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EVALUATING PERFORMANCE OF A POST HOLE DIGGER

El-Gendy H.A.; S.N. Abd El-Halim; H.A. Morghany and A.M. Aboukarima
Agric. Eng. Res. Inst., ARC, Egypt.

ABSTRACT

Mechanization plays an essential role in agriculture and assures timely completion of farm operations. For planting trees, it is required to dig many holes to finish planting in certain time. This operation is done by helping of hole digger. It is the fastest method to dig holes by PTO driven implement, made for all types of soil and easy to transport. The purpose of this study was to evaluate the effect of diameter of the hole digger and presence or absence shares on the tip of it on power requirements and time needed for evacuating soil from a hole. The study was carried out at Nubaria area "Ahmed Shouky village", the soil texture was sandy. The treatments included all possible combinations of diameter and presence or absence shares on the hole digger tip. Digging depth was accomplished to a 600 mm depth. The rotary speed for tractor PTO was constant at 540 rpm and decreased by hole digger gear-box to 350 rpm. The tractor had category III- three point hitch and power of 48.5 kW "65 hp". The required torque and time consumed to evacuate soil from a hole were measured. The auger diameter of the hole digger and presence or absence shares on the auger tip had significant effect on the required torque and time consumed to evacuate soil from a hole. The highest time consumed to evacuate soil from digging hole and the highest power requirement at dig hole were 105.96 s and 63.34 kW, respectively. The power requirement (kW) of hole digger could be obtained using auger diameter (D, mm) and index for shares (I = 0 or 1 when the shares on the auger tip were presented or absent, respectively) as follows:

$$Power = 76.52 - 0.044 \times D - 35.65 \times I \qquad R^2=0.995$$

INTRODUCTION

Mechanization plays an essential role in agriculture and assures timely completion of farm operations as well as less expenditure per unit area. Various types of hole diggers machines are now available in the market. However, modification could be done on them to suit the local conditions of Egypt or adopted for trees planting. The employed planting practices are insufficient and unproductive since the planting holes are prepared a few days before actual planting commence (El Pebrian and Yahya, 2003).

Time for preparing the planting hole refers to the total time taken to erect the auger, rotate and at same time move the auger to penetrate the soil surface, lift up the auger, and tilt the auger to its rest position. Measurement for the time duration immediately started when the operator shifted the hydraulic control lever to erect the auger and terminated when the auger was at its rest position and the clamping covering mechanism at the convenient height position to the operator (El Pebrian and Yahya,2003).

Preparing the planting hole was the most time consuming operation, whereas conveying the seedling was the least time consuming operation about 30.05% of the total time for mechanized transplanting of seedlings was spent in preparing the planting hole.

Rotz and Muhtar (1992) indicated that performance of the modified auger was evaluated by measuring the auger capacity and power input at the auger drive for the above setting. The capacity of the modified auger was also compared to that of the conventional auger.

According to ASAE Standards (2000), power-takeoff (PTO) power is power required by the implement from the PTO shaft of the tractor or engine. Typical PTO power requirements can be determined using rotary power requirement parameters given in ASAE D497, clause 4. It would, therefore, be desirable to provide an apparatus to improve the operation of drilling a hole for the replacement of harvested trees, particularly in tree farm operations in which the trees are arranged in a grid pattern and the replacement seedlings are to be planted between more mature.

Post hole digger is a PTO driven machine that digs holes in rows on equal distances mechanically. Post hole digger is a digging tool which is very useful for plantation. It is fastest method to dig up hole as it is driven by PTO. Post hole diggers are ideal for a wide variety of applications- like tree plantations. Auger size can be decided as per the required hole size. The digging gets done at a faster pace and nearer way as compared to manual digging.

