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ENERGY REQUIREMENTS FOR OPERATING THE ROTARY PLOW UNDER EGYPTION CONDITIONS

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ABSTRACT

The experiments were carried out at the farm of El-Gimmaza Research Station, El-Gharbia Governorate , on clayey soil .

The field study was conducted to determined the energy requirements for operating the rotary plow as primary and secondary tillage machin under Egyption conditions .

The results indicated that , the energy requirement for operating the chisel plow the equivalent of 67% from the energy requirement rotary plow at the same operating speed and soil conditions .The rotary plow produce a suitable seedbed without a secondary tillage operation . Therefore , the use of rotary plow to prepare a suitable seedbed as secondary tillage need the energy equivalent to 82 % of the energy needed using the chisel plow for seedbed preparation.

INTRODUCTION

The most important effect on crop production economy is the energy requirements. The efficiency of using the energy sources of agricultural machinery needed more studied. Primary tillage has always been one of the largest power consuming operations on a farm. Thus, it is the operation that most influences the amount of the power unit required for the total farm operation. Increases field capacity achived by increasing the machine width or by increasing the plowing speed. The specific energy affected the field capacity. Rotary tools, reduce the draft requirements and have greater versatility in manipulating the soil to obtain the desired results, and it also reduces the time required to get an optimum seedbed by combining the primary and secondary tillage operations. This allows the farmer to increase his farm acreage which becomes less dependent on hired farm labor, performs operations more timely and obtains higher yields.

The power requirements for soil pulverization increases with forward speed, Karahashi *et al*. (1984), Triplett and Sprague (1986). Minimum tillage due to its minimum soil disturbance, lower cost and less fuel consumption is considered as long as there is no general compaction in the topsoil to be removed. In this case, the principle of tilling the soil from the top down should be adopted to produce fine seedbeds. In the first pass, a shallow cultivation is performed; then, in the second pass, the working depth of the tillage implement is increased. This is expected significantly to reduce the size of clods and also produce a firmer seedbed when compared with plowing since the shallow depth of tilled soil reacts well to consolidation (Ward *et al.*, 1985, cited by Hemmat, 2009).

The clods mean weight diameter decreases with plowing speed, but in case of using rotary plow, the clods mean weight diameter increases with forward speed Hamad *et al.* (1992). Abdel-Mageed and El-Sheikha (1993), evaluated an active-passive implement for conservation tillage production for flax, they reported that, the clods mean weight diameter (M.W.D.) increases with the increase of tilling depth under different tillage treatments,and also the rotary tiller alone gave the highest pulverization of soil, and the least pulverization was presented by the treatment of chisel plow and rotary tiller in separate trips.

Abo-Habaga (1994) identified the influence of the kinematic parameters (λ = R/F) of a rotary tiller on the seed-bed quality. The kinematic parameters of 2.58, 2.82, 2.84, 3.17.and 2.31, 2.54, 2.72, 3.04 at ploughed and un-ploughed soil respectively. He reported that, the treatment were used (R1/F2) with theoretical kinematic parameters of rotary tiller (3.04) was considered the suitable rotary tiller speed ratio for operation at ploughed and un-ploughed soil. It recorded a seed-bed with lower clods mean weight diameter, soil surface roughness, torque requirement, each of soil shear and penetration resistance , and also high soil surface stability and pulverization .

When operating the power tiller, the clods mean weight diameter decreases with the increase of speed ratio (λ). By other means it increases as the forward speed increases. While the soil pulverization ratio ($\varphi \leq 22$ mm) increases with the increase of speed ratio (λ) . Khadr (1997).

Peruzzi *et al.* (2000), carried out experimental tests with two different adjustments of the machines and in three different operative conditions (clay and sandy-loam ploughed soil and untilled sandy soil). The results emphasized that the new rotary hoe recorded lower values of fuel consumption, specific power and specific energy with respect to the conventional implement; while the quality of work (clod size distribution, soil roughness, degree of biomass burying, etc.) of the two hoeing machines used with the same adjustment was never significantly different in any of the three operative conditions.

Helmy *et al.* (2001) found that the rotary plow gave the lowest fuel consumption and energy requirements compared with the chisel plow (one pass), chisel plow (two passes) and moldboard plow followed by disk harrow. Where the energy requirements were 12.28, 13.35, 23.80 and 37.87 kWh/fed for rotary plow, chisel plow (one pass), chisel plow (two passes) and moldboard plow followed by disk harrow respectively.

