Role of agricultural engineering in environmental and sustainable development for the valley and delta areas: 1034- 1047
FARM MACHINERY AND POWER

PERFORMANCE OF A TRACTOR MOUNTED SUGARCANE HARVESTER

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ABSTRACT

A single row tractor mounted sugarcane harvester was fabricated and tested in the field. The unit consists of a frame, a base cutter and windrowing guide. It operated by the tractor PTO. The experiments were carried out at shandawill experiments station, Sohag governorate to determine of machine performance.

The results indicated that:

1- Increasing forward speed from 2.37 to 3.75 km/h increased the total losses of sugarcane yield. Higher forward speed decreased cutting and harvesting efficiencies.

2-Decreasing the star wheel height of windrowing guide, the collecting efficiency increased.

3- Minimum total losses were 8.313 ton/fed. recorded at forward speed 2.37 km/hr and oblique angle of knife 30°. Maximum cutting efficiency was 98.46 % and harvesting efficiency was 98.86 % achieved at forward speed 2.37 km/h and oblique angle of knife 30°. Higher the collecting efficiency was 70.69 % achieved at star wheel height 105 cm.

INTRODUCTION

Harvesting of sugarcane is the single most costly operation in sugarcane farming. That needs to cut the base of cane stalks, windrowing the stalks, clean cane stalks from dry leaves (detrashing), cut the green tops (toping), load cane from several furrows to vehicles and transport to mill. Sugarcane harvesting in Egypt is done manually. Manual harvesting involves cutting and windrowing the stalks

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by cutters that require 16 men for one feddan, cleaning and topping by boys that require 40 boys for one feddan **(Abdel Mawla and El-Geddawy, 1997)**. Most of the cutters may be use a long-handled knife or hoe to cut the sugarcane stems at the base and by impact force exerted by hand. As the hand muscles are used to cut the stalks of sugarcane, the cutters develops fatigue after working for only a few hours and needs rest pause quite often particularly when work in the hot and humid climate under the sun. Any delay for milling beyond 72 hours, will reduce the recovery of sugar. Also many farmers are facing labor shortage, because the younger, better educated generation shuns the heavy manual work of cutting sugar cane in an uncomfortably hot climate.

The current study was devoted to fabricate and test a single row harvester for sugarcane. The machine was considered to be mounted on three point hitch of the tractor and powered by the PTO of the tractor.

REVIEW OF LITERATURE

Blackburn (1984) stated that the sugarcane is a tall tropical grass, it forms a single unbranched stem that reaches an average height of 3-4m. The stem diameter ranges between 3 and 5cm depending on the species and it is from the stem which the sugar is extracted. The stem is clearly differentiated into joints that are comprised of nodes and internodes. **El-Nakib et al (1996)** studied some physical and mechanical properties of sugarcane mainly: stalk dimensions, mass, number of buds, curvature, hardness and coefficient of friction and their relation to mechanization. They found that the average length and diameter of the sugarcane stalk for the Egyptian variety C9 were 178 cm and 2.3 cm respectively, the average stalk mass was 0.794 kg, the average stalk radius of curvature was 560 cm. The cane stalk hardness was 775 centi-N and the average coefficient of friction were 8.8 degree for wood, 7.6 for rubber and 8.9 for steel. **Iqbal Hossain et al (1996)** found that the manual harvesting require about 150 laborers (40% of the total laborer requirement) by using spade or hashua. Manual harvesting accounts for more than 7% yield loss since the canes are cut 8 to 16.5 cm above the ground. **Smit et al (2001)** studied that Oxygen consumed per minute (VO_2), energy expenditure (EE), heart rate (HR) and productivity of manual cutting burnt and green cane. They found that the average relative VO_2 for cutting burnt cane and the calculated relative EE were both significantly lower than those for green cane. The average HR during work was not significantly different for burnt or green cane, neither was the maximal HR. Rate of productivity for burnt cane was significantly higher than that of green cane. Energy per kilogram required for burnt cur cane was significantly lower than for green cane. **Kanafojski** and **Karwowski (1976**) mentioned that for cutting plants a rectangular knife sharpened at its two longer sides, made of alloy steel, is now generally used. For preventing the knives against damaging on running into a field obstruction, they are connected with the disk by hinges. The actual method of connection of the knives with the disk should enable their facile and fast disconnection in the event of damaging or for the purpose of sharpening, or of resetting another knife. **Mello and Harris (2003)** studied the influence of the type of blades (forward and backward) and the pitch of serration (3 and 7 mm) in the presence of a flection moment caused by the action of the knockdown roller. One standard blade was used as a reference and four replications were used for each type of cut. An experiment was conducted using a factorial design with two kinds of blades and two pitches of serration. The damages caused in the sugarcane and the energy spent on each type of cut were compared. The forward blade with serrated pitch of 3 mm presented the best result. **Oduori and Gupta (1992)** developed a revolving knife type sugarcane base-cutter, 440 mm nominal diameter with four smooth-edged blades of twenty-degree edge angle. The base-cutter and the cutter blades were, laboratory-tested to determine the optimum combination of base-cutter rotational speed, tilt angle, and blade oblique angle, the objective being to minimize the cutting energy expanded per unit field area of cut cane. The conclusions were drawn as follow:

