PAPER • OPEN ACCESS

Requirements and Indicators of the Energy and Capacity for Some Secondary Equipment to Prepare the Soil and Fragmentation Index of Soil

To cite this article: Mahmood J Aldaoseri and Sadiq J Muhsin 2022 *IOP Conf. Ser.: Earth Environ. Sci.* **1060** 012138

Requirements and Indicators of the Energy and Capacity for Some Secondary Equipment to Prepare the Soil and Fragmentation Index of Soil

Mahmood J Aldaoseri [1] and Sadiq J Muhsin [2]

[1,2] Department of Agricultural Machines and Equipment, College of Agriculture, University of Basrah, Iraq.

[1]E-mail: Mahmood.jasim@uobasrah.edu.iq

Abstract. A survey was carried out in the field of the Faculty of Agriculture, Basra University. The mechanical field try was done by isolating the field's property as indicated by the Randomized Completely Block Design (R.C.B.D) included two factors, the first factor uses two primary tillage implements was mounted moldboard plough and digger plough, and second factor was four kinds of auxiliary culturing implements: Disk harrows, Axe harrows, spring cultivator and Rotary plough. The research was conducted in silty loam soil to investigate the influence of fuel consumption, traction force, field efficiency and the soil Fragmentation index. The purpose of this study was to investigate the influence of trowel type on the performance indicators of mechanical units to adapt them to the soils studied. The use of agricultural machinery contributed significantly to reducing the time, costs, effort and wages of workers in the field. The most prominent of these processes are the primary and secondary preparation of the soil and the mixing of manure residues with the surface layer of the soil. In this research, the superiority of the rotary plow over the rest of the machines was observed by recording the lowest pulling force and the lowest fuel consumption rate that it needs while moving and it was 1.60 kN and 14.42 L. ha-1 respectively, in addition to that giving it the best field efficiency and the best fragmentation degree and it was 68.66%, 6.5 mm respectively.

Keywords. Disk harrows, Spring cultivator, Rotary plough, Traction force, Fuel consumption, Field efficiency, and Fragmentation index.

1. Introduction

Cultivating the soil is considered one of the biggest home jobs and requires most of the energy expended on pastures [1]. Tillage is considered one of the greatest duties of a ranch, as it requires the greatest amount of kinetic energy of any kind in crop production, and is considered an inconceivable part of the cost of creation. The energy used as fuel corresponds to the area of production being developed. In any case, any rationalization will reduce overall consumption, but also natural pollution from burning objects and leaks that deplete the ozone layer [2-4]. As a result of the difficulty of securing fuel and its high price, the amount of fuel needed for agricultural operations should be used. [5] It is important to note that primary ploughing and ploughing with moldboards consume the most fuel, and the increased depth and speed of the mechanized units also lead to high fuel consumption.

The requirements of the disc harrows in force of draft increase with the increase in the depth of plowing as a result of the increase in the size of loose soil masses, which requires additional traction force to overcome the resistance of the soil to loosening [6].
The disc harrows were significantly superior in recording the lowest pulling force of 11.14 KN, while the moldboard plough recorded the highest pulling force of 24.98 kN, with an increase of 30.58 and 124.24% compared to the digging plough and the disc harrows, respectively. The moldboard plough records the highest pulling force to its role in the process of cutting, separating and flipping the soil slices, as well as the large surface area of the plough weapon in contact with the soil, which increases the force required to overcome the resistance of the soil to plowing, and this in turn increases the pulling force, while the digger plough works on splitting and dismantling Soil without overturning, as well as a decrease in the surface area of the plough arm in contact with the soil, and this reduces the force required for the plough to overcome the resistance of the soil to loosening and plowing compared to the moldboard plough [7].
Field efficiency as a percentage decreases when using the moldboard plow compared to other different types of plows in addition to the type of puller used with different speeds during the plowing process in the field. As the difference in the plow and the tractor, and then the difference in speed and depth, would affect the field efficiency ratio [8]. It was observed in a study that included the use of moldboard plows, suspended disc harrows and pulled disc harrows in two types of soils (silty loam and clay) when plowing at a depth of 20 cm that the suspended disc harrow gave the highest field efficiency in both types of silty loam and clay soils, which amounted to 90.33 % and 86.37%, respectively, while the moldboard plow gave the lowest field efficiency of 72.40% and 65.50% for both types of soils, respectively. The reason for this was attributed to the decrease in the practical productivity of the moldboard plow as a result of the low practical speed and the increase in its requirements of traction compared to the disc harrows [9]. [10]Also referred to the possibility of replacing the field efficiency with the so-called time utilization factor, which is equal to the percentage between the times actually used in the production process to the available theoretical time. This is as a result of the presence of many situations that represent a waste of time, such as a technical failure in the machine or lifting the plow when changing the direction of plowing and the need for the machine to reset some balances during work.
The soil Fragmentation index is defined as the percentage weight by volume of different soil masses. It is affected by a number of factors, including the number of plowing times, the type of plow used, the strength and texture of the soil, as well as the time of the plowing operations [11,12]. Fragmentation Index decline with speeding up or using secondary tillage equipment, for example, disk harrow [13].