Khadr *et al.*, (2008) reported that the highest energy value was 76.87 MJ/fed using the rotary tiller while the corresponding energy values were 38.23, 38.71 and 43.24 MJ/fed for chisel plow 2nd pass, disc harrow and chisel plow 1st pass respectively.

MATERIALS AND METHODS

Field experiments:-

Field experiments were carried out at the farm of El-Gimmza Research Station, El-Gharbia Governorate, on clayey soil. The experiment area about 0.85 feddan (45× 80 m) was divided into 6 plots .The experimental treatments consisted of the following :

1 – Chisel plow once followed by rotary tiller (CH. R.) { reduced tillage}
2 – Rotary tiller (R.) {minimum tillage} .

Clods size distribution:

The clod size was measured according to Pucrliner (l923) using an apparatus consisting of six different sieves mounted on each other and. installed on a. frame, The soil samples were taken from 5 different pieces after treatment and were left to dry in air. After sieving all the Individual fractions they were weighed and -converted as a percentage of total sample weight. The mean weight Diameter (M.W.D.) of the soil clods was calculated using the following equation according to Van Bavel(1949):

$$\mathbf{M.W.D.} = \sum_{I=1}^{n} x_i \cdot w$$

where:

x_i: The mean diameter of each size fraction ,(mm.).

w_i: The proportion on the total sample weight occurring in the corresponding size fraction, where the summation is carried out over all n size fraction, including the one that passes through the finest sieve-.

Field capacity determination:

The field capacity was calculated according the following formula:

$$\text{Theoretical field capacity} = \frac{\text{Plowing width (m)} \times \text{speed} (\text{m.s}^{-1}) \times 3.6}{4.2} \ \text{feddan.h}^{-1} \ldots\ldots(1)$$

Actual field capacity = 1÷ Total tillage time , h feddan. h^{-1} ………..(2)

Total tillage time = Theoretical tillage time + losses time

Plowed soil volume rate (V) determination

It was determined according the following formula:

$$V = \frac{D(\text{m}) \times \text{actual field capacity}(\text{feddan.h}^{-1}) \times 4.2}{3.6} \quad \text{m}^3.\text{s}^{-1} \ldots\ldots\ldots\ldots\ldots(3)$$

Where:

V : the plowed soil volume rate, $m^3.s^{-1}$.

D : the plowing depth, m.

Fuel consumption rate measurement:

A local manufactured fuel meter Fig. (1) was connected with the fuel pipeline instead of the tractor fuel tank. A stopwatch was used to determine the time for a certain fuel volume consumed by the tractor with the nearest cubic centimeter which controlled with a control valve. From the time and the fuel volume consumption, The fuel consumption rate ($L.h^{-1}$) was determined with the same method and the same instrumentation used by Khadr (2004). It could be determined as follow:

$$\text{Fuel consumption rate} = \frac{\text{Fuel volume consumption, cm}^3 \times (10^{-3}\ \text{Liter/cm}^3)}{\text{Fuel consumption time, s} \times (3.6 \times 10^3)^{-1}\ \text{h/s}}, \ \text{Liter.h}^{-1} \ldots(4)$$

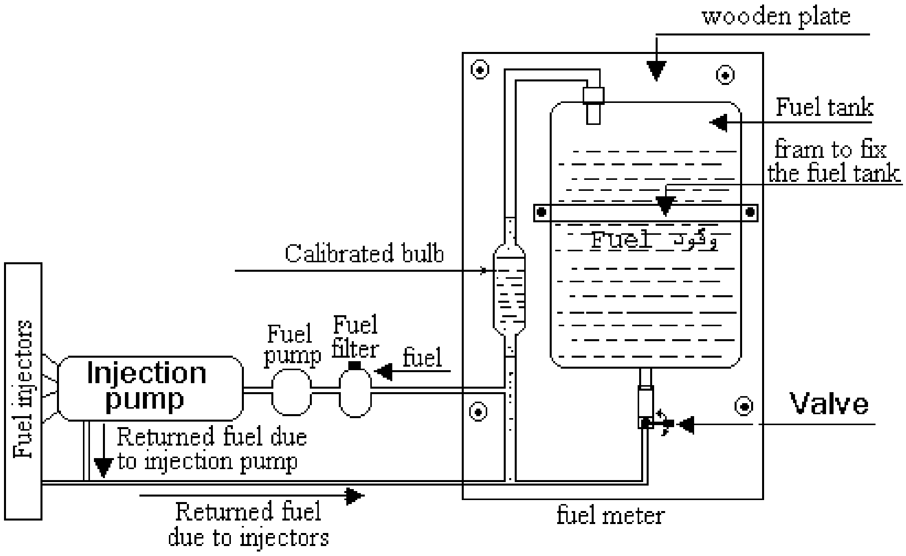

Fig. (1): Sketch drawing of the fuel meter connected with the tractor fuel system.