1-The feeding power component of the cutting power to be negligible.

2-There has a strong positive correlation between the cane diameter and the peak cutting torque. Values of the cane diameters obtained as averages from each of the three replications however showed little variation and had a standard deviation of 1.5 mm. This variation was taken to be negligible.

3-The rotational speed of base-cutter was the single parameter with the most significant effect on the cutting torque.

4-Variation among the replications was found not to have a statistically significant effect on the cutting torque.

5-The results obtained indicated a tilt angle of about 27 degrees, and oblique angle of about 35 degrees. The rotational speed between 600-800 rpm (knife peripheral velocity at the base-cutter's nominal diameter of between 14 -18 m/s) to be most suitable, with the feeding velocity being 0.225 m/s.**Mello and Harris (2000)** compared between the conventional harvester blade, a smooth curved blade and three serrated, curved blades of different pitches. An investigation was done by on using serrated, curved blades to minimize the losses and damages to sugarcane during cutting. It is difficult to determine the losses and damage in the cutting process. An acceptable indication for losses is to measure the mass lost in cutting and for measuring damages one use. **Eiland and Clayton (1983)** determined the fuel consumption and performance of mechanical systems in unburned and burned cane in Florida. Harvester fuel consumption per gross tone of cane averaged 112% higher in unburned than in burned cane. Cane recovery per hectare in unburned cane was only 83% of that in burned cane. **Gupta et al (1996)** evaluated the developing self-propelled sugarcane harvester. They found that effective field capacity varied from 0.11 to 0.15 ha/h (average 0.13 ha/h) and field efficiency varied from 66 to 79 % (average 71.25%). The material handling capacity varied from 3.8 to 6.5 Mg/h.This type was found suitable for burnt cane harvesting.

MATERIALS AND METHODS

Field experiments were carried out on Sugarcane crop at 2009/2010 cane growing season in shandawill experiments station. The experimental area was about 1.03 feddan. Sugarcane variety G.T.54/9 (C.9) planted in loam soil (28.2% clay, 27.4 % silt and 44.4 % sand). The aim of this study devoted to developed single row harvester machine and test its performance represented in cutting and harvesting efficiencies, total losses.

1-Materials:

a- Tractor:

The unit designed to be mounted on the three point hitches of the tractor. Field experiments were accomplished by mounting the harvester on a tractor UTB (Romanian tractor model U 650 M), 47.8 kW.

b. The developed sugarcane harvester:

A tractor mounted harvester was developed as an experimental unit as shown in Fig. (1), (2) and (3). The main parts of the machine are:-

(1)- Machine frame:

The frame had a rectangular shape 600 x 2000 mm. Hitching arrangement was designed as an offset hitch to facilitate the expansion of the machine frame to the left side of the tractor. Therefore the unit harvest a single cane row with respect to the on the left side of the driver.

(2)-Power transmission:

This power to the base cutter and windrowing guide is provided from tractor power take-off shaft using a universal joint. A horizontal shaft arrangement was mounted to the universal joint toward the left of the machine at which a bevel gear was connected to power the vertical shaft of base cutter. The transmission system allows 610 rpm for the machine base cutter.

(3)-Base cutter:

It was fabricated by forming a 10 mm thick disc of 400 mm diameter. Four knives of 60 mm width 150 mm long 10 mm thick was bolted on the disc. The tip angle of the knife was 20˚. The disc was bolted the end of the base cutter shaft which is powered as described before.

(4)-Cut cane directing mechanism :

The mechanism consists of three parts; 1- Vertical shaft mounted at a position just in front of the base cutter. 2- A star wheel was fabricated by forming a hub at which five soft rods were fixed. 3- Power transmission that connected to the main shaft which reduces rotation speed to 1: 11. The star wheel could be slided up and down the vertical shaft to be fixed at variable positions.