Post hole diggers are powered by the tractor's PTO. Rural homeowners use post hole diggers for trees planting. Hole diggers are usually purchased separately from the digger head. Augers for tree planting are available in sizes to 30 inches (762 mm), but the largest sizes are usually intended for larger tractors. Post hole diggers work well in some soils but may have trouble penetrating hard soils. Although post hole diggers are often used to dig planting holes for trees and shrubs, the augers have a tendency to "slick" and compact the soil on the sides of the hole, limiting root growth. If an auger encounters roots or other obstacles in the soil, they can be forced down rapidly and may break a shear pin. Both the PTO shaft and the auger can cause serious injury if a person becomes entangled.

Huba *et al.* (1962) used hole-diggers with borers of various diameters (180–320 mm) with various construction. The weight of the hole-diggers together with the borers ranged from 20 to 47 kg. The quality of hole-diggers was evaluated according to the average Calorie consumption per performance unit (kCal per 1 m of hole depth) which in the case of the various hole-diggers ranged within very broad limits (3.2 to 16.2 kcal in turfy soil and 2.3 to 8.3 kcal in turfless soil).

In literatures there was different information about farm implements that used torque transducers to obtain their power requirements (Crolla and Chestney,1978). Salokhe *et al.* (1994a) made field testing of a PTO powered disk tiller in clay soil. Tests were conducted at different forward speeds of 1,2,3,4 and 5 km/h and 33, 28 and 23° gang angles. Average PTO speed was 540 rpm and average soil moisture content was 26% during all the tests. The PTO torque was measured by a slip ring torque transducer. Salokhe *et al.* (1994b) conducted field experiments in clay soil with a PTO driven disk tiller to collect the draft force and torque variation data. Miszczak (2005) mentioned that there were many models describing the work of rotary tillers, including torque valuation because the torque requirement may be very important for designers, as well as for other experts applying such machines in the field operations.

The objective of this research work was to evaluate the performance of a PTO driven 3-pt mounted post hole digger. Modifications will be done, including changing auger diameter and presence or absence of shares on the auger tip.

MATERIALS AND METHODS

Site and implement:

The field experiments were carried out at Nubaria area "Ahmed Shouky village". The field experimental area was 2 feddans and it was divided into twelve plots. The length of each plot was 32 m and the width was 22 m. The square distance between holes was 6x6 m. However, each treatment was repeated three times.

Three soil samples of the experimental field from the layers of 0-300 and 300-600 mm depth before digging were taken using standard steel core. Particle size distribution, soil bulk density and soil moisture content were determined. Soil moisture content was determined by the standard oven method by drying soil samples in oven at 105oC for 24 hours. All soil characteristics were obtained according to Black *et al.* (1965). Average of some soil characteristics at the experiment site are shown in Table (1). The soil texture was sandy with average of 93% sand, 2.3% clay and 4.7 % silt.

The hole digger (Fig. 1) which used for this work has two expire parts with diameters of 460 and 325 mm. Two rotary tiller blades with 90º angle (Fig. 2) were adding around the auger end and fixed by bolts. The characteristics of hole digger are shown in Table (2).

Table (1):Some soil characteristics at the experiment site.

Depth (mm)	Bulk density (kg/m^3)	Moisture content (%,db)	W.P. (%)	F.C. (%)
0 - 300	1500	5.9	5.6	11.5
300 – 600	1730	4.8	4.8	9.7

Table (2): Characteristics of implement was used in this research.

Hitch	Category III
Input rpm on PTO	540 rpm
Drive protection	Shear bolt
Drive shaft size (ASAE)	Category III

(a) (b)

Fig. (1): Photo of the hole digger used in the field experiments
a: with diameters of 460 mm b: with diameters of 325 mm

(a) (b)

Fig. (2): Photo of the rotary tiller blades with 90º angle.
a: the hole digger with blades b: the blades

4-Tractor and treatments:

The tractor was used is category **III** with 48.5 kW (65 hp). The traveler speed between holes was 5 km/h. Four treatments, Table (3), were laid out in completely randomized blocks with three replicates. Treatment combinations comprised two levels of auger diameter and two levels of shares addition on auger tip.

Table (3): Treatments labels* at experiment site.

