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A STUDY ON THE DEVELOPMENT OF THE FORAGE CHOPPER PERFORMANCE FOR CHOPPING SOME CROP STALKS

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Abstract

The performance of a forage chopper was tested using three adapted cutter blades namely, straight, triangular and V-shaped, at different rotating speeds of the blades (500, 750, 1100 and 1300 r.p.m) and different forward speeds of the chopper (1.98, 2.7, 3.85, 5.15 and 6.5 km./h).

Experiments were carried out at the experimental Sakha Agri. Res. Station, Kafr El-Sheikh Governorate, Egypt.

Results indicated that the triangular type cutter blade (Tb) operated at a rotating speed range from 750 to 1100 rpm and the forward speed range from 2.7 to 5.15 km/h may be considered as optimum operating conditions in the chopping process of cotton, corn and sunflower stalks. The corresponding fuel consumption values were 6.98, 5.80 and 5.93 L/h for cotton, corn and sunflower stalks respectively. The results also showed that the optimum total costs per unit area were 25.82, 24.15 and 24.84 LE/Fed.compared with 90.63 and 72 LE/Fed. for manual chopping cotton stalks, (corn or sunflower) crop stalks respectively.

INTRODUCTION

Nowadays, mechanization techniques are no longer considered a luxury. It is of utmost necessity to use mechanization specially in clearing farm fields from crop residues. Cotton-stalks removal is one of most urgent field operations for planting the subsequent crop in due time. Okabt residues removal is among important operations to mechanize, because of the timeliness importance of land clearance since, in particular, labor has become so scarce and expensive (Awady, *et al.*, 1985).

Cutting and shredding crop stalks has many uses: fooder for animals, soil fertilizer, a renewable source of biomas fuel, compressed wooden boards and other pa-

per industries. Removal of these field wastes will help in avoiding fire hazards as well.

Hanna *et al.* (1985) compared four types of mowers: tractor mounted mower, ensilage combine, self proplled harvester, and cotton stalks shredder. They recommended the use of the shredder in cotton stalk removal because of its high productively (0.41 fed./h. at an optimum energy of 98.06 kw.h/fed. when operated at 1.8 km/h).

Abdel Maksoud *et al.* (1985) investigated the energy required to cut cotton stalks and alfalfa which was found to vary with plant variety, moisture content and knife velocity.

El-Nakib (1985) investigated the performance of the rotary cutter shredder in cutting cotton stalks. He found that a low speed of 1.65 km/h. gave finer stock and clean cut with short stubs of 8.1 cm mean height, while a high speed of 6.3 km/h. gave a ruptured cut with longer stubs of 18.7 cm mean height.

Awady *et al.* (1988) designed an apparatus which measures the resistance of plant stems for cutting. The results obtained from measurements on artificially wetted lawn, wheat stems and cotton stalks showed significant differences. Resistance parameters vary with size of plant stems, moisture content, and plant intensity.

El-Danasory (1990), found that properties of cotton stalks would affect energy requirements for cutting. The cutting energy increased as stalk diameter increased while decreased by increasing the cutting height and moisture content of stalks, but it increased by increasing the number of stalks in hill.

Morghany (1995) evaluated some different retrieving systems (tractor-mounted mower, shredder, ensilage combine, and self-propelled harvester), used in clearing land from residues of some crops (cotton, corn, and sunflower). He recommended the use of the shredder machine in cutting crop residues due to its low cost of operation.

Taieb and Imbabi (1995), studied the energy requirements of the cutting operation of some crops as cotton, maize, wheat, sunflowers, soybean, sweet sorghum, alfalfa and beans, they found that cutting energy increased by increasing the diameter and cross-section area of stem for all plants, but at variable rates.

The aim of the present work is to study the performance of a forage chopper in cutting the stalks of cotton, corn, and sunflower crops under different conditions of cutter blades, rolational speeds and forward speed of the machine.

MATERIALS AND METHODS

The field experiments were carried out at the experimental Agri. Res. Station at Sakha, Kafr El-Shiekh Governorate during the planting season of 1996 with the aim to test the performance and efficiency of a modified cutter blade developed for the forage chopper in cutting and chopping cotton, corn and sunflower stalks.