2. Material and Methods

2.1. The experiment Design

Field experiment was conducted during 2022 at University of Basrah - Agriculture College - Qarmat Ali. The field experiment was carried out in soil texture was silty loam. The soil was ploughed at 30 cm profundity by moldboard plough and digger plough, after that each site split into four parts, first part was friability by tandem disk harrows, second part was friability by Axe harrows, third part was friability by spring cultivator and forth part was friability by rotary plough. Complete randomized blocks design in factorial experiment was used with three replications. Information was dissected measurably with investigation of difference (ANOVA) methodology utilizing Genstat v. 12. A contrast among treatments implies were assessed with the most un-massive distinction (LSD) test acknowledged at 5% probability. Table 1 shows the physical and chemical properties of the soil used in the research.

Table 1. The physical and chemical properties of the soil.

Soil properties			Soil depth (cm)	
			0-15	**15-30**
Soil Separators	Sand	$gm.\ kg^{-1}$	202.39	183.48
	Silt		587.91	594.97
	Clay		209.70	221.73
soil texture			Silty loam	Silty loam
Dry bulk density		$Mg.m^{-3}$	1.27	1.34
Particle density			2.61	2.66
Soil moisture		%	21.46	26.17
CI		$MN\ m^{-2}$	2.47	3.24

2.2. The Implements and Tractors

2.2.1. Moldboard Plough
A mounted moldboard plough was utilized in the review. The furrow determinations are: weight 220 kg, width 1.05 m, and comprises of three moldboards (universally useful) of 35 cm width for every moldboard.

2.3. Chisel Plough
The Chisel plough is manufactured by the General Company for Mechanical Industries / Alexandria. The furrow particulars are: weight 458.87 kg and had a plan width 1.65 m and 7 edges (bend type) in two lines, three cutting edges in the first column and four edges in the back column and every sharp edge has 5cm width. The cutting edges are fixed on the casing on the other hand. The distance between edges in same column is 48 cm. The distance between first line and back column is 55 cm.

2.3.1. Tandem Disc Harrows
was used to friability soil block after soil tilth by moldboard plough and chisel plough. The tandem disk harrow comprise of two groups in front column and two posses in back line and each pack had 8 plates (16 plates in column). The distance across of each plate is 0.50 m. The plan width of tandem disc harrow is 3 m.

2.3.2. Axe Harrows
This type of harrow breaks up the topsoil after the process of plowing the soil with a moldboard plow and chisel plough. The weapons of the Axe harrows are installed on a pole that takes its motion from the continuity of the movement of the weapons with the ground. The arrangement width of Axe harrows is 1.85 m.

2.3.3. Spring Cultivator
The spring cultivator was used to pulverization soil after soil plowing by moldboard plough and chisel plough. The arrangement width of spring cultivator is 1.7m.

2.3.4. Rotary Plough
The rotary plow consists of one horizontal rotating shaft on which the blades are fixed and takes its movement from the power take off of the tractor. The rotary plough was used to pulverization soil after soil plowing by moldboard plough and chisel plough. The revolving furrow had 32 cutting edges. The arrangement width of rotary plough is 1.5 m.

