conditions influenced to test the performance of a T-shaped rotary blade plow under different levels of soil moisture content, plowing depth, and rotational speed in some of the studied indicators. The following conclusions can be drawn from the results; When soil moisture content increases, draft force, energy requirement, and fuel consumption decrease. However, the increase in soil moisture content leads to an increase in disturbed soil volume and the percentage of soil clods that have a diameter of less than (5) cm. Increased rotation speed results in an increase in draft force, energy requirement, and soil disturbed volume. However, the increase in rotational speed results in a decrease in fuel consumption and in the percentage of soil clods with a diameter of less than (5) cm. It has been established that the increase in tillage depths results in an increase in draft force, energy requirements, fuel consumption, soil disturbed volume, and the percentage of soil clods with a diameter of less than (5) cm. It appears that T-shaped blades provide several benefits, including low energy consumption and effective soil loosening ability. Moreover, these results may facilitate future research on the optimal utilization of the rotary plow.

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CONFLICT OF INTEREST

The authors state that there are no conflicts of interest with the publication of this work.

تقييم أداء اسلحة المحراث الدوراني الجديدة (T-SHAPE) تحت مستويات مختلفة من رطوبة التربة وأعماق الحراثة في بعض المؤشرات الحقلية

ليث محمود يحيى
قسم المكائن والآلات الزراعية/ كلية الزراعة والغابات / جامعة الموصل / الموصل / العراق

الخلاصة

تتضمن الدراسة تقييم اداء اسلحة المحراث الدواني على شكل حرف (T). حيث نفذت التجربة فى احد حقول قرية الكبة الواقعة شمال محافظة نينوى/العراق، حيث شمل البحث قياس مؤشرات متطلبات القدرة والتي تمثلت بقياس قوة السحب و متطلبات الطاقة و استهلاك الوقود، و قياس مؤشرات الاداء الحقلي والتي تمثلت بقياس حجم التربة المثار و نسبة عدد الكتل الترابية التي اقطرها اقل من (5) سم، تحت تأثير ثلاث مستويات من المحتوى الرطوبي للتربة (10-12)% و(13-15)% و(16-18)%، وعمقي حراثة (5-10) سم و (10-20) سم، وثلاث سرع دوران للمحور الحامل للاسلحة (140،180،220) دورة/دقيقة. أظهرت النتائج أن جميع التداخلات بين (المحتوى الرطوبي واعماق الحراثة وسرعة الدوران الاسلحة) له تأثير معنوي في جميع الصفات المدروسة. حيث تفوق المحتوى الرطوبي (16-18) مع سرعة دوران (140) دورة/دقيقة عند عمق حراثة (5-10) سم في تسجيل اقل قوة سحب ومتطلبات طاقة كانت (5.11) كيلونيوتن و(10.20) كيلوواط.ساعة/هكتار على التوالي. في حين تفوق المحتوى الرطوبي (16-18)% مع سرعة دوران (220) دورة/دقيقة عند عمق حراثة (5-10) سم في تسجيل اقل استهلاك للوقود كانت (4.10) لتر/هكتار. بجانب ذلك تفوق المحتوى الرطوبي (16-18)% مع سرعة دوران (220) دورة/دقيقة عند عمق حراثة (10-20) سم في تسجيل اعلى قيمة لحجم التربة المثار بلغت (1237.77) مترمكعب/ساعة. علاوة على تفوق المحتوى الرطوبي (10-12)% مع سرعة دوران (220) دورة/دقيقة عند عمق حراثة (5-10) سم في تسجيل اقل نسبة عدد كتل ترابية التي اقطرها اقل من (5) سم بلغت (67.30)%. وفقا للنتائج اعلاه يتبين أن الشفرات على شكل حرف T لها العديد من المزايا، من بينها تفكيك التربة بشكل جيد مع الحد الأدنى من متطلبات الطاقة. إلى جانب ذلك، يمكن أن تسهل هذه النتائج أيضًا البحث المستقبلي في تحسين اداء المحراث الدوارني.

الكلمات المفتاحية: قوة السحب، متطلبات الطاقة، استهلاك الوقود، شفرات المحراث الدوار، محتوى رطوبة التربة.

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