D1-Yes	D1-No	D2-Yes	D2-No
(T1)	(T2)	(T3)	(T4)

*** The treatment (D1-Yes) means that the auger diameter is 460 mm and there are shares on the auger tip.**

Measurements and methods:

The slip ring torque transducer (El-Gwadi, 2005) was used to measure torque requirement during field experiments. Digging depth was accomplished to a 600 mm depth. The rotary speed for tractor PTO was constant at 540 rpm and reduced by hole digger gear-box to 350 rpm. The required torque and time consumed to evacuate soil from hole were measured. The required power could be obtained as follows (Hunt, 1995):

$$Power = \frac{2\pi \times n \times T}{60000} \quad \text{.................(1)}$$

Where n is auger revaluations (rpm), T is the required torque (N.m) and 60000 is conversion unit.

Data analysis:

The field data for the required torque, power requirement and time consumed to evacuate soil from a hole were statistically analyzed, using two-way analysis of variance (ANOVA) for the randomized complete design with three replicates. The used software was SAS (1986) using ANOVA procedure. Comparisons among treatment means, when significant, were conducted using least significant difference (LSD) at p = 0.05 level.

Multiple linear regression analysis was performed using the data analysis tool within Microsoft Excel. The multiple linear regression analyses were performed on experimental data obtained from field data to establish a mathematical relationship for estimating the power requirement (dependent variable) as a function of the two main independent variables (auger diameter and shares addition on the auger tip). The mathematical relationship has the following form:

$$Y = \beta_0 + \beta_1 \times D + \beta_2 \times I \quad \text{...........(2)}$$

Where D is auger diameter (mm) and I is the index for shares (I = 0 or 1 when the shares on the auger tip were presented or absent, respectively). Y is the dependent variables [i. e. power requirement (kW) to dig hole], β_0 , β_1 and β_2 are regression coefficients.

RESULTS AND DISCUSSION

Auger diameter and the shares on the auger tip had significant effect on the torque required, power requirement and time consumed to evacuate soil from a hole, Table (4). The interactions among treatments had significant effect on the required torque power requirement and time consumed to evacuate soil from a hole, Table (4).

Table (4): Source of variation, degree of freedom (DF) and probability (P-values) from ANOVA the required torque, power requirement and time consumed to evacuate soil from a hole.

Source of variation	DF	P- values		
		The required torque (N.m)	The required power (kW)	The time consumed to evacuate soil from hole (s)
D	1	0.0001	0.0001	0.0001
S	1	0.0001	0.0001	0.0001
$D \times S$	1	0.0001	0.0001	0.0001
Model Pr>F		0.0001	0.0001	0.0001
R^2		0.9998	0.9998	0.9985
C.V, %		0.864	0.875	1.247

D = Auger diameter and S = shares on the auger tip.

Average values of the required torques were 1046.63 and 1209.63 N.m for auger diameter D1 (460 mm) and auger diameter D2 (325 mm), respectively. It is obvious that the auger diameter D2 needed higher values of torque to operate compared to auger diameter D1, Table (5). However, average values of time consumed to evacuate soil from a hole were 78.67 and 83.70 s for auger diameter (D1) and auger diameter (D2), respectively. It is obvious that the auger diameter (D2) needed higher time to evacuate soil from a hole compared to auger diameter (D1), Table (5). This suggested that the hole which had large diameter needed less time to remove loose soil from inside and around the hole area due to simplicity of handling tools (shovel).

Table (5): Mean+ the required torque, power requirement and time consumed to evacuate soil from a hole as affected by auger diameter and shares addition on the auger tip.

	The required torque (N.m)	The required power (kW)	The time consumed to evacuate soil from a hole (s)
D1	1046.63b	38.33b	78.67b
D2	1209.63a	44.32a	83.70a
Shares addition (Yes)	641.58b	23.52b	62.63b
Shares addition (No)	1614.68a	59.13a	99.73a
LSD (5%)	13.78	0.51	1.41

D1 = auger diameter = 460 mm and D2 = auger diameter = 325 mm.

