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DEVELOPMENT OF A MOWER FOR GRASS HARVESTING

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ABSTRACT

This study aims to develop, construct and field evaluate small-scale mower for grass harvesting. The mower machine is fabricated from local materials which redesign and modify the cutting drum. The results indicated, reducing friction and improved the mower performance, reduce noise, maximize cutting efficiency and minimize energy requirements. The results can be summarized as follows: Maximum effective field capacity of 587.4 m^2/h was obtained with forward speed of 2.16 km/h, cutting height of 2 cm and cutting speed of 6 m/s, the maximum cutting-efficiency of 98.8 % was obtained at forward speed of 0.84 km/h, cutting height of 2 cm and cutting speed of 6 m/s, and the maximum specific energy of 11.27 kW.h/fed. was obtained at forward speed of 0.84 km/h, cutting height of 5 cm and cutting speed of 6 m/s.

INTRODUCTION

Public and special gardens play a vital role in the population life. The green bed (grass) refines the atmosphere from the bad particles of pollution in the air. Green bed is used widely as a playground for most games in different clubs. The grass had to be cut at such periods to be ready for using. This process is still operated depending on primitive methods using manual tools. So, grass cutting by means of up to date technology taking into consideration machine efficiency, durability and decrease in energy requirements (Magar *et al.* 2010). Chattopadhyay *et al.* (2010) evaluated four types of forage harvesting machines, namely flail mower, rotary mower, rotary disc mower and mechanical rake-cum-windrower for harvesting grasses (Cencrusciliaris) and their performances were compared with improved sickle (Gujarat Agro). The average effective field capacities were found to be 0.21, 0.03 and 0.285 ha/h for flail mower, rotary mower and rotary disc mower respectively and 133 man-h/ha was required for harvesting the grasses by Gujarat Agro sickle. Meanwhile Magar *et al.* (2010) stated that the grass cutting machine is available in the various types like reel (cylinder) mower, rotary and mulching mower, hover mower, riding mower, professional mower etc. but these are very costly and unaffordable. It required a skilled person to operate. Kemper *et al.* (2012) stated that disc mowers cutting principle is based upon using the inertia and bending forces of the grass blades. The established technology is reliable but others provide potential for reducing the power requirements. At the Institute of Mobile Machines and Commercial Vehicles an overlaying cut as an alternative cutting principle in a disc mower has to be proven. Therefore, a modified cutting unit is designed with two cutting discs. Piccarolo (2012) mentioned that professional lawns in parks and the like in Italy require special care and a scientifically based choice of grasses and machinery and emphasizes the close connection between mowing frequency and height, and that the choice of mower and type of cutting tool depends on the types of surface and the required mowing height. Celik (2006) designed, fabricated, and tested a push type cutter bar mower for use by small-scale enterprises in forage harvesting. Price, land condition, and enterprise size were considered as the main criteria for the design and development process. The cutter bar mower consisted of six main components including the cutting, transmission, power, handling, frame, and transporting units. A two-cycle engine that produced 1.47 kW at 7000 rpm provided power for the cutting unit. Two skids were attached to the cutter bar unit, one on each side, to control cutting height. The total mass of the mower was 41 kg. Performance tests of the mower resulted in an average 0.11 ha/h effective field capacity, 10.00 L/h fuel consumption, 0.875 field efficiency, 2.24 t/h effective wet grass harvesting capacity, 4.43 L/t wet grass specific fuel consumption, and 64 mm cutting height. Kumhala *et al.* (2003) developed and tested two methods for the measurement of the mowing machine material feed rate (based on the conditioner power input measured by a torquemeter, and/or on the material change in momentum measured by a curved impact plate).The mowing machine (ZTR 216 H) used in the study was from the Czech Republic. A mixture of lucerne and grass was used in the measurements. The measurements carried out in the year 2001 proved that a very good linear relationship existed between the conditioner power input, output frequency of the apparatus measuring the impact force by means of the impact plate, and the material feed rate through the mowing machine. The calculated R-squared values were approximately 0.95. Keepin (2003) mentioned that keeping mower blades really sharp can lead to a reduction in turf maintenance costs. Improving the quality of the cut helps to make the grass less susceptible to disease and reduces the need for water and chemicals. Kumhala (1998) compared between 3 types of mowing machinery for meadow grass. The machines using a cutter bar mower with 2 drum mowers were investigated in 1996, and machines using a cutter bar mower and one drum mower were compared and evaluated in 1997. The capacity of work was higher for the cutter bar mower, and the rotary drum mowers always had higher energy consumption (about twice as much) in equal working conditions compared with the cutter bar mower. Jagielski and Treder (1998) said that mowing grass in orchards is a time and energy consuming task. In Poland, mowing is carried out using rotary mowers that cut grass to a minimum height of 5 cm, which causes fast regrowth and necessitates frequent mowing. Drum mowers are able to cut the grass lower, causing damage to nodes, periodical growth inhibitions and prolonged regrowth. Comparative tests proved the usability of drum mowers in orchards. Although both types of drum mower (KB-2 and KB-1.8) required more power than the rotary mower (RG-1.5), a reduced number of cuttings makes their use cheaper over the year.