Power determination:

As mentioned by (Hunt, 1983), the power required for plowing the soil is predicted from the fuel consumption by the following equation:

$$\text{Thermal efficiency } (\zeta_{th}),\% = \frac{P \times C}{FC \times \text{Fuel heating value (HV)}} \quad \ldots(5)$$

$$(\zeta_{th}),\% = \frac{P\,(kW) \times 3600\,(s.h^{-1})}{FC\,(kg.h^{-1}) \times 11 \times 10^{3}\,(k\,Cal.\,kg^{-1}) \times 4.187\,(kJ.\,k\,Cal^{-1})} \quad \ldots(6)$$

Where:

P: brake power, kW.,

C: constant

(ζth) : Thermal efficiency, it is assumed to be equal 30%.

FC : Fuel consumption, $kg.h^{-1}$.

Assuming that the lower colorific value for the fuel = 11×10^{3} k $Cal.kg^{-1}$.

Specific power determination:

The specific power is the power needed for plowing and pulverizing a unit area. It was calculated as follow:

$$Sp.power = \frac{\text{Needed brake power, kW} \times (10^{3}\,W/kW)}{\text{Plowed soil cross sectional area, } cm^{2}}, \ W.cm^{-2}. \quad \ldots(7)$$

Specific energy (SEA and SEV) determination:

The specific energy (SEA) was determined by dividing the drawbar power required for plowing and disturbing the soil per the actual field capacity ($feddan.h^{-1}$), and also the specific energy (SEV) which is the energy required for plowing a unit volume from the soil (m^{3}) was determined by dividing the drawbar power per the plowed soil volume rate ($m^3.s^{-1}$). The following formulas were used to determine the specific energy (SEA and SEV).

$$\text{Specific energy per area (S.EA)} = \frac{\text{Power (kW)} \times 3.6}{\text{field capacity (feddan.h}^{-1})} \quad \text{MJ.feddan}^{-1} \qquad \ldots(8)$$

$$\text{Specific energy per volume (SEV)} = \frac{\text{SEA (MJ.feddan}^{-1}) \times 10^2}{4.2 \times \text{Actual plowing depth (cm)}}, \quad \text{kJ.m}^{-3} \qquad \ldots.(9)$$

RESULTS AND DISCUSSION

Fuel consumption:

Datad in Fig. (2) indicated the effect of plowing speed on the fuel consumption . The results show that , the tractor fuel consumption increases with the increase of plowing speed in case of using chisel plow and rotary plow as primary and secondary tillage tools.

The tractor fuel consumption increased from 9.10 to 9.63 , 10.20 – 8.90 to 9.44 , 10.10 and 14.90 to 15.71,16.60 as the plowing speed increased from 3.0 to 3.4 and 3.8 km.h^{-1} in case of using chisel plow and rotary plow as a secondary and primary tillage respectively.

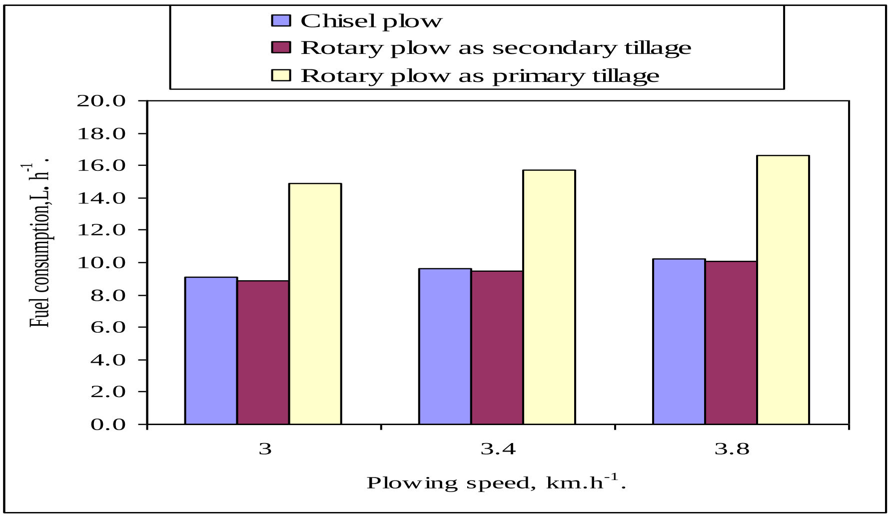

Fig. (2): Effect of plowing speed on tractor fuel consumption for three tillage systems