The main treatments were as follows:

1. Cutter blade type: stright blade (Sb), Trianguler blade (Tb) and V-shaped blade (Vb).

2. Blade rotating speed levels: were 500, 750, 1100 and 1300 r.p.m.

3. Forward speed levels were: 1.98, 2.70, 3.85, 5.15 and 6.50 Km/h.

A pulled type forage chopper (Bulgarian make) was used in the present investigation for cutting and chopping cotton, corn and sunflower stalks. It has a width of cut of 1.50m, 30 cutter blades pulled by 45 kw, Fiat 55-66 DT. tractor.

The modified blades were made of mild steel flat plates of 50 mm width and 7 mm thickness as shown in Fig. (1).

A representative sample of 100 stalks of cotton, corn and sunflower crops was taken randomly, to measure dimensions and moisture contents. Average values are given in table (1).

Table 1. Cotton, corn and sunflower stalks average dimensions and moisture content.

Crops	Cotton	Corn	Sunflower
Mean diameter (cm)	1.18	1.42	1.46
Mean height (cm)	188	279	231
Average moisture content (%)	40	51	47

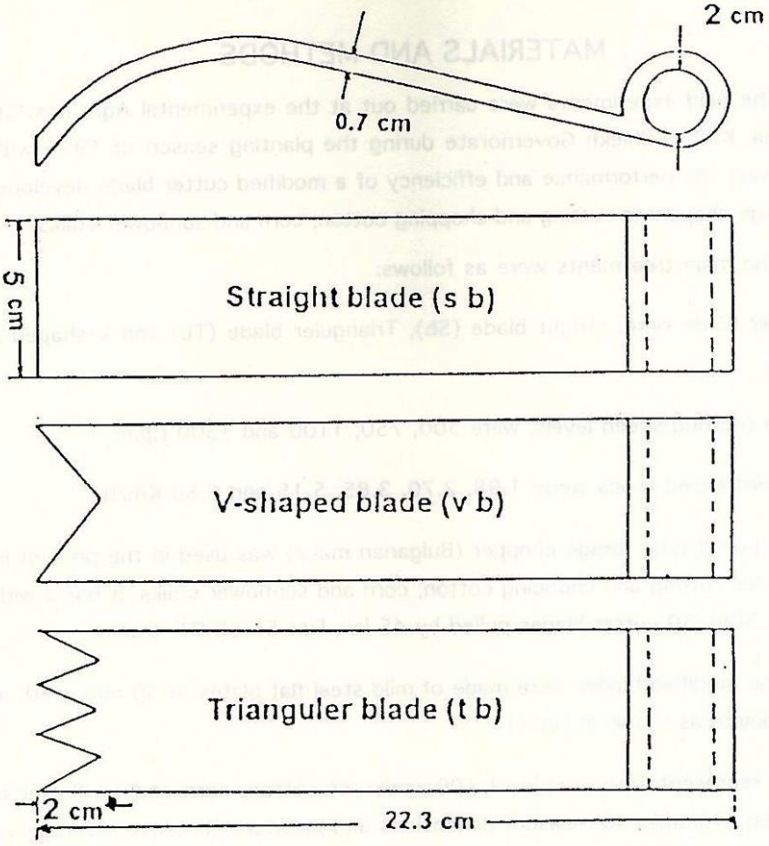

Fig. 1. The experimented blades of the forage chopper.

In each run, the forward speed (km/h.), blade rotating speeds (r.p.m.) distance traveled, time duration needed for this distance and fuel consumption were determined. A stop watch and measuring tape were used in measuring the distance traveled and elapsed time and hence the forward speed was calculated. The fuel consumption was determined by measuring the volume of fuel consumed throughout the test run, using a graduated glass cylinder and the stop watch. A multi range hand tachometer was used to measure the blade rotational speeds.

Cutting height of stalks was measured from ground to the stalk tops. Moreover, cutting length of stalks was also measured on pieces gathered from the ground. Calculations were carried out as follows:

1. Cutting efficiency was calculated using the following formula by Hanna *et al.* (1985):

$$Ec = \frac{Ha-Hb}{Ha} \times 100$$

where,

Ec : Cutting efficiency (%).

Ha : Height of plant stand above the soil surface before cutting in cm.

Hb : Height of the stubble after cutting (height of cut) in cm.