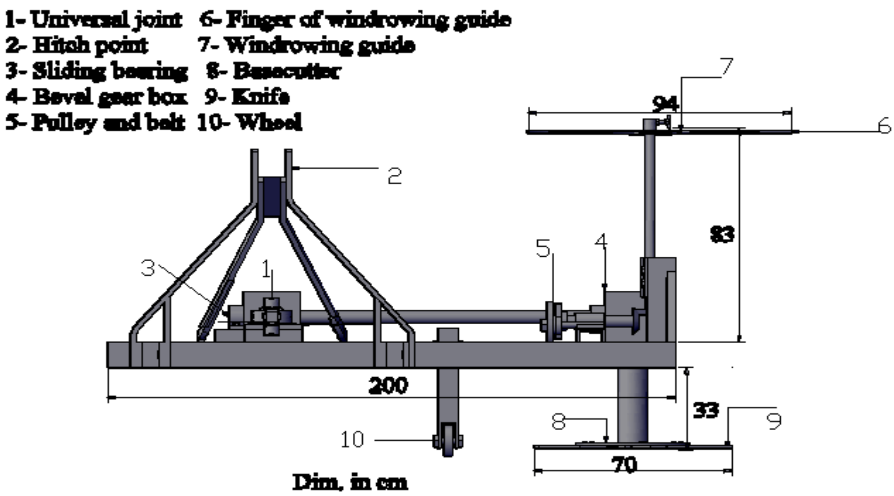

Fig. (1): Front view of the developed sugarcane harvester

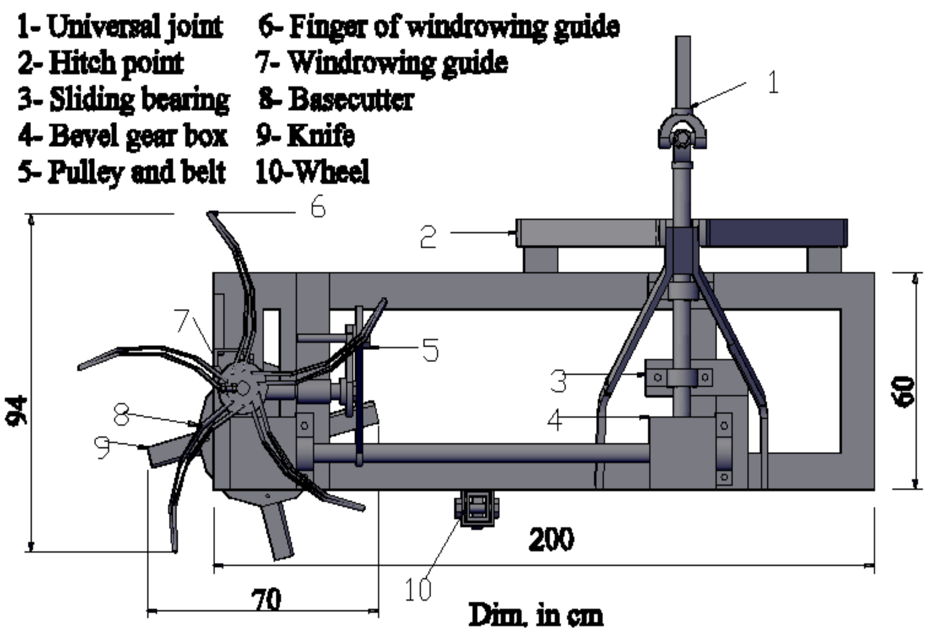

Fig. (2): Plane view of the developed sugarcane harvester

Fig. (3): Photograph of the developed sugarcane harvester

c. Measuring instruments:

It was balance, volumetric graduated cylinder, 30 meter survey tape and stop watch.

2. Methods:

The main variables considered for testing were three forward speed (2.37, 3.46 and 3.75 km/h), four oblique angles of the knife on base cutter (20˚, 30˚, 40˚ and 50˚) and three heights of star wheel of windrowing guide (125, 115, 105 cm).

a-Cutting efficiency:

The cutting efficiency was calculated by using the following formula by Hanna et al. (1985):-

$$Ec=\frac{Ha-Hb}{Ha} \text{ x } 100, \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(4\text{-}2)$$

Where:

Ec: Cutting efficiency %

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

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

b-Harvesting efficiency:

The harvesting efficiency was calculated by using the following formula by Awady et al. (1996):-

$$E_h = \frac{Wa - Wb}{Wa} \times 100, \qquad (4\text{-}3)$$

Where:

E_h : Harvesting efficiency (%),

W_a: Weight of removed yield in kg.