So, the mean of the present research directed to developing, constructing and testing a grass mower to improve its performance and minimize the operational cost.

MATERIALS AND METHODS

The imported grass mower : there are many types of the imported mowers In Egypt, with different of styles, manufactures and powers. According by it has been selected the most spread one with the following specifications : imported from Kory (Honda), diesel motor of 5.5 hp at 2850 rpm and 4 wheels. **Fig. (1)** shows the main features of both the local and imported mowers and its price (3000 and 8500) E.L. and weight (31 and 35) kg, respectively.

(a) (b)

Fig 1: Photographs of developed grass-mower (a) and import (b).

The developed grass mower : The developed grass-mower was fabricated by using a local materials and tested in a small areas for public gardens in Cairo Governorate and Nadi El Said club in the golf course (in Giza Governorate). The photographs and views of developed grass-mower are shown in **Fig. 2**. The overall dimensions are : total length of 460 mm, total width of 430 mm, effective width of 400 mm, greatest height of 1155 mm. The developed grass-mower consists of the following parts:

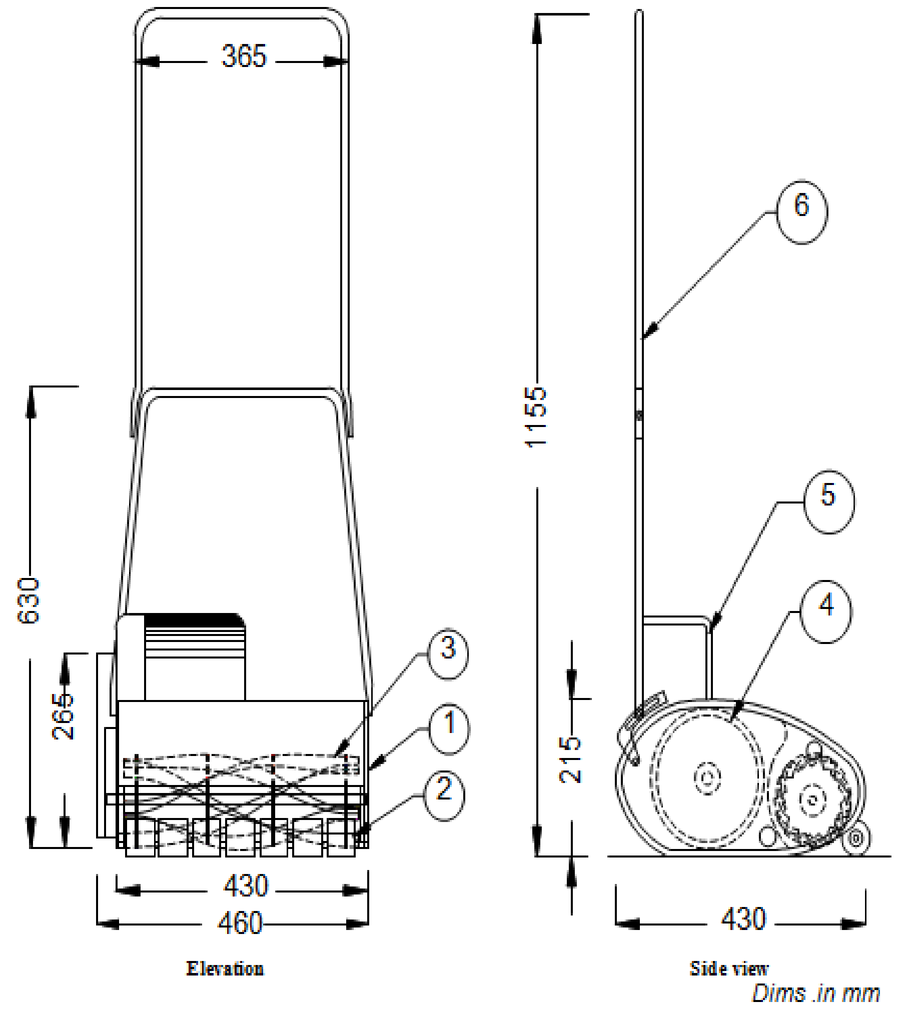
(1) Frame: frame made of steel metal with thickness of 3 mm with total diminutions of 115.5 x 36.5 cm.