2. Actual field capacity (C_{fa}) was calculated by using the formula:

$$C_{fa} = \frac{1}{Ta} \times 100$$

where, (Ta): Actual time consumed to cut stalks of one feddan.

3. Field efficiency (E_f) was calculated using the following formula by Culpin, 1975:

$$Ec = \frac{C_{fa}}{C_{ft}} \times 100$$

where,

C_{fa}: Actual field capacity (fed./h.)

C_{ft} : Theoretical field capacity (fed./h).

= width of cut x forward speed.

4. Power consumption was approximated through measuring fuel consumption for each treatment using the following formula :

$$BHP = \{ Fc \times \frac{1}{3600} \} \times \rho \times L.C.V. \times 427 \times \eta_{th} \times \eta_{m} \times \frac{1}{75}$$

where,

Fc = Fuel consumption, Lit./h.

ρ = Density of the fuel, kg/lit (for solar fuel 0.85 kg/lit).

L.C.V. = Lower calorific value of fuel (kcal/kg = 10^4 Kcal/kg for most petrol fuels).

427 = Thermo - mechanical equivalent, Kg. m/Kcal.

η_{th} = Thermal efficiency of the engine (considered to be 40% for most diesel engines).

η_{m} = Mechanical efficiency of the engine (considered to be 80% for most diesel engines).

5. Cost of chopping stalks operation per unit area (LE./fed.) was based on equations by Hunt, 1983.

N.B. The data were arranged in split-split plot design for the statistical analysis.

RESULTS AND DISCUSSION

1. Performance parameters by using chopper machine:

The performance of forage chopper was evaluated by studying the effect of the forward speeds of 1.98, 2.70, 3.85, 5.15 and 6.50 km./h., the cutter blade rotating speeds of 500, 750, 1100 and 1300 rpm and cutter blade types of straight (Sb), triangular (Tb) and V-shaped blades (Vb) on the cut length of the stalks, cutting efficiency, actual field capacity, field efficiency, fuel consumption, power requirements and the cost of operation.

2. Cut length of stalks and cutting efficiency :

The effect of forward speed and cutter blade rotating speed on the cut length of stalks (Y1) and cutting efficiency (Y2) for cotton, corn and sunflower stalks are shown in Fig. 2. The length of stalks (Y1) and cutting efficiency (Y2) for different crops had a reducing effect on forward speed. This may be due to the tendency of