It may be noticed also that, for operating the rotary plow, the tractor consumes fuel consumption more than that consumes for rotary after chisel plow and rotary after chisel plow at each operating speed. That may return to the effect of more soil pulverization at a constant plowing depth compared with the chisel plow that even the rotary plow works at a depth less than the chisel plow.

Power requirements:

The tractor power requirements has been determined through the experimentally tractor fuel consumption rate calculation at operating plowing speed. The effect of plowing speed on tractor brake power for operating both of chisel plow and the rotary plow as a secondary and primary tillage isillustrated in Fig. (3).

The power increased from 34.93 to 36.96 , 39.15 - 34.16 to 36.23 , 38.67 and 57.19 to 60.30 , 73.71 KW as the plowing speed increased from 3.0 to 3.4 and 3.8 km.h^{-1} in case of using the chisel plow and the rotary plow used as secondary and primary tillage implement . It may be noticed that the power requirements increase with speed at the different operating implement conditions.

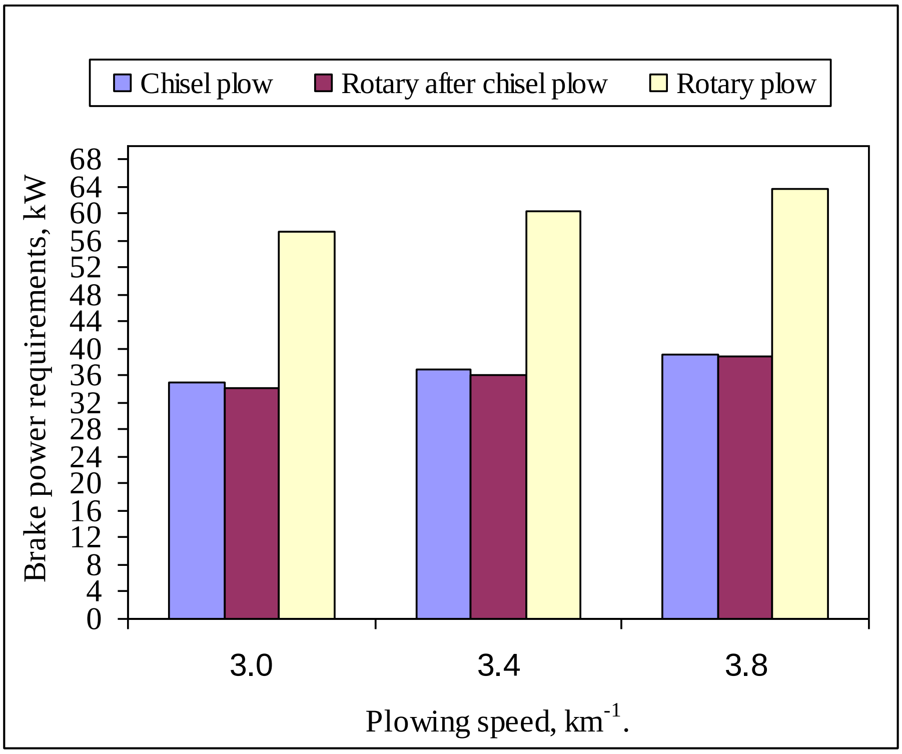

Fig. (3): Effect of plowing speed on tractor power requirements for three tillage systems.

The rotary plow needs more power compared with chisel plow and rotary plow used as a secondary tillage implement at the same operating speed levels. The power needed for operating the implement increases with plowing speed that may return to the increases of soil pulverization, which needed more power in case of using chisel plow as a primary tillage implement. And the increases of power for operating the rotary plow with the increase of forward speed may due to the increase of plowing pitch.