(2) Gauge rollers: gauge rollers numbers are 7 with diameter of 3.7 cm. The gauge rollers used to adjust the cutting height by moving them using two sluts at two sides of the machine

(3) Cutting mechanism : cutting mechanism consists of cutting drum with 4 knives was run on the grass cutting-drum with fixed knife. Cutting drum had diameter of 13 cm and length of 43 cm.

-Grass cutting-drum (Figs. 3 and 4): grass cutting-drum consists of 4 flanges and 4 knives with 400 mm length, 18 mm width 3 mm thickness.

-**Knives (Fig 5, a and b):** were curved with drum externally sharpened edges fixed at an angle of 33^o to the horizontal axis (flail type) in **Fig (5-c)** shows design of rotated knife. The carbon steel knives were heat treated (hardened and tempered) for longer service life, number of knives on drum 4 knives for superior cutting and ease of pushing and one fixed knife, clearances between it less than a millimeter. This reduces friction



1-Frame 2 - Gauge rollers 3- Knives 4- Drive drum 5- Electrical motor 6- Pushing handle

Fig. 2: The schematic diagram of the main parts of developed grass-mower.

Fig. 3: Photographs of developed cutting drum

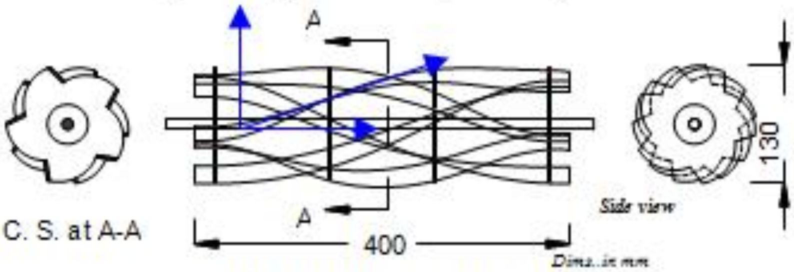
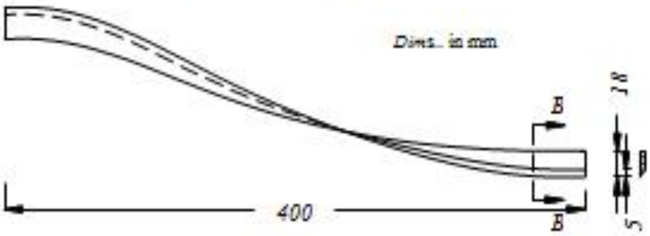
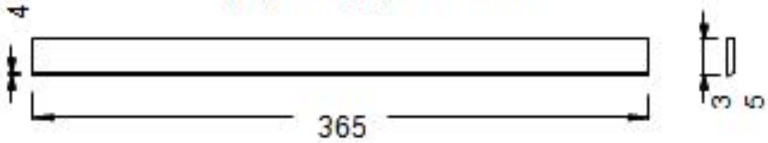


Fig 4: Views of grass cutting-drum.



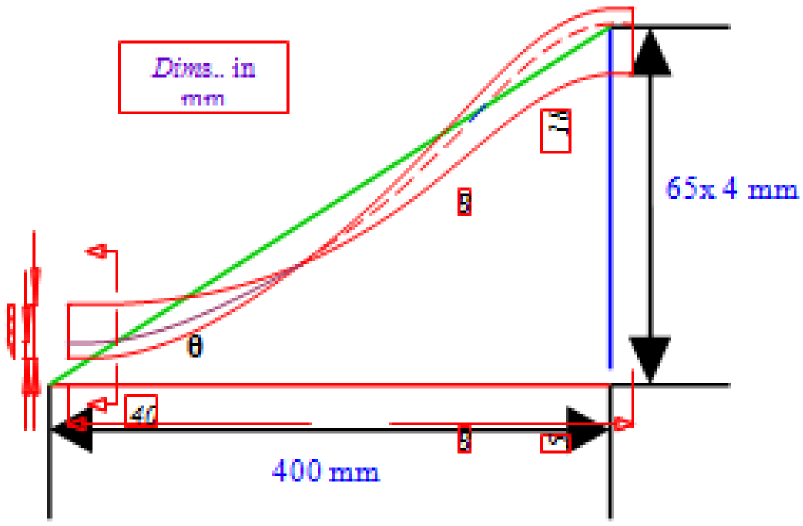
(a) Rotated knife.

(b1) Photograph Fixed knife



(b2) Fixed knife. Dims..in mm

Fig. 5: Views of cutting knives : (a) Rotated knife and (b) Fixed knife of developed grass-mower.



$$\theta = \tan^{-1} 4*65/400 = 33.02^{\circ}$$

Fig. (5-C): Design of rotated knife.

and allows the mower to cut the grass like scissors, Fig. 6 shows the cutting knives of imported grass-mower.