[+] Means followed by different letters in each column are significantly different at P = 0.05.

[$] LSD = least significance difference.

Average values of the required torques were 641.58 and 1614.68 N.m for shares presence and absence on the auger tip, respectively for any augur diameter, Table (5). It is obvious that the torque needed was reduced in the case of presence share due to simplicity of digging. However, average values of time consumed to evacuate soil from hole were 62.63 and 99.73 s for presence shares and absence on the auger tip, respectively for any augur diameter, Table (5). It is obvious that the presence shares on the auger tip loosing the soil in more efficient compared to absence of the shares because simplicity of removing soil from the digging hole. This implied that the suggested modifications in this work finish digging holes faster.

Fig. (3) shows the effect of studied treatments on power requirement and time consumed to evacuate soil from digging hole. It is clear that the treatment (T1) needed 21.72 kW to dig a hole, meanwhile, the treatment (T3) needed 25.29 kW to dig a hole. Also, the two treatments are close in time consumed to evacuate soil from a hole of 63.83 and 61.45 s. The highest time consumed to evacuate soil from digging hole and the highest power requirement to dig hole were belonged to treatment (T4) of 105.96 s and 63.34 kW, respectively.

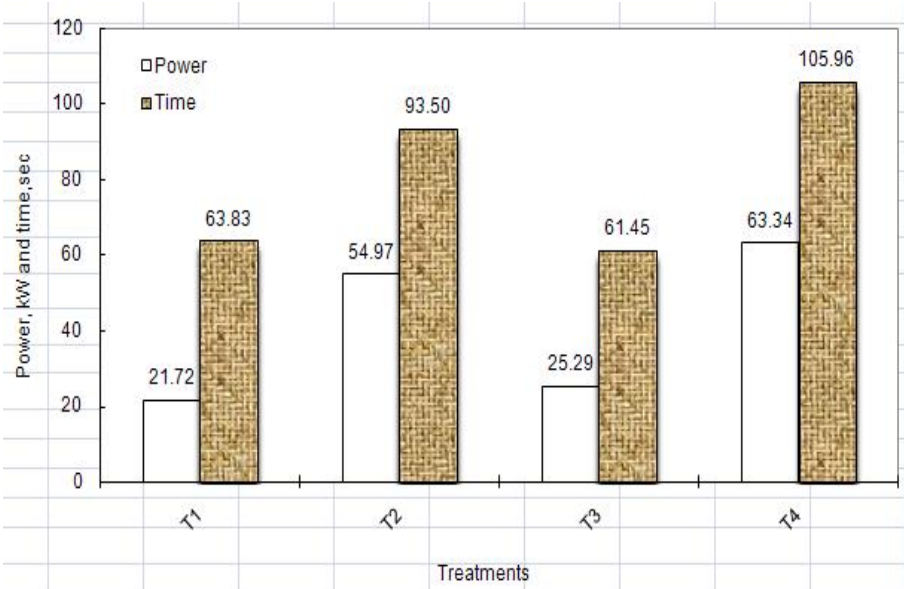

Fig. (3): Effect of studied treatments on power requirement and time consumed to evacuate soil from digging hole.

Fig. (4) shows the change percentage in power requirement and time consumed to evacuate soil from digging hole with auger diameter of 460 mm with presence shares on its tip compared to absence shares. It is clear that the treatment (T1) was needed power to dig hole less than (T2) by 60% and need time to evacuate soil from digging hole less than (T2) by 32%, Also, it is clear that the treatment (T3) was needed power to dig hole less than (T2) by 54% and need time to evacuate soil from digging hole less than (T2) by 34%, Meanwhile, the treatment (T4) was needed power to dig hole more than (T2) by 15% and need time to evacuate soil from digging hole more than (T2) by 13%. These results suggested that auger with big diameter and presence shares on its end tip caused significant reduction in power requirement and time consumed to evacuate soil from digging hole than the control treatment (T2).