Specific energy:

The specific energy requirements are the energy needed to pulverize a unit area from the field (SEA) or the energy required to pulverize the unit volume from the soil (SEV). Energy has been estimated for tillage system (chisel plow + rotary plow) used as reduced tillage system and rotary plow used as minimum tillage system.

AS Indicated in Fig. (4), the energy (SEA) for operating tillage systems decreased with the increase of forward speed, that in both of reduced tillage system and minimum tillage system. It may be to that, rate of field capacity decreases is higher than the decreasing rate of power with the increased forward speed. The specific energy decreased from 248.71 to 232.49 , 221.43 MJ.feddan^{-1} and from 205.87 to 191.53 , 181.08 MJ.feddan^{-1} as the operating speed increased from 3.0 to 3.4 , 3.8 km.h^{-1} for both of reduced tillage system and minimum tillage system respectively. Also the results showed that the specific energy for minimum tillage system is less than the reduced tillage system at the same operating speed. Using minimum tillage system reduced the specific energy (SEA) than the reduced tillage system by 17.22, 17.62 and 18.22% at operating speeds 3.0, 3.4 and 3.8 km.h^{-1} respectively. These results are valid at the operating field condition and the speeds rate.

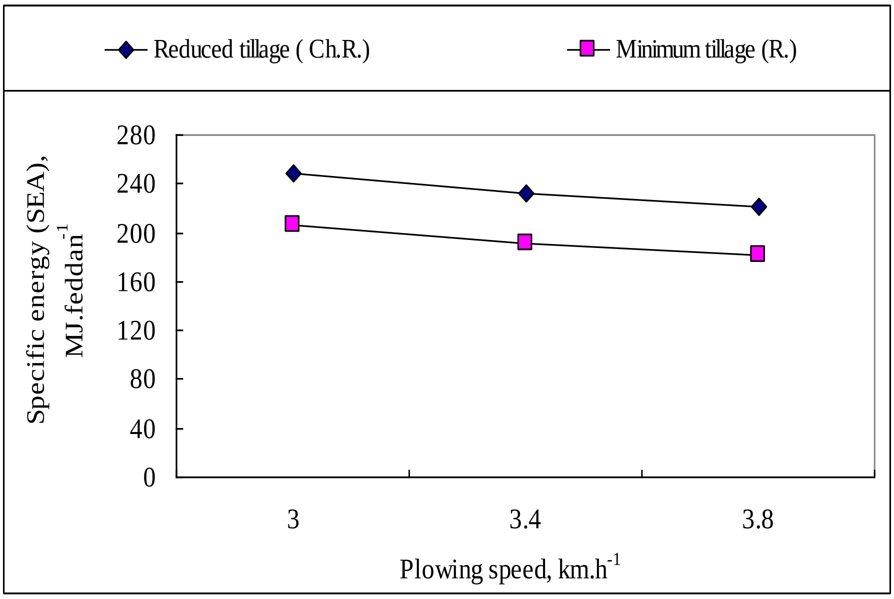

Fig. (4): Effect of plowing speed on specific energy for tow tillage systems.

Clods mean weight diameter (M.W.D.):

The clods mean weight diameter is an indicator of seedbed preparation quality. As indicated in Fig. (5), the clods mean weight diameter decreased as the plowing speed increased , that in case of using chisel plow, while it increased as the plowing speed increased in case of using the rotary plow, that may be return to the increases of plowing pitch. The clods mean weight diameter in case of using rotary plow used as secondary tillage is less than that for chisel plow, this returns to more pulverization by the rotary plow for the plowed soil with chisel plow.