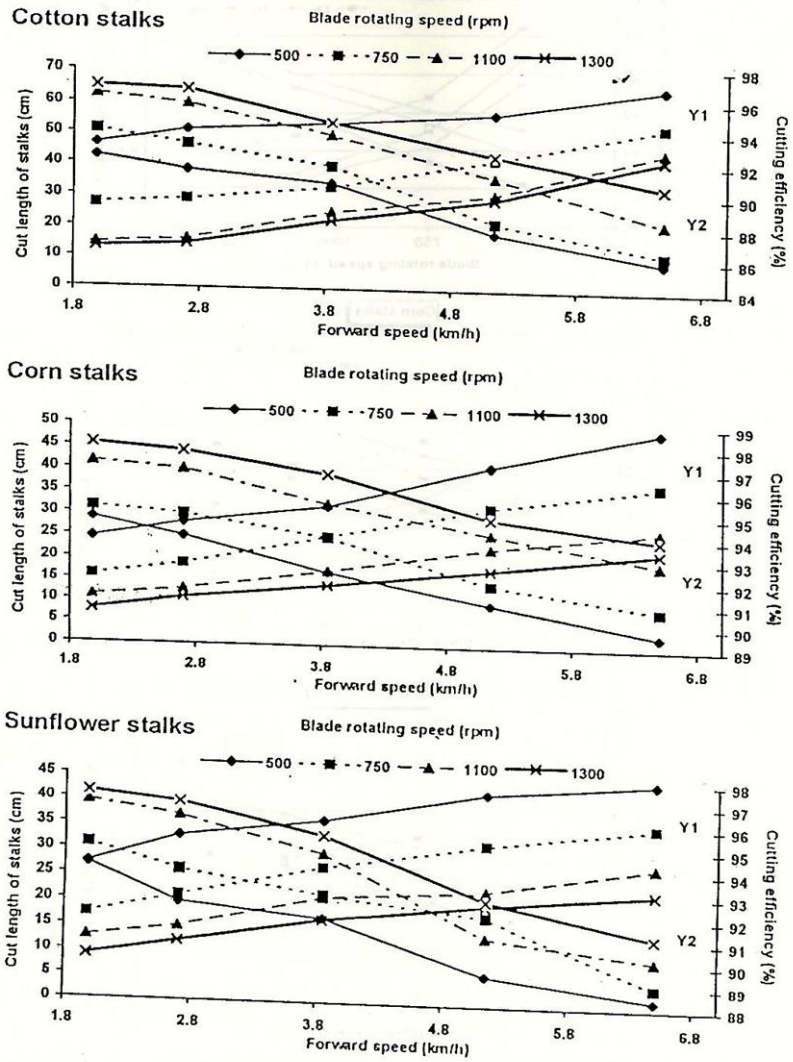

Fig. 2. Effect of forward speed and blade rotating speed on the cut length of stalks and cutting efficiency for cutting cotton, corn and sunflower stalks.

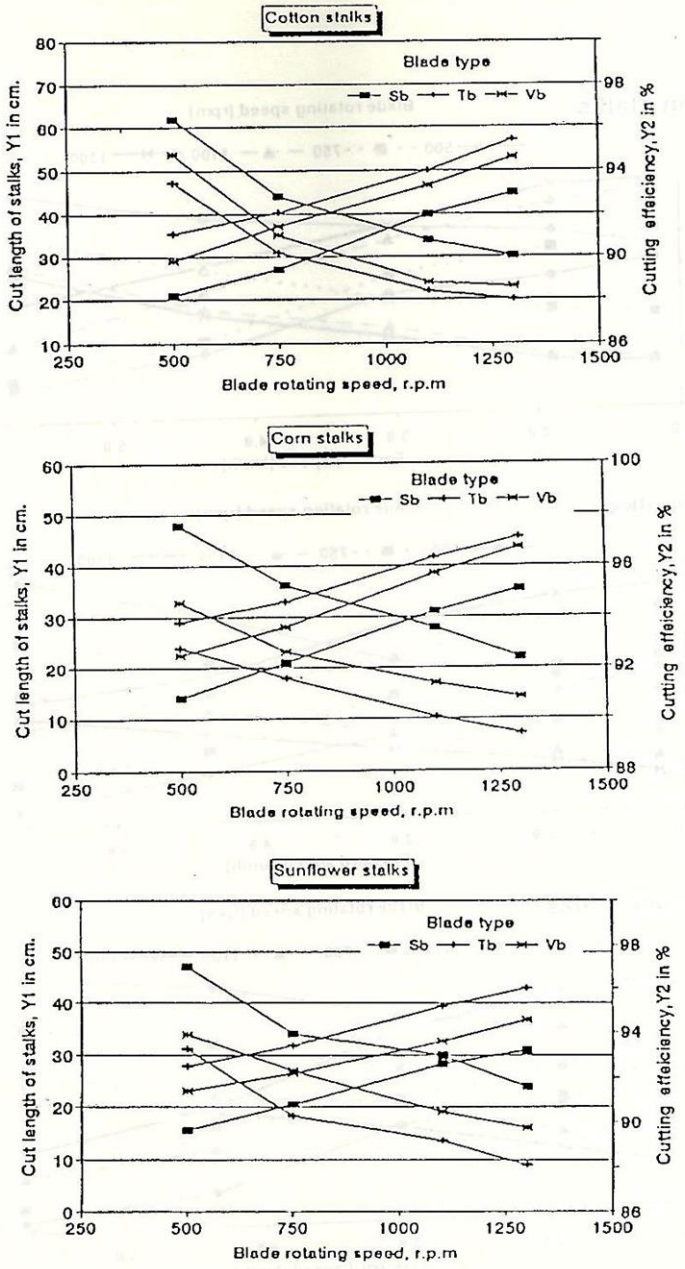

Fig. 3. Effect of blade rotating speed and cutter blnde type on the cut length of stalks (Y1) and cutting efficiency (Y2) for cutting cotton, com and sunflower stalks.

cutting unit vibration and crop stalks to slipout of the cutting unit by increasing chopper machine forward speed.