2.3.5. Tractors
Massy Ferguson (MF) work vehicle model 440 xtra and Case IH (CH) farm hauler model JX75T were utilized in this review. The MF farm truck was given diesel motor of 77 kW (4 chambers) for testing

secondary tillage implements as the stuff shaft was placed on inactive, while CH work vehicle with diesel motor of 55 kW (4 chambers) was utilized to pull the (CH) farm truck with secondary soil preparation implements during estimating draft force under various given testing factors. The draft was estimated by utilizing a load cell sensor that coupled between two farm vehicles (pull farm truck toward the front (MF) and mounting secondary soil preparation implements work vehicle in the back (CH).

2.4. Measurement of Mechanical Performance Indicators

2.4.1. Traction Force

The total pulling force of the tiller was measured using a load cell device. The device was fixed on the MFXtra440 and the front of the case JX75T tractor and the tiller tied on it was tied to the other end of the load cell by a thick rope. The tractor engine speed (MFXtra440) was fixed at 1500 rpm-1 and its forward speed was at 0.37 $m.sec^{-1}$. The case JX75T tractor and the machine tied on it were pulled by the MFXtra440 tractor the total pulling force was measured during the hauling process and during a longitudinal distance of 10 m. The depth was pre-established by the hydraulic device of the Case JX75T tractor and according to the tillage machine used. The values of drag force were recorded by a laptop computer connected to the load cell device, the measurement process was repeated three times for all tillage machines used in the experiment, and the drag force was calculated from the following equation taken from [11].

$$F=Ft-R$$

Where:
F= Traction Force of Tillage implements (KN)
Ft= Total traction force (KN)
R= Rolling resistance of the tractor CASE JX75T (KN)

2.4.2. Fuel Consumption Rate (Fcr)

According to the rate of fuel consumption from the following equation according to the method proposed by [14].

$$Fcr = \frac{10 \times TFC}{Bp \times Va}$$

Where:
Fcr= Fuel consumption rate ($L.he^{-1}$)
TFC= Temporal Fuel Consumption ($L.h^{-1}$)
Bp= Actual working width of the tillage implement (m)
Va= Actual velocity ($m.h^{-1}$)

2.4.3. Field Efficiency

The field efficiency of all tillage machines was calculated from the following equation according to the method mentioned in [15].

$$Fe = \frac{Bp \times Va}{B \times Vt} \times 100$$

Where:
Fe= Field efficiency (%).
B= Design working width of the tillage implement (m).
Vt= Theoretical velocity ($m.h^{-1}$).

2.4.4. The Soil Fragmentation Index

After conducting the experiments with different secondary equipment to prepare the soil (disc harrows, axe harrows, spring cultivator, rotary plow). The samples were collected from the field randomly and with three replications for each treatment, bringing the number of samples taken from the field to 24 samples. These samples were transferred to the laboratory and left to dry, then sieved manually by a group of sieves of different diameters (2.8, 5.6, 12,5, 16, 25, 31.5, 45, 50, 63, 75, 100)mm, the soil above each sieve was weighed and the total weight of the sample was calculated by summing the weights of the aggregated soil on each sieve, then the percentage of each weight on each sieve was calculated according to the method mentioned in [16] Through the following equation:

$$Xi=\frac{Wi \times \acute{M}}{W}$$

Where:
Xi= Diameter rate for any volumetric range of separated assemblies (mm).
Wi= Weight of soil collected on each sieve (kg).
´M= Average diameter of the sieve used before, and the sieve used after (mm).
W= total weight for sample (kg).

3. Results and Discussion

3.1. Traction Force

The draught force is defined as the force needed to pull the machine towards the power source (the tractor), and the traction force is inversely proportional to the pulling speed when the power is stable. It is considered one of the important mechanical indicators in evaluating the performance of agricultural machinery, as it is affected by several factors, including the type of plowing machine used, the depth and speed of plowing, the working width of the plowing machine, in addition to the type of soil and conditions of use of the machine.