Regression statistics for results of multiple linear regressions of field performance criteria of a hole digger are shown in Table (6) for power requirement. The high coefficient of determination (R2) indicate that power requirement can be estimated as a function of auger diameter and the index for shares with a high degree of accuracy.

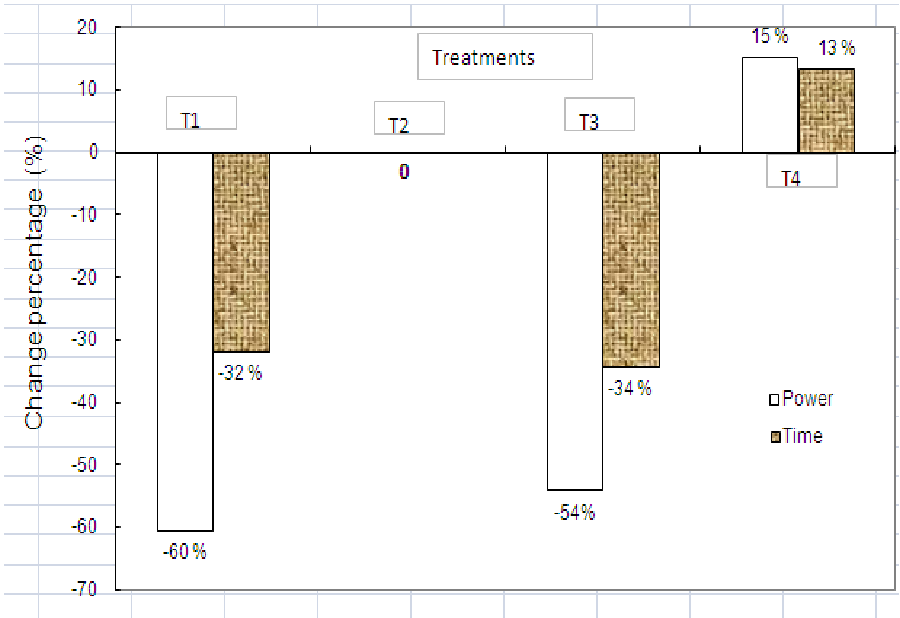

Fig. (4): Change percentage in power requirement and time consumed to evacuate soil from digging hole compared to treatment (T2).

Table (6): Regression statistics for different multiple linear regression model of power requirement of hole digger.

Multiple R	**0.998**
R^2	0.995
Adjusted R^2	0.994
Standard Error	1.424
Observations	12

The first step in determining a significant relationship between the dependant and independent variables was to conduct an F test. The F test was used to determine if there was a significant relationship between the dependant and the chosen independent variables. The null hypothesis was that there was no linear relationship between the dependent and independent variables; the alternative hypothesis was that at least one regression coefficient was not equal to zero. The null hypothesis is rejected at a certain level of significance if the estimated value F is greater than the critical value of F. Table (7) indicates the Excel's ANOVA calculation provided the values of F and significance level for power requirement of the hole digger.

Table (7): Excel's ANOVA calculation provided the values of F and significance level for power requirement of hole digger.

Source of variation	DF	Sum of square	Mean squares	F
Regression	2	3919.309	1959.654	966.837*
Residual	9	18.24184	2.026872	
Total	11	3937.551		

DF = Degree of freedom and * = Significant at 95% confidence level.

For a 95% confidence interval, it is shown that F- value was greater than the critical value of critical F, Table (7), and the conclusion show that at least one of the independent variables was related to the dependant variables. The next step was to test individual portions of the multiple linear regression models using T test to determine if an individual independent variable had a significant effect on the dependant variable, taking into consideration the other independent variables. The null hypothesis was that there was no relationship between the independent and dependant variable. The alternative hypothesis was that there was a relationship. The decision rule was to reject the null hypothesis if the estimated t was less than negative t critical or greater than t critical. For a 95% confidence interval, the critical value for t was obtained from Makridakis *et al.* (1998) critical t Table. The critical value of t (0.025, 2) is -4.30 and +4.30. In reviewing the t values, it was determined that there is a significant relationship between power requirement and all independent variables, Table (8). It is shown from Table (8) that the auger diameter was inversely proportional to power requirement. Auger diameter has significant effect on power requirement at level of 5%., whereas P-value is less than 0.05. The obtained statistical model for the power requirement of the hole digger is as follows:

$$Power = 76.52 - 0.044 \times D - 35.65 \times I \qquad R^2=0.995$$

Table (8): Results of regression for different multiple linear regression model of power requirement of hole digger.

Independent variables	Regression coefficients symbols	Value	Standard error	t stat	P-value
Constant	β_0	76.52	2.46	31.11	0.0000
Auger diameter (mm)	β_1	-0.044	0.006	-7.27	0.0001
Index for shares (---)	β_2	-35.65	0.823	-43.37	0.0000

CONCLUSION

Conclusions can be summarized in the following points:

1. There was significant effect of auger diameter and presence or absence of shares on the auger tip on the required torque, power requirement and time consumed to evacuate soil from a hole,.
2. The highest time consumed to evacuate soil from digging hole and the highest power requirement to dig hole were belonged to treatment (auger diameter of 325 mm and absence shares on its tip) with values of 105.96 s and 63.34 kW, respectively.
3. The auger diameter was inversely proportional to power requirement.
4. The auger diameter with big diameter and presence shares on its end tip caused significant reduction in power requirement and time consumed to evacuate soil from digging hole.

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تقييم أداء حفار ميكانيكي معلق يعمل بعمود الإدارة الخلفي للجرار

هانئ عبد العزيز الجندى، شكري نصر عبد الحليم، حمزة عبد العزيز مرغني و عبد الواحد محمد أبوكريمة
معهد بحوث الهندسة الزراعية ، مركز البحوث الزراعية – مصر.

عند موسم زراعة الأشجار، يكون الهدف حفر أكبر عدد من الجور في أقل وقت ممكن، وهذه العملية تتم عن طريق استخدام الحفار الميكانيكي ذو البريمة المعلق ويعمل بعمود الإدارة الخلفي للجرار، حيث أنه يصلح لجميع أنواع التربة ويسهل التنقل به. والغرض من هذه الدراسة هو تقييم تأثير قطر بريمة الحفر ووضح أسلحة على نهايتها على القدرة اللازمة للتشغيل والوقت اللازم لإزالة التربة من الجور بعد عملية الحفر. وقد أجريت هذه الدراسة في "قرية أحمد شوقي" بالنوبارية، محافظة البحيرة وكان قوام التربة رملية. شملت المعاملات التفاعلات الممكنة بين قطر البريمة ووجود الأسلحة وكررت كل معاملة ثلاث مرات. وقد أنجز عمق الحفر إلى ٦٠٠ مم. وكانت سرعة دوران عمود الإدارة الخلفي ٥٤٠ لفة/دقيقة وخفضت بواسطة حفار الحفر الميكانيكي ذو البريمة إلى ٣٥٠ لفة/دقيقة. وكان الجرار من الفئة الثالثة قدرة ٤٨,٥ ك.وات (٦٥ حصان). قيس عزم الدوران المطلوب والوقت اللازم لإخلاء التربة من الجورة. وقد أوضحت النتائج أن هناك تأثير معنوي لكل من قطر البريمة ووجود الأسلحة على نهايتها على عزم الدوران المطلوب والوقت اللازم لإخلاء التربة من الجورة. فعند استخدام قطر بريمة ٤٦٠ مم عليه أسلحة إضافية، فإن القدرة المطلوبة لحفر جورة انخفضت بنسبة ٦٠٪ مقارنة مع القطر الأخر (٣٢٥ مم) سواء في وجود أو عدم وجود الأسلحة على البريمة. وكان أقصى وقت مطلوب لإخلاء الجورة من التربة هو ١٠٥,٩٦ ثانية عند الحفر بالبريمة ذات القطر ٣٢٥ مم وبدون أسلحة على نهايتها.