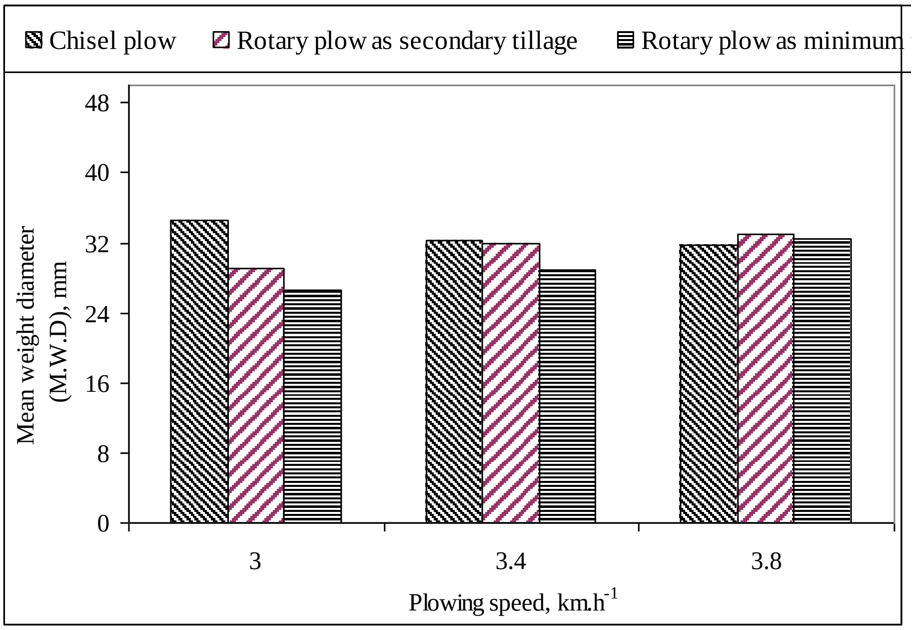

Fig. (5): Effect of plowing speed on clods mean weight diameter for three tillage systems .

The clods mean weight diameter for the rotary plow used as a minimum tillage implement is less than that used as secondary tillage implement, that also may return to the soil plowed depth by the chisel plow is higher than the plowed depth by the rotary, that causes a part from the plowed soil with the chisel doesn't pulverized with the rotary plow as secondary tillage implement.

For chisel plow, the clods mean weight diameter decreased by 16.03% as the plowing speed increased from 3 to 3.8 km.h^{-1}, but it increased by 13.96%, 22.18% as the plowing speed increased from 3 to 3.8 km.h^{-1} in case of using rotary plow as secondary tillage implement after chisel plow and rotary plow used as primary tillage respectively.

The relationship between mean weight diameter and specific energy:

Energy for soil pulverization classified to energy required for plowing a unit area from the soil (SEA) and Energy per unit volume from the soil.

As shown Fig. (6), the clods mean weight diameter has a reverse relationship with the energy required for plowing a unit area, as the soil mean weight diameter increased from 29.01 to 33.06 mm for reduced tillage system , the specific energy (SEA) decreased by 10.97%. On the other hand as it increased from 26.51 to 32.39 mm for minimum tillage system , the specific energy decreased by 12.04%.

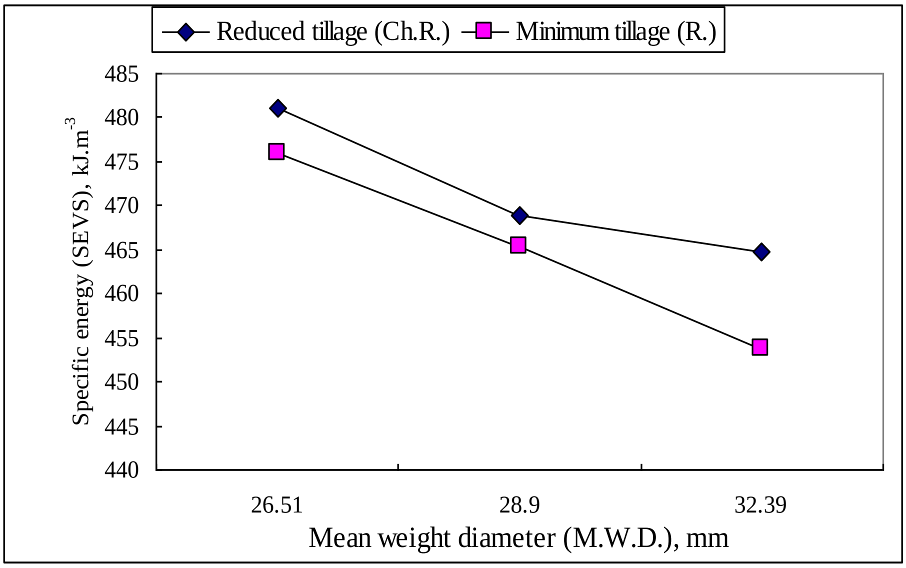

Fig. (6): The relationship between the clods mean weight diameter (M.W.D.) and the specific energy (SEA).

Fig. (7) showed that, the mean weight diameter decreased as the energy required for plowing and pulverizing a unit volume from the soil (SEV) increased. It decreased by 12.25% as the specific energy increased by 3.51% that in case of using traditional tillage system (chisel plow + rotary plow). While in case of using a minimum tillage system (rotary plow) it decreased by 18.15% as the specific energy increased by 4.86%.