Fig. 6: Photograph of cutting knives of imported grass-mower.

(4) Drive drum: drive drum has diameter of 20 cm and length 43 cm.

(5) Electrical motor and power transmission: electric motor of 1 hp (0.75 kW) at 1400-2000 rpm and 4 wheels, 4 gears, sprockets and belts. The transmission system details were shown in **Figs. (7 and 8).**

(6) Pushing handle: handle made of pipes with outside diameter of 6 mm. The total dimensions of handle are height of 115.5 cm and 36.5 cm width.

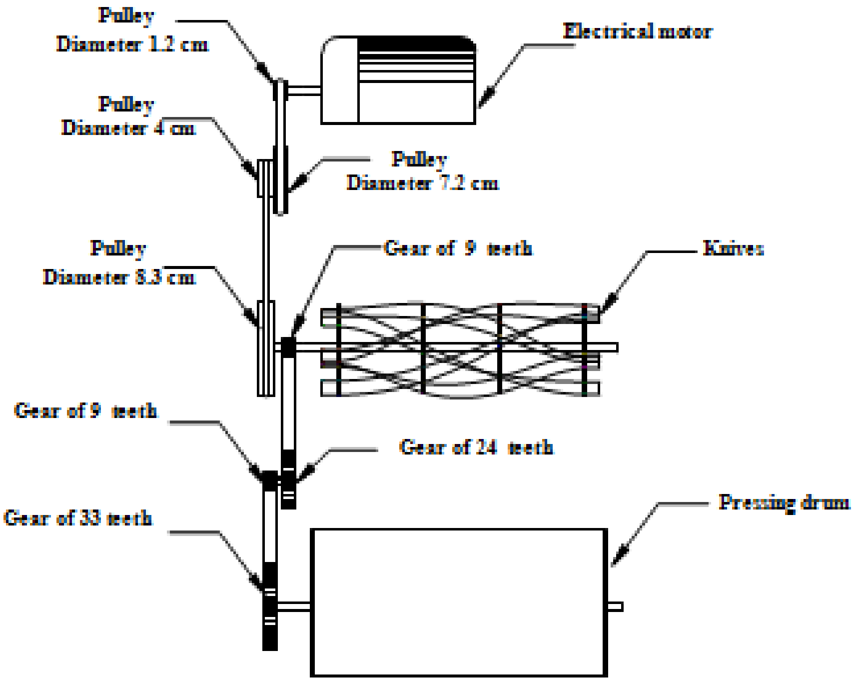


Fig. 7: Transmission system

Fig. 8: Photograph of transmission system

Some physical properties of grass : Three different varieties of grass (Tefwaw, C-shore and Passplem) were randomly collected and chosen to determine the grass length, average weight, specific density and number of plants in one squire meter of the field. Each sample was 100 grass these data tabulated in **Table (1).**

Average weight of grass in terms of the deferent months shown in **Fig. 9.**

Table 1: Some physical properties of grass.

Varieties of grass	Average length, cm.	Number of grass/m^2	Average number of Grass cutting, month	Average weight of grass cutting, kg/m^2
Tefway	10:20	1300	2 : 3	2.14
C-shore	15:20	1500	2 : 4	2.69
Passplem	20:30	1700	3 : 5	3.50

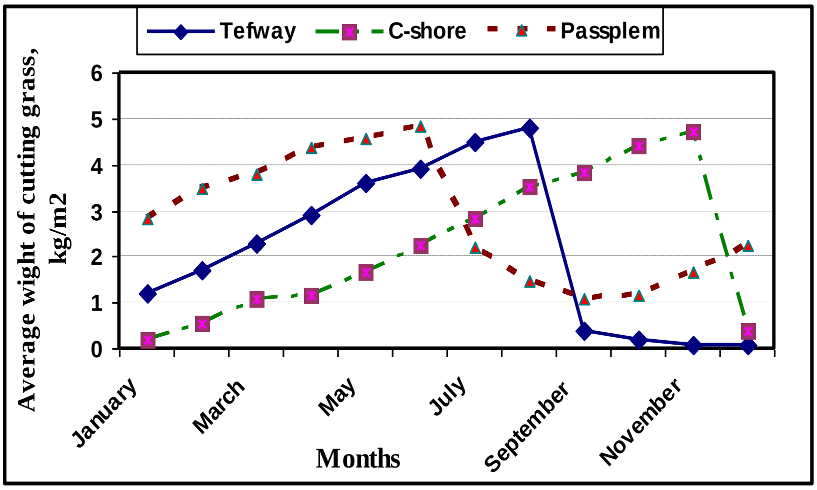


Fig 9: Average weight of cutting grass in deferent months.