The data shown in Table 2 showed that the traction force of the rotary plow was significantly superior to the rest of the secondary equipment to prepare the soil, as it recorded the lowest pulling force compared to the other machines, in both cases after using the moldboard plough and the digger plough where the traction force was 1.91 and 1.29 kN after using the moldboard and digger plows, respectively, while the spring cultivator recorded the highest draft force after using the moldboard plow and the digger plow, and the amount of draft force was 4.86 and 5.05 KN, respectively. The rotary plow is pushed in the same direction as the tractor, which helps move the tractor forward. While there was no significant effect when using the moldboard plough and digger plough on reducing the draft force. All of the above is reliable with [17].

Table 2. Influence of primary and secondary tillage implements on traction force.

Primary Tillage	Secondary Tillage				Means	$LSD_{0.05}$
	DH	AH	SC	RP		
MP	2.64	3.15	4.86	1.91	3.14	
DP	1.88	2.86	5.05	1.29	2.77	0.740
Means	2.26	3.01	4.95	1.60	2.96	
$LSD_{0.005}$			1.046			1.479

DH=Disk harrows, T2=Axe harrows, T3=spring cultivator, T4=Rotary plough.
MP=Moldboard Plough, DP=Digger plough.

3.2. Fuel Consumption

The importance of studying the energy requirements of agricultural machinery contributes to saving cost, fuel and pollution. This study alone is not sufficient to determine the performance of agricultural machinery, so it is necessary to study the field performance of the machines in addition to the energy requirements. The amount of fuel consumed by the mechanized unit is related to several factors, including: the horsepower of the engine, its condition, and the type of fuel used and the time of completion associated with the type of soil, its moisture content and the type of agricultural process.

The fuel consumption rate of the secondary equipment to prepare the soil is less than that of the primary soil preparation equipment due to the low depth that the secondary equipment reaches, as well as the possibility of completing the work in less time because this type of equipment needs less traction force than the primary equipment needs. In addition, the secondary equipment comes to work after the plows that prepare the soil, so you find that the soil is loose and does not require a high capacity to dismantle it. The data shown in Table 3 showed that the rate of fuel consumption of the rotary plow achieved the lowest rate of consumption with a highly significant difference from the rest of the machines, as it achieved 14.28 and 14.55 L.ha-1 when conducting The secondary conditioning process after the turntable plow and the digger plow, respectively, while the axe harrow achieved the highest fuel consumption rate when the soil softening was carried out after plowing with the turntable plow and the digger plow, which are 17.34 and 16.94 L.ha-1. This is in agreement with [18], which was concluded that the soil treatment with a rotary plow and a tractor speed of 5 km h^{-1} was superior in giving the lowest fuel consumption rate of 28.31 liters hectare-1, superior to the spring cultivator and disc harrow, and attributed the reason for this to the light weight of the rotary plow compared to With the rest of the smoothing equipment, he also explained that the increase in the practical speed led to a decrease in fuel consumption, and he attributed the reason for this to the fact that the increase in the practical speed leads to the raising of the weapon and then to the decrease in its depth.

Table 3. Influence of primary and secondary soil preparation implements on fuel consumption.

Primary Tillage	Secondary Tillage				Means	$LSD_{0.05}$
	DH	AH	SC	RP		
MP	17.08	17.34	16.62	14.28	16.33	
DP	16.80	16.94	16.23	14.55	16.13	0.459
Means	16.94	17.14	16.43	14.42	16.23	
$LSD_{0.005}$	0.650					0.919

3.3. Field Efficiency

It implies finishing a specific field activity while burning through minimal measure of time, fuel, and ranch assets. The term alludes to the time the activity ought to take as opposed to turning and other inefficient time. For instance, investing an unreasonable measure of energy pivoting at the finishes of short, wide fields or covering culturing tasks inside a field can bring about higher fuel utilization per section of land. It incorporates the impact of time lost in the field and inability to use the full width of the machine.