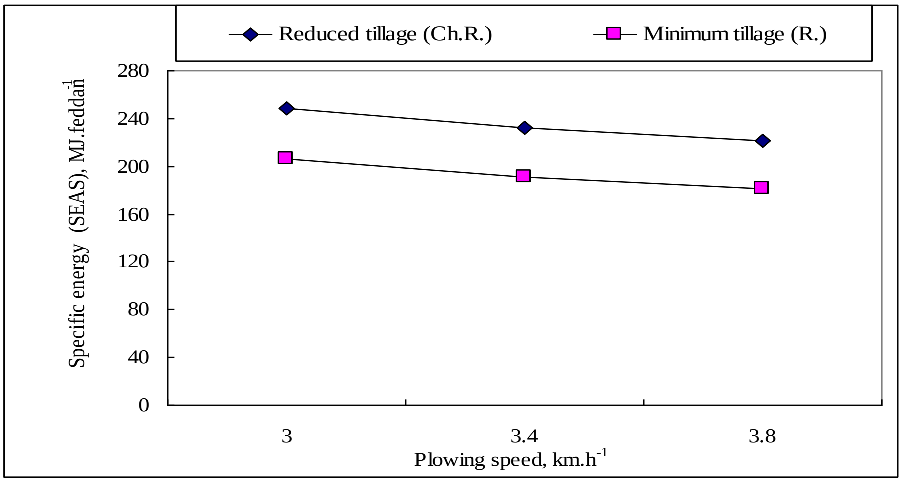

Fig. (7): Effect of operating speed and tillage system on specific energy (SEV) and soil mean weight diameter.

CONCLUSION

The results optained from this study show that the power requirement for operating the rotary plow more that the power requirement for operating the chisel plow , the equivalent of 67 % at the same operating speed and soil conditions .

Preparing a suitable seedbed for planting by using the chisel plow requires secondary tillage process , while using the rotary plow produce a suitable seedbed without a secondary tillage operation. Terefore , the use of rotary plow as secondary tillage to prepare a suitable seedbed need the power equivalent to 82 % of the power needed using the chisel plow for seedbed preparing .

REFERENCES

Abdel-Mageed H. N. and M. A. El-shikha (1993): "Evaluating an active-passive implement for the conservation tillage production of flax". Misr J. Agric. Engineering, 10(2): 218-229.

Abo-Habaga, M. M. (1994): "Influence of the kinematic parameters of a rotary tiller on the seed-bed quality". J. Agric. Sci., Mansoura Univ., 19(12):4533-4543.

Hamad S. A., H. N. Abd El-Mageed and S. El-Kawaga (1992): "Effect of tillage methods on soil physical characteristics and corn yield". Misr J. Agric.Engineering, 9(1): 32-42.

Helmy, M. A., S. M. Gomaa, H. M. Sorour and H. A. El-Khateeb (2001): "Effect of some different seedbed preparations systems on irrigation water consumption and corn yield". Misr J. Agric. Engineering. 18 (1): 169-181.

Hemmat, A. (2009): "Reduction in primary tillage depth and secondary tillage intensity for irrigated canola production in a loam soil in central Iran". J. Agric. Sci. Technol., 11: 275-288.

Hunt, D. (1983):"Farm power and machinery management" 8th edition,PP: 29.

Karahashi, M.; K. Morimoto; K. Seyama; S. Yagi and K. Miura (1984): "Performance of a new up-cut rotary tiller with rake- type filtering screen". JARQ, 17(4): 248-254.

Khadr, KH. A. A. (1997): "Development of a combination unit for seed-bed preparation and seeding". Unpublished Ph.D. Thesis. Faculty of Agriculture. Mansoura University.

Khadr, Kh.A.A.(2004): "Energy requirements for some seed-bed preparation implement under Egyptian conditions". the 12th annual conference of the " Misr Society of Agricultural Engineering", PP: 481-491.

Lees, L.J. (1992): "Machinery Management". Hand book created by Deere & Company Service Publications, Dept. FOS/FMO, John Deere Road, Moline, IL/Fourth Edition, ISBN 0-86691-170-7; p 28.

Puchner, H. (1923): "Badenkunde Für landvirt" Stuttgart – Germany .