The minimum mean values of the cut length of stalks (Y1) obtained were 7.8, 8.8 and 13.3 cm for corn, sunflower and cotton stalks respectively at the lowest level of forward speed (1.98 km/h.) and the highest level for blade rotating speed (1300 rpm.).

The results indicate that increasing cutter blade rotating speed tends to decrease the length of stalks (Y1), whilst increase the cutting efficiency (Y2). These were found to be in the forward speed range from 2.70 to 5.15 km./h. The optimum speed was found to be around 3.93 km/h. It was obtained from the intersection of the curves of cut length of the curves of cut length of stalks and cutting efficiency.

The effect of cutter blade types and blade rotating speed on the cut length of stalks (Y1) and cutting efficiency (Y2) for cotton, corn and sunflower stalks are shown in Fig. (3).

The results of field experiments indicated that the triangular (Tb) shaped blade gave the bast results of cut length of stalks (Y1) and cutting efficiency (Y2) compared with other cutter blades, for all treatments. This phenomenon can be explained by the fact that the triangular (Tb) has the largest tip contact area used in the cutting operation than the other.

On the other hand, it is evident from the results that increasing the cutter blade rotating speed tends to decrease the length of stalks (Y1), and increase the cutting efficiency (Y2) for all treatments.

The highest cutting efficiencies (Y2) (95.4, 96.1 and 97.1%) were obtained with triangular blade (Tb) at cutter blade rotating speed 1300 rpm for cotton, sunflower and corn stalks respectively. While the minimum mean values of the cut length of stalks (Y1) obtained were 7.3, 8.5 and 20.3 cm for corn, sunflower and cotton stalks respectively at the cutter blade rotaing speed of 1300 rpm with triangular blade (Tb).

On the other hand, no significant difference was found between 1100 and 750 rpm cutter blade rotating speeds. The least value of the cut length of stalks (Y1) and the best cutting efficiency (Y2) were found to be within the range of cutter blade rotating speed from 750 to 1100 rpm. The optimum cutter blade rotating speed was equal to 925 rpm.

1.2 Actual field capacity and field efficiency:

Fig. (4) illustrates the effect of using different operating speeds on the actual field capacity (Y1) and field efficiency (Y2) for cotton, corn and sunflower stalks. In general, the figure shows that the actual field capacity (Y1) increases and the field efficiency (Y2) decreases as the operational speed increased for cotton, corn and sunflower stalks.

The optimum field efficiencies (Y2) obtained considering the maximum cutting efficiency of stalks and the minimum cut length of stalks at the optimum operating speeds were (85% and 74%) for different crop stalks.

1.3 Fuel consumption and energy requirements :

The effect of cutter blade speed and forward speed on fuel consumption for cotton, sunflower and corn stalks are shown in fig (5) and fig (6). The fuel consumption increased with increasing the cutter blade rotating speed and forward speed for cotton, sunflower and corn stalks.

The highest values of fuel consumption obtained were 7.08,7.37 and 8.41 L/h. for corn, sunflower and cotton stalks respectively when using the forage chopper at highest forward speed 6.50 km/h. At the same time, the highest values were 7.37, 7.51 and 8.85 L/h for corn, sunflower and cotton stalks respectively at the highest cutter blade rotating speed 1300 rpm.

Data in table (2), show the effect of forward speed of machine on fuel consumption and power requirements for the three crop stalks. Increasing forward speeds tends to increase fuel consumption and power requirements for all crops stalks.

On the other hand, the cotton stalks require higher energy and fuel consumption than corn and sunflower stalks due to excessive stiffness of cotton stalks.

Table 2. Effect of forward speed on fuel consumption and power requirements for cutting cotton, corn and sunflower stalks.

Forward Speed Km/h.	Fuel Consumption L/fed.			Power requirements Kw		
	Cotton	Corn	Sunflower	Cotton	Corn	Sunflower
1.98	9.89	6.11	7.02	24.3	17.1	18.7
2.70	8.04	5.61	6.29	25.9	19.8	20.8
3.85	6.91	5.37	5.65	30.0	24.9	25.5
5.15	6.42	4.73	4.83	34.5	28.1	28.6
6.50	5.68	4.19	4.41	36.2	30.4	31.7

1.4 Cost analysis:

Table (3) shows the total costs per hour for both tractor and forage chopper used in the chopping operation for different crop stalks.