W_b: Weight of remaining stubble in kg respectively.

c- Sugarcane losses: it included:-1-Stubble losses: it was manually cut at ground surface respectively and collected to weight of them for each plot. 2-Whole stalks (Uncut): it was collected and weight of them for each plot.3- Damage stalks from tractor pass (DS): It was manually cut at ground surface respectively and counted them for each plot. The losses of damage stalks from tractor pass calculated by using the following formula:-

DS=Number of damage stalks per m^2 X average weight of stalk

4- Billets: it manually collected and weight in each plot.

d- Collecting efficiency:

The theoretical directing action and the falling position were determined for comparison. To evaluate the performance of the harvester for directing the cut cane, the following steps were taken:

1-Before start moving with the machine, the cane row was inspected and classified as follow:

(1)- Cane tilt toward the machine motion direction.

(2)- Cane tilt backward the machine motion direction.

(3)- Cane tilt lift side of base cutter.

(4)- Cane tilt right side of base cutter.

Angle of tilt was recorded for each stalk. Only 20 meters were inspected and recorded for that test along the row. The test was repeated 3 times for each star wheel height which was tested at 3 heights (125, 115 and 105 cm).

2-After harvesting the inspected sample of the row, the lying stalks by star wheel were recorded and compared with the theoretical direction.

e-Classification of sugarcane damage:

The harvested cane was inspected and classified according to the degree of damage following the classification of **Kroes (1997)**. Fig. (4) show Kroes's classification of damage.

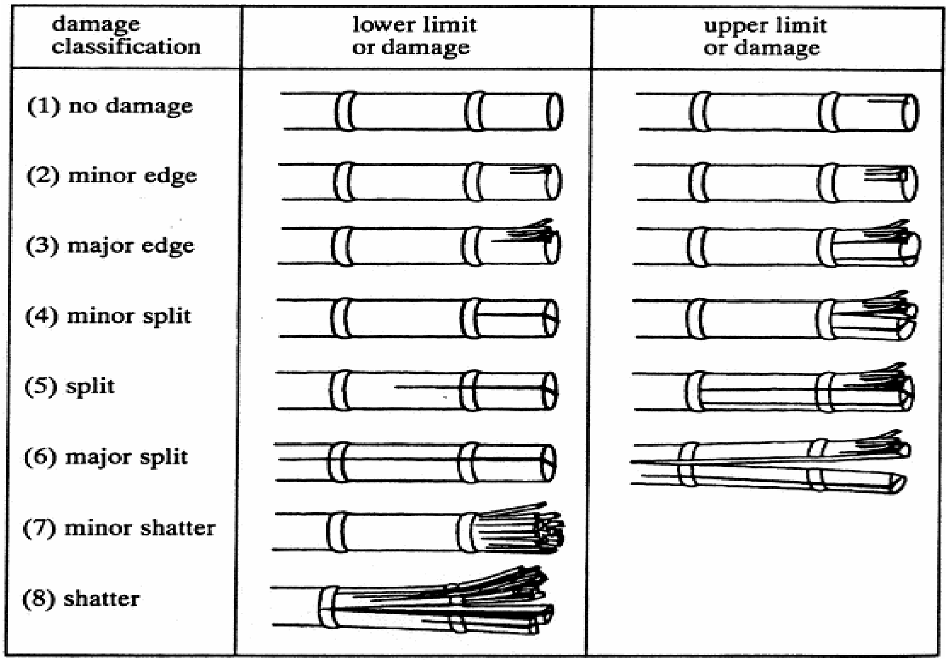

Figure (4) Classification of sugarcane damage **kroes, (1997)**

RESULTS AND DISCUSSION

1.Cutting and Harvesting efficiencies

Fig. (5) shows that increasing forward speed from 2.37 to 3.75 km/h decreased the cutting efficiency from 97.75, 98.46, 98.31 and 98.03 % to 97.19, 97.75, 97.19 and 96.91 % at oblique angles of knife on base cutter 20°, 30°, 40° and 50°.Fig. (6) shows that increasing forward speed from 2.37 to 3.75 km/h decreased the harvesting efficiency from 98.34, 98.86, 98.76 and 98.55 % to 97.93, 98.34, 97.93 and 97.72 % at oblique angles of knife on base cutter 20°, 30°, 40° and 50° .