The experimental treatments:

The experimental were carried out during autumn season 2013 on grass. The average number of plants was 1500 plant per square meter. And in an area of about 7 x 100 m for three different varieties of grass .

The experimental Design:

It is used the complete randomized block design where treatment are**:**

(1) Cutting speed **(C)**: the tested cutting-speeds were 4.1, 4.7, 5.3 and 6 m/s.

(2) Cutting height **(H)**: the tested cutting-heights were 2, 3, 4 and 5 cm from soil surface.

(3) Forward speed (S): the tested forward-speeds were 0.84, 1.33, 1.76 and 2.16 km/h.

It is used (The multiple regression Analysis) to found relationship between cutting efficiency and both of drum speed , cutting speed and cutting height

Measurements :

(1) The effective field capacity**(EFC)**, m^2/h;

(2) Cutting efficiency (**η**) , % ;

(3) Power (**P**), kw and specific energy (**E**), kw.h/fed.**;** for the mower local**.**

The effective field capacity: (EFC) of grass mower units was calculated using the following equation:

$$EFC = 1 / ATT$$

Where:

ATT = The actual total time in hours required per square meter.

Cutting efficiency: cutting efficiency was calculated by measuring the stem length before cutting and the length of residual after cutting. The cutting efficiency was calculated according to the following equation:

$$\text{Cutting efficiency } (\eta \%) = (Lb - La) / Lb$$

Where:

Lb = Length before cutting.

La = Residual length after cutting.

The height of the residuals before and after cutting were determined as average of 100 random samples.

Power : It was calculated by using the following equation:

$$P = I \cdot V \cdot \cos\theta / 1000 \quad , kW$$

Where:

I = Line current strength, in amperes, for the clamp meter ;

V = Potential difference Volt ; and

Cos θ = Power factor (being equal to 0.8),

Specific energy : It was calculated by using the following equation:

$$E = P / M$$

Where:

E = Specific energy kW.h/fed.;

P = Total power, kW; and

M = The effective field capacity; fed./h.

RESULTS AND DISCUSSION

Effect of forward speed, cutting speed and cutting height on the effective field capacities .

Data presented in Fig. (10) showed that by increasing the forward speed, cutting speed and the cutting height increases the effective field capacity. Consequently the minimum effective field capacity 210.4 m^2/h (0.05 fed./h) was obtained forward speed of 0.84 km/h, cutting height of 2 cm and cutting speed of 4.1 m/s. In terms of the maximum effective field capacity of 587.4 m^2/h (0.14 fed./h) was obtained with forward speed of 2.16 km/h, cutting height of 5 cm and cutting speed of 6 m/s.

The fit curve can be illustrate the effect of the forward speed and cutting speed on the mower machine the effective field capacity is the linear curve. The best linear equations and the regression can be shown in the following equation:

Cutting height		
2	EFC = -0.5377x + 234.12	R^2 = 0.1244
3	EFC = -0.8113x + 353.29	R^2 = 0.1244
4	EFC = -1.2896x + 561.55	R^2 = 0.1244
5	EFC = -1.2896x + 561.55	R^2 = 0.1244

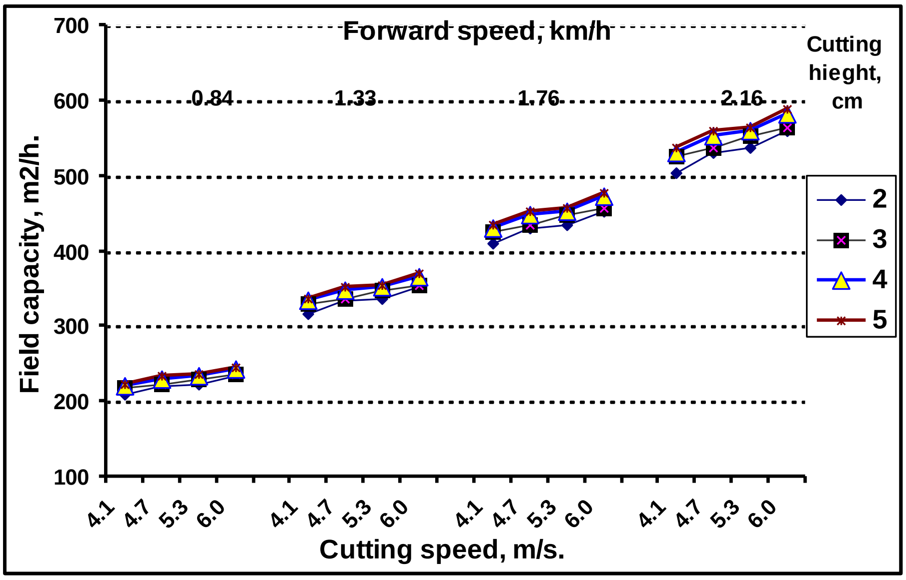


Fig. 10: Effect of forward speed on the effective field capacities at different the cutting speed and cutting height.