Table 3. Fixed and variable costs for tractor and chopping machine in LE/h .

Item	Tractor LE/h.	Machine LE/h.
A. Fixed Costs:	-	-
1- Depreciation LE/h.	9.95	1.80
2- Interest, shelter, taxes and insurance LE/h.	5.29	1.93
Total Fixed Cost LE/h.	10.24	3.73
B. Operating Costs :	-	-
1- Repairs and maintenance.	5.39	1.15
2- Fuel and oils	4.07	-
3- Labour LE/h.	1.50	-
Total operating cost	10.96	1.15
Total cost	21.20	4.88

Total cost for tractor and chopping machine = 26.08 LE/h.

The cost calculations were based on the list price of LE 55000 for the tractor and L.E. 6000 for the chopping machine.

Table (4) shows the total costs per unit area at the different forward speeds of operation used for different crop stalks. It has been noticed that increasing forward speed tends to decrease the total cost as a result of increasing the actual field capcity.

The daily wage for one laborer to manually chop stalks was about 1.5 LE/h. On the other hand, the total costs were about 90.63, 60 and 72 LE/fed. when chopping cotton stalks, corn and sunflower stalks manually respectively.

Table 4. The total costs for chopping machine in LE/h .

Crop	Forward Speed Km/h.	Actual Field capacity fed/h.	Total Cost LE/fed.
Cotton	1.98	0.57	45.75
	2.70	0.75	34.77
	3.85	1.01	25.86
	5.15	1.25	20.86
	6.50	1.48	17.62
Corn	1.98	0.65	40.12
	2.70	0.82	31.80
	3.85	1.08	24.15
	5.15	1.38	18.90
	6.50	1.69	15.43
Sunflower	1.98	0.62	42.06
	2.70	0.77	33.87
	3.85	1.05	24.84
	5.15	1.38	18.90
	6.50	1.67	15.62

CONCLUSION

Data obtained from field experiments under the conditions described in this study support the following conclusion:

1. The least cut length of stalks and the corresponding adequate cutting efficiency were found to occur in the range from 2.70 to 5.15 Km/h. forward speed.
2. The performance of the triangular blads (Tb) gave better results of cut length of stalks and cutting efficiency as compared with other v-shaped (vb) and straight blades (sb) for all treatments.
3. Increasing the cutter blade rotating speed tends to decrease the cut length of stalks, while increases the cutting efficiency for all treatments. The optimum cutter blade rotating speed ranged from 750 to 1100 rpm.
4. The optimum field efficiencies were 74, 80 (sunflower or corn stalks) and 85% for cutting cotton.

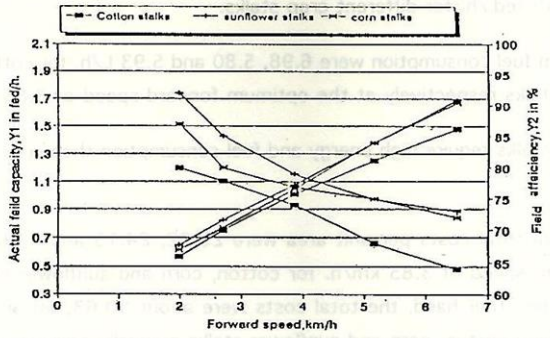

Fig. 4. Effect of foraward speed on actual field oapacity (Y1) and field efficiency (Y2) for cutting cotton, sunflower and com stalks.

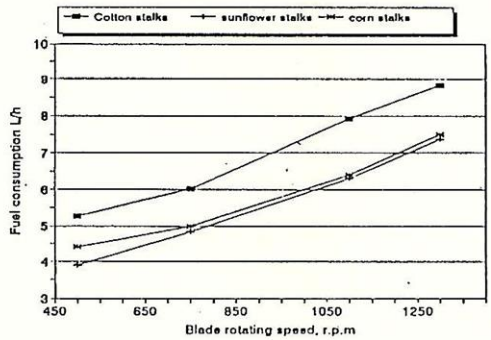

Fig. 5. Effect of blade rotating speed on fuel consumption for cutting cotton, sunflower and com stalks.