The field efficiency of primary and secondary equipment for soil preparation varies. The data shown in Table 4 showed that there is a highly significant difference between the primary equipment alone and the secondary equipment alone and there is no highly significant difference between the bilateral interference between the primary and secondary equipment. The data also indicated the superiority of the rotary plow by giving it the highest field efficiency after using the moldboard plow and digger plow, with a score of 68.43 and 68.89%, respectively. While the soil treatment with the spring cultivator achieved the lowest field efficiency after treating the land with the moldboard plow and the digger plow, as it recorded 57.43 and 58.22%, respectively. All of the above is reliable with [19].

Table 4. Influence of primary and secondary soil preparation implements on field efficiency.

Primary Tillage	Secondary Tillage				Means	$LSD_{0.05}$
	DH	AH	SC	RP		
MP	67.08	60.09	57.43	68.43	63.26	
DP	67.76	61.32	58.22	68.89	64.05	0.787**
Means	67.42	60.71	57.82	68.66	63.65	
$LSD_{0.005}$	0.557**					1.114

3.4. The Soil Fragmentation Index

The study of the effect of the type of machine used in the primary and secondary operations to prepare the soil and give the degree of plowing and softening required to prepare the seedbed, which can be inferred through the study of the fragmentation index, which is of greater importance than the field efficiency, Soil volume disturbed and actual productivity, considering these characteristics are related to the amount of work performed during the unit area , while the fragmentation guide is concerned with the type of tillage in providing the appropriate environment for the growth of seeds. Moreover, the fragmentation index can be considered as one of the most important features that can be adopted in mixing organic waste with the soil. When the soil fragmentation increases, it means the ability of the machine to mix materials with the soil. There is a note that can be referred to, which is that an increase in soil fragmentation means a decrease in the volume of soil masses formed after soil service operations.

The results shown in Table 5 express the existence of a highly significant difference between the basic factors (primary and secondary equipment for soil preparation), while there is no highly significant difference under the probability level (0.05) in the binary interaction between the factors included in the experiment. It is also noted from the table that the rotary plow was superior by giving it the highest degree of friability, meaning that it gave the lowest mean weight diameter of soil particles when used after the moldboard plow and the digger plow and its values were 7.30 and 5.70 mm, respectively. While the Axe harrows achieved the lowest degree of fracturing, which means that the average weighted diameter was the highest after the moldboard plow and the digger plow, and it was 23.83 and 21.93 mm. The reason for this is due to the type of the work of each of the machines, as the rotary plow breaks the soil by hitting the blocks with the plow's weapons at a high speed and this speed is taken by the plow from the power take off in the tractor, in addition, the fragmentation of the soil increases when the soil blocks hit the cover Plow The breaking up of the soil by the rotary plow depends on two main factors: the speed of the power take off in the tractor and the distance of the plow cover from the plow arms. Likewise, other machines do not take their movement from an external source, but rather depend in their movement on their friction with the surface of the soil.

Table 5. Influence of primary and secondary soil preparation implements on soil Fragmentation**.**

Primary Tillage	**Secondary Tillage**				**Means**	**$LSD_{0.05}$**
	DH	**AH**	**SC**	**RP**		
MP	17.47	23.83	14.00	7.30	15.65	
DP	14.77	21.93	12.83	5.70	13.81	0.689**
Means	16.12	22.88	13.42	6.50	14.73	
$LSD_{0.005}$	0.974				1.377	

Conclusions

The results of this research showed the superiority of the rotary plow by giving it the least traction force by the tractor to overcome the conditions of the field after using the moldboard plow and the digger plow. It was also concluded that the rotary plow needs the lowest fuel consumption rate to perform the work. The reason for the superiority of the rotary plow in the traction force and the rate of fuel consumption is due to the quality of the plow's work that helps it in this, as the direction of movement of the plow arms and the collision of the soil in the plow cover work to push the tractor forward. In addition, the results indicate the superiority of the rotary plow by giving it the highest field efficiency and the best fragmentation evidence as a result of the aforementioned reasons, in addition to the speed of the plow's movement, which works to hit the soil masses at high speed in the plow cover, which increases the degree of soil fragmentation.