The multiple regression analysis of the relation between mower-machine speed ration for forward speed and cutting speed (**Sr**) and cutting height on the effective field capacities giving by the following equation :

EFC = 45.04031 – 15.7854 **Sr** + 105.9965 **H** **(R^2 = 0.986)**

From the above equation it can be clear that the effective field capacities has an inversely relationship between the forward speed but it has a direct relationship between cutting height levels.

Also, the analysis of variance for the data of the effective field capacities at different forward speed and cutting height indicated a highly significant differences between the treatments with **(R^2= 0.986)**

This trend can be explained as follows: at low cutting height, the knife cannot be able to cut grass successfully because of high cutting resistance which is due to shear. Using four knives on the cutting drum increased machine the effective field capacities than using one knife.

Effect of forward speed, cutting speed and cutting height on cutting efficiency.

Data presented in **Fig. (11)** indicated that by increasing the forward speed the cutting efficiency decreasing. Where is by increasing the cutting speed and cutting height of residual the cutting efficiency increases.

Consequently the minimum cutting efficiency 83.3 % was obtained at forward speed of 2.16 km/h, cutting height of 2 cm and cutting speed of 4.1 m/s. With respect of maximum cutting efficiency of 98.8 % was obtained at forward speed of 0.84 km/h, cutting height of 5 cm and cutting speed of 6 m/s.

The fit curve can be illustrating the effect of cutting speed and forward speed on the mower machine cutting efficiency is the linear curve. The best linear equations and the regression can be shown in the following equations:

Cutting height		
2	$\eta = -0.6035x + 97.214$	$R^2 = 0.668$
3	$\eta = -0.5886x + 96.18$	$R^2 = 0.652$
4	$\eta = -0.5636x + 95.117$	$R^2 = 0.644$
5	$\eta = -0.5268x + 93.994$	$R^2 = 0.624$

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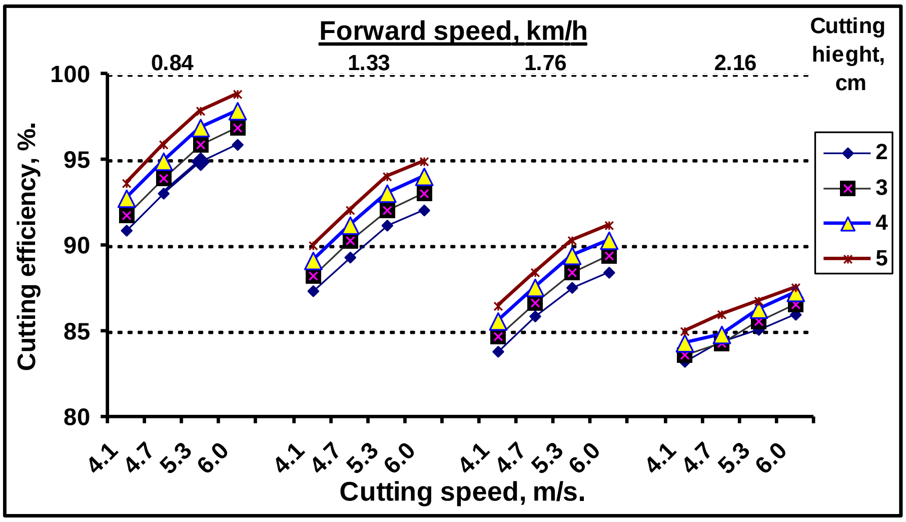

Fig. 11 : Effect of cutting speed on cutting efficiency at different the forward speed and cutting height.

The multiple regression analysis of the relation between mower-machine speed ration and cutting height on the cutting efficiency giving by the following equation :

$$\eta = 82.17 - 0.79367\ \mathbf{Sr} + 0.9008\ \mathbf{H} \qquad (\mathbf{R^2 = 0.9147})$$

From the above equation it can be clear that the efficiency has an inversely relationship between the mower-machine speed ratios but it has a direct relationship between cutting height levels.

Also, the analysis of variance for the data of cutting efficiency at different speed ratios and cutting height indicated a highly significant differences between the treatments with **(R^2= 0.9147)**

Higher value of forward speed more than 2.0 km/h was more effective in decreasing cutting efficiency owing to increase grass losses which in turn higher impact of the machine's knives on the grass. Low values of forward speed less than 1.33 km/h also increased cutting efficiency because of the excessive of knife impact per unit time on the grass, resulting in reducing damage.