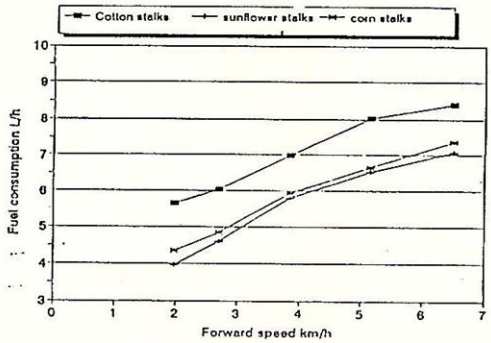

Fig. 6. Effect of foraward speed on fuel consumption for cutting cotton, sunflower and corn stalks.

5. The actual field capacity at optimum at optimum operating conditions ranged from 1.01 to 1.38 fed./h. for different crop stalks.

6. The optimum fuel consumption were 6.98, 5.80 and 5.93 L/h. for cotton, corn and sunflower stalks respectively at the optimum forward speed of 3.85 Km/h.

7. The cotton stalks require high energy and fuel consumption then corn and sunflower stalks.

8. The optimum total costs per unit area were 25.82, 24.15 and 24.84 LE/fed. at the optimum speed of 3.85 km/h. for cotton, corn and sunflower stalks respectively. On the other hand, the total costs were about 90.63, 60 and 72 LE/fed. when chopping cotton, corn and sunflower stalks manually respectively.

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دراسة على تطوير أداء آلة فرم الأعلاف لفرم سيقان بعض المحاصيل

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إستهدف هذا البحث محاولة زيادة إستغلال وتحسين أداء آلة فرم الأعلاف المجرورة خلف الجرار فى فرم المخلفات الحقليه لسيقان بعض المحاصيل مثل القطن والذرة وعباد الشمس وتم ذلك عن طريق دراسة العوامل الهندسيه المؤثرة على أداء الآله الآتيه :-

١) شكل سكاكين الفرم حيث تم تصنيع شكلين مختلفين من الاسلحة بالاضافه للاصلى بالآله اليوغسلافية الصنع (Tb-Vb-Sb) .

٢) سرعة دوران سكاكين الفرم (٥٠٠ – ٧٥٠ – ١١٠٠ – ١٣٠٠ لفه /ق).

٣) سرعة تقدم الآله بالحقل (١,٩٨ – ٢,٧٠ ، ٣,٨٥ ، ٥,١٥ ، ٦,٥٠ كم / ساعه).

وقد تم تقييم أداء الآله عملياً بالحقل على فرم سيقان محاصيل القطن والذرة وعباد الشمس وقد اسفرت الدراسة على النتائج الآتيه:

١) أفضل الاسلحه هو السلاح Triangular blade (Tb) حيث اعطى أفضل النتائج من حيث كفاءة القطع لجميع انواع السيقان مقارنه بالاسلحة الاخرى.

٢) زيادة سرعة دوران اسلحة الفرم أعطت أقل اطوال قطع للسيقان بينما ادى ذلك الى زيادة كفاءة القطع للسيقان وكانت افضل سرعات دوران للسكاكين تتراوح بين ٧٥٠ – ١١٠٠ لفه /دقيقه.

٣) أفضل سرعة تقدم تستخدم عندها الآله تتراوح بين ٢,٧ – ٥,١٥ كم/س حيث تعطى أقل اطوال قطع للسيقان واحسن كفاءة قطع لجميع سيقان المحاصيل المستخدمه بالدراسه.

٤) باستخدام سرعة تقدم ٣,٨٥ كم/س سجلت افضل قيم لاستهلاك الوقود (٦,٩٨ – ٥,٨ – ٥,٩٣ لتر/ساعه) لفرم سيقان القطن والذرة وعباد الشمس على التوالى.

٥) دائما كان فرم سيقان القطن بالاله يسجل اعلى قيم للقدرة المستهلكه وكذلك إستهلاك الوقود عن فرم سيقان الذرة وعباد الشمس وذلك للخواص النسجية الفعليه لسيقان القطن.

٦) التكاليف الكليه للفرم بالاله كانت ٢٥,٨٢ ، ٢٤,١٥ ، ٢٤,٨٤ جنيه/فدان بينما للطريقة اليدويه كانت ٩٠,٦٣ ، ٦٠,٠ ، ٧٢ جنيه/فدان لسيقان القطن والذرة وعباد الشمس على التوالى.