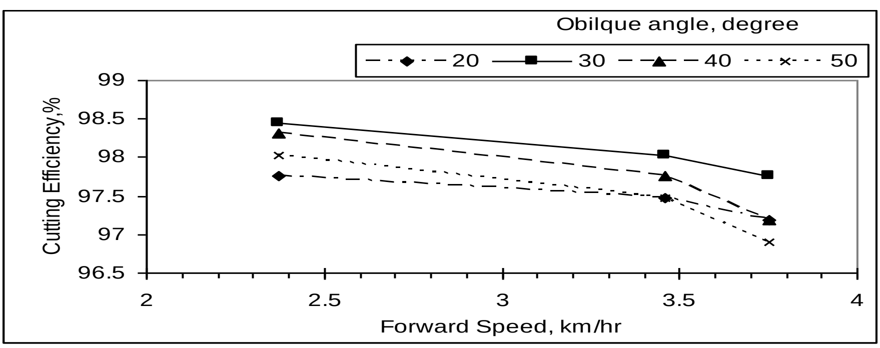

Fig. (5) Effect of forward speed on cutting efficiency

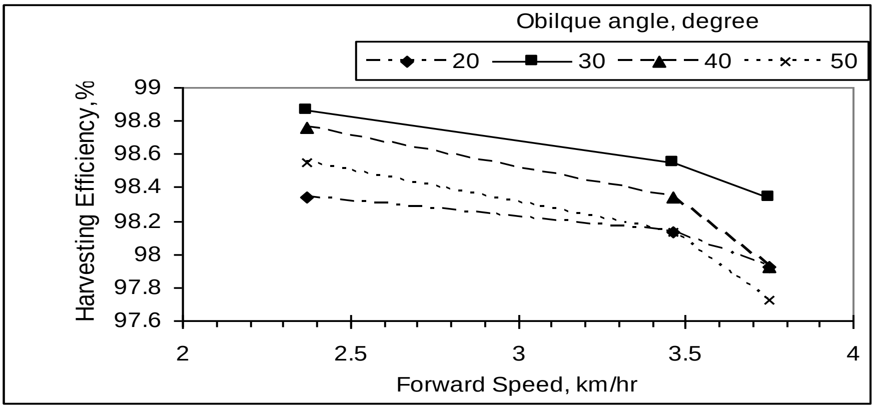

Fig. (6) Effect of forward speed on harvesting efficiency

2. Losses of sugarcane yield:

Fig. (7) shows that increasing forward speed from 2.37 to 3.75 km/h increased the total losses from 9.062, 8.313, 12.391 and 14.128 ton/fed. to 10.506, 11.084, 11.901 and 13.481 ton/fed. at oblique angles of knife on base cutter 20°, 30°, 40° and 50°.

3. Classification of sugarcane damage:

Fig. (8) show that increasing forward speed from 2.37 to 3.75 km/h increased the classification of damage (minor edge, major edge, minor split, split, major split, minor shatter and shatter) from 118, 118, 118 and 118 stalk damage/ 10 m′ to 119, 119, 120 and 121 stalk damage / 10 m′ at oblique angles of knife on base cutter 20°, 30°, 40° and 50°.

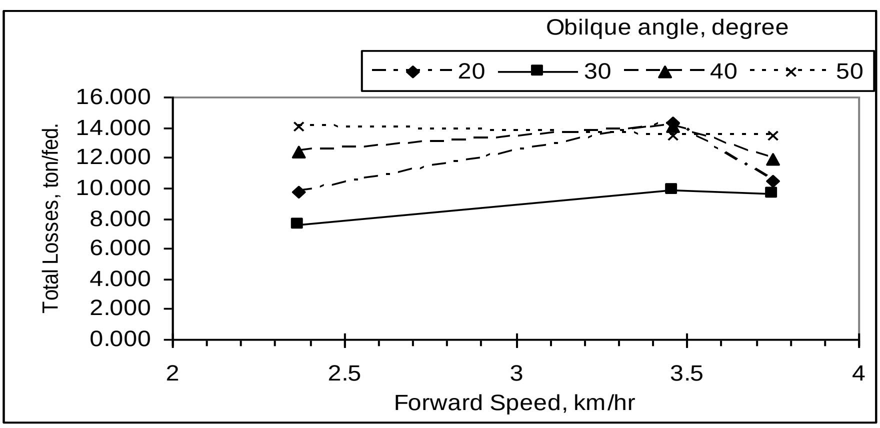

Fig. (7) Effect of forward speed on total losses