Effect of forward speed, cutting speed and cutting height on power requirements.

Fig. (12) illustrated showed that by increasing the forward speed, cutting speed and decreasing the cutting height increases the power requirement. Consequently the minimum power requirement of 0.39 kW was obtained at forward speed of 0.84 km/h, cutting height of 5 cm and cutting speed of 4.1 m/s. In terms of the maximum power requirement of 0.70 kW was obtained with forward speed of 2.16 km/h, cutting height of 2 cm and cutting speed of 6 m/s.

The fit curve can be illustrating the effect of cutting speed and forward speed on power requirements is the linear curve. The best linear equations and the regression can be shown in the following equations:

Cutting height		
2	P = 0.0099x + 0.4156	R^2 = 0.6804
3	P = 0.0082x + 0.4594	R^2 = 0.5402
4	P = 0.0063x + 0.5062	R^2 = 0.3616
5	P = 0.0073x + 0.5312	R^2 = 0.5816

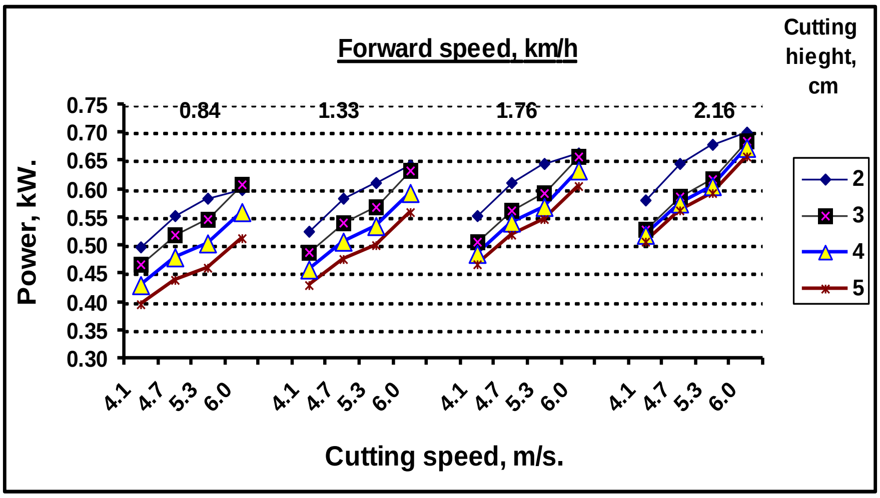

Fig. 12 : Effect of cutting speed on power requirements at different the forward speed and cutting height

The multiple regression analysis of the relation between mower-machine speed ration and cutting height on the power requirements giving by the following equation :

$$\mathbf{P} = 0.4914 + 0.0029\,\mathbf{Sr} - 0.0298\,\mathbf{H} \qquad (\mathbf{R^2 = 0.273})$$

From the above equation it can be clear that the power requirements has a direct relationship between the mower-machine speed ratios but it has an inversely relationship between cutting height levels.

Also, the analysis of variance for the data of power requirements at different speed ratios and cutting height indicated a highly significant differences between the treatments with **(R^2=0.273)**

The increase in power required by increasing forward speed is attributed to the excessive material in front of the machine .

Effect of forward speed, cutting speed and cutting height on specific energy.

Data presented in Fig. (13) showed that by decreasing both of the forward speed and the cutting height and increasing cutting speed increases the specific energy. Consequently, the minimum value of specific energy of 3.97 kW.h/fed. was obtained at forward speed of 2.16 km/h, cutting height of 5 cm and cutting speed of 4.1 m/s. In terms of the maximum value of specific energy of 10.83 kW.h/fed. was obtained with forward speed of 0.84 km/h, cutting height of 2 cm and cutting speed of 6 m/s.

The fit curve can be illustrate the effect of cutting speed and forward speed on specific energy is the linear curve. The best linear equations and the regression can be shown in the following equations:

Cutting height		
2	E = -0.2198x + 7.8279	R^2 = 0.7251
3	E = -0.2593x + 8.7034	R^2 = 0.7477
4	E = -0.3069x + 9.6779	R^2 = 0.7637
5	E = -0.3298x + 10.467	R^2 = 0.7933