Peruzzi, Raffaelli A. and Ciolo (2000): "Finger-harrowing of durum wheat under different tillage systems". Biological Agriculture and Horticulture, 17: 285-303.

Triplett G B and M A Sprague (1986): "No-tillage and Surface Tillage Agriculture". the Tillage Revolution. A Wiley-Interscience Publication, John Wiley and Sons, Inc, USA, 1986

Ward, J. T., Bashford, W. D., Hawkins, J. H., and Holliday, J. M. (1985): "Oilseed rape". farming press Ltd. 298 P.

متطلبات الطاقة اللازمة لتشغيل المحراث الدوراني تحت الظروف المصرية

مصطفي محمد الدسوقي أبوحباجة* ، خفاف أبوالعلا عبدالعزيز خضر و عمر السيد محمد محمد نعيم*****

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نظرا لما يتميز به المحراث الدورانى فى تجهيز مرقد بذرة مناسب بأقل عدد من مرات الحرث بالمقارنة الى معدات الحرث الأخرى ، لإلا أن لإنتشاره لم يكن بالصورة المرجوه لما يتردد عن إحتياج هذا المحراث لقدره عالية فى التشغيل .

لذا أجريت هذه الدراسة بغرض تقدير القدرة اللازمة لتشغيل هذا المحراث فى تجهيز مرقد بذرة مناسب للزراعة تحت الظروف المصرية .

تم تجهيز مرقد البذرة فى تربة طينية بمزرعة بحوث الجميزة بمحافظة الغربية باستخدام المحراث الدورانى فى نظام الحد الأدنى للحرث وكذلك كآلة حرث ثانوى فى نظام الحرث القليل

وتم التوصل الى عدة نتائج يمكن تلخيصها فيما يلى : -

1- معدل إستهلاك الوقود زاد بنسبة 12.09, 13.48, 11.41% بزيادة سرعة الحرث من 3.0 إلي 3.8 كم.س-1 وذلك عند استخدام كل من المحراث الحفار كحرث أولي, المحراث الدوراني للحرث الثانويوالحرث المخفض علي التوالي.

2- بزيادة سرعة الحرث من 3.0 إلي 3.8 كم.س-1 زادت القدرة الفرملية اللازمة للتشغيل من 34.39 إلي 39.15, من 34.16 إلي 38.67, من 57.19 إلي 73.71 كيلو وذلك عند إستخدام المحراث الحفار للحرث الأولي, المحراث الدوراني للحرث الثانوي والحرث المخفض علي الترتيب.

3- بزيادة سرعة الحرث من 3.0 إلي 3.8 كم.س-1 انخفضت الطاقة النوعية لوحدة المساحة (SEA) بنسبة 11.52, 10.41, 12.04% وإنخفضت أيضا الطاقة اللازمة لحرث وإثارة وتفتيت وحدة الحجوم من التربة (SEV) بنسبة 2.96, 3.66, 4.64% وذلك عند استخدام المحراث الحفار للحرث الأولي, المحراث الدوراني للحرث الثانوي والمخفض علي الترتيب.

4- سرعة الحرث من 3.0 إلي 3.8 كم.س-1 متوسط قطر قلاقيل التربة انخفضت بنسبة 16.03% عند استخدام المحراث الحفار. وزادت بنسبة 13.96, 22.18% عند استخدام المحراث الدوراني في الحرث الثانوي والحرث المخفض علي الترتيب.

5- متوسط قطر قلاقيل التربة يتناسب عكسيا مع الطاقة اللازمة لحرث وحدة المساحة (SEAS) بزيادة متوسط قطر قلاقيل التربة من 29.01 إلي 33.06 مم وذلك عند اجراء الحرث التقليدي (محراث حفار يتبعه محراث دوراني).

6- متوسط قطر قلاقيل التربة يتناسب طرديا مع الطاقة اللازمة لحرث وحدة المساحة (SEAS) عند استخدام المحراث الدوراني في الحرث المخفض. بزيادة متوسط قطر قلاقيل التربة من 26.51 إلي 32.39 مم زادت الطاقة اللازمة لحرث وحدة المساحة بنسبة 12.04%.

7- تجهيز مرقد بذرة مناسب باستخدام المحراث الدورانى كحد أدنى للحرث يتطلب ما يعادل 82 % من القدرة اللازمة لتجهيز مرقد بذرة باستخدام نظام الحرث المخفض تحت نفس ظروف التشغيل .

قام بتحكيم البحث

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