References

[1] Abbaspour-Gilandeh, Y.; Alimardani, R.; Khalilian, A.; Keyhan, A. and Sadati, S.H. (2006). Energy requirement of site-specific and conventional tillage as affected by tractor speed and soil parameters. Int. J. Agric. Biol., 8(4): 499-503.

[2] Janulevičius, A., Šarauskis, E., Čiplienė, A., Juostas, A., (2019). Estimation of farm tractor performance as a function of time efficiency during ploughing in fields of different sizes. Biosyst. Eng. 179, 80–93.
[3] Janulevičius, A., Damanauskas, V., (2015). How to select air pressures in the tires of MFWD (mechanical front-wheel drive) tractor to minimize fuel consumption for the case of reasonable wheel slip. Energy. 90, 691–700.
[4] Lovarelli, D., Bacenetti, J., Fiala, M., (2017). Effect of local conditions and machinery characteristics on the environmental impacts of primary soil tillage. J. of Clean. Production. 140, 479–491.
[5] Himoud M.S. (2018). Evaluation of some performance indicators the tractor (CASE JX75T) Iraqi Journal of Agricultural Sciences 49(5):609-621.
[6] Nassir, A.J. 2014. Requirements of Pulverization Energy of a Tandem Disc Harrow at Different Pulverization Depth and Forward Speed. Basrah Journal of Agricultural Sciences, 27(1): 275-289. https://iasj.net/iasj/article/113580.
[7] Al-Mousa, M.F.H. (2020). Effect of tillage systems and application of soil Amendments on some soil properties, Growth and Yield of Wheat (Triticum aestivum L.) and Mechanical Indicators in Clay Soil. Master thesis, Agriculture college-University of Basrah. (In Arabic).
[8] Almaliki, S.,(2017). Development and Evaluation of Models for MF-285Tractor Performance Parameters Using Computational Intelligence Techniques. Ph.D. Dissertation. University of Tehran, Iran pp: 215.
[9] Muhsin, S.J. (2017). Performance Study of Moldboard Plow with Two Types of Disc Harrows and Their Effect on Some Soil Properties Under Different Operating Conditions. Basrah Journal of Agricultural Sciences, 30(2): 1-15.
[10] Alsharifi .S.K .، Ghali .A and Hamzah .I.J. (2021b). A study some growth characteristics for maize , Bohooth 106 variety under affecting mechanical for machine (moldboard plow type) .IOP Conference Series: Earth and Environmental Science. https://doi:10.1088/1755-1315/735/1/012007.
[11] Mckyes, E. (1985). Soil cutting and tillage. 1st ed. Elsevier Science Publishers.
[12] Kepner, R.A., R. Bainer and E. Bragaers (1982). Principles of farm machinery. 3th ed., Avi. Pub. Co. west part, conn. U.S.A.
[13] Nassir, A.; Mashal, A.A. & Abd, T.J. (2016). Effect of tillage and smoothing passages on pulverization index and draft force requirement and down to less pulverization index when different front speed and depths. J. Modern Sci. Heritage, 4(3): 513-523. (in Arabic).
[14] Almaliki, S.; R. Alimardani and M. Omid (2016). Fuel consumption models of MF285 tractor under various field conditions. Agricultural Engineering International: CIGR Journal, 18(3): 147-158. https://cigrjournal.org/index.php/Ejounral/article/view/3776.
[15] Joseph, K.C. (1990). Machines in crop production. Cornell University, New York USA.
[16] Hillel D. (1980). Fundamentals of Soil Physics. Academic Press Inc. New York, U.K.
[17] Askari, M. and S. Khalifahamzehghasem (2013). Draft force inputs for primary and secondary tillage implements in a clay loam soil. World Applied Sciences Journal, 21(12): 1789-1794.
[18] Rawdhan S.A. 2017. The effect of pulverization tools and Tractor speed on some machinery performance and yield of Barley (Horidium Volgari L.). Al-Qadisiyah Journal For Agriculture Sciences, 7(1):22-27. (In Arabic)
[19] Abdullah A.A. and Yahya L.M. Comparison study of shaped blades (T) designed and locally manufactured with conventional blades in performance of rotary plow. Journal Of Kirkuk University For Agricultural Sciences, 4(2):81-95.