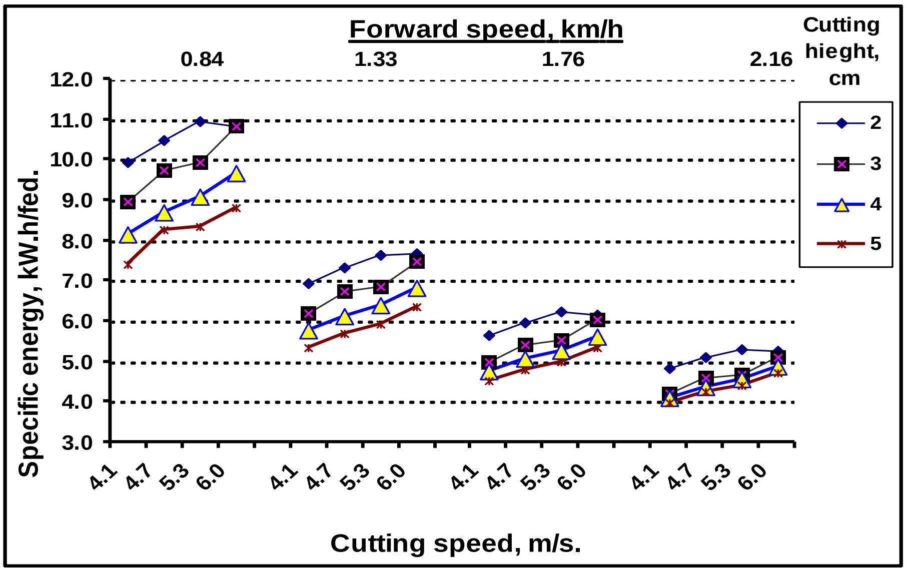

Fig. 13 : Effect of cutting speed on specific energy at different the forward speed and cutting height.

The multiple regression analysis of the relation between mower-machine speed ration and cutting height on specific energy giving by the following equation:

$$E = 2.942 - 0.3306\ Sr - 0.2603\ H \qquad (R^2 = 0.958)$$

From the above equation it can be clear that the specific energy has an inversely relationship between the mower-machine speed ratios and between cutting height levels.

Also, the analysis of variance for the data of specific energy at different speed ratios and cutting height indicated a highly significant differences between the treatments with **(R^2= 0.958)**

The decrease of energy requirements by increasing forward speed is due to the increase of machine field capacity. In point view of consumption power at higher machine efficiency. It is recommended 1.76 km/h forward speed, 4 cm cutting speed at 4.1 m/s cutting speed with the minimum value of specific energy 4.74 kW.h/fed.

CONCLUSION

It is found that the price of locally fabricated grass mower reached about one third of imported machine price. The optimum conditions of using the developed grass-mower were: forward speed of 0.84 km/h, cutting speed of 6 m/s and cutting height of 5 cm. The obtained results at optimum conditions were: the effective field capacity of 0.06 fed/h (244.9 m^2/h), cutting efficiency of 98.8 %, power of 0.51 kW, specific energy of 8.8 kW.h/fed.

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تطوير آلة لحش النجيل

ميرفت محمد عطاالله
معهد بحوث الهندسة الزراعية

يهدف هذا البحث إلى تصنيع آلة حش النجيل محلية الصنع مِن خامات محلية للمسطحات الخضراء ذات المساحات المنخفضة وتقييم آدائها على متغيرات التشغيل المختلفة المؤثرة على آدائها. الآلة المصنعة تم فيها تعديل وتصميم اسطوانة القطع وسكاكين القطع لقص النجيل وهذا التعديل يؤدى إلى تقليل الأحتكاك وبالتالى مقاومة أقل وكذلك يزيد كفاءة القطع ويقلل الطاقة المستهلكة, فهى ذات قدرة أقل. المحشة ذاتية الحركة تستمد الحركة من أسطوانة قائدة مما يؤدى إلى سهولة الدَفْع. الآلة تعمل بدون ضوضاءِ. وتمت دراسة العوامل المؤثرة على كفاءة آداء الآلة وهى السرعة الأمامية (0.84 ، 1.33 ، 1.76، 2.16) كم/س، سرعة قطع(4.1 ، 4.7 ، 5.3 ، 6) م/ث، إرتفاع القطع (2 ، 3 ، 4، 5، 6) سم، وكان ملخص النتائج كالتالى :

تم الحصول على أعلى سعة حقلية فعلية 587.4 م2 /س (0.14 فدان/س) عند سرعةِ اماميةِ 2.16 كم/س، إرتفاع قطع 2 سم، وسرعةِ قطع 6 م/ث.

تم الحصول على أعلى كفاءة القطع 98.8 % عند سرعةِ اماميةِ 0.84 كم/س، إرتفاع قطع 2 سم، وسرعةِ قطع 6 م/ث.

الطاقة النوعية القصوى 10.29 ك وات.س/فدان عند سرعةِ اماميةِ 0.84 كم/س، إرتفاع قطع 2 سم، وسرعةِ قطع 6 م/ث.

وكانت أنسب ظروف التشغيل هى سرعة أمامية 0.84 كم/س، إرتفاع قطع 4 سم، وسرعةِ قطع 6 م/ث.

قام بتحكيم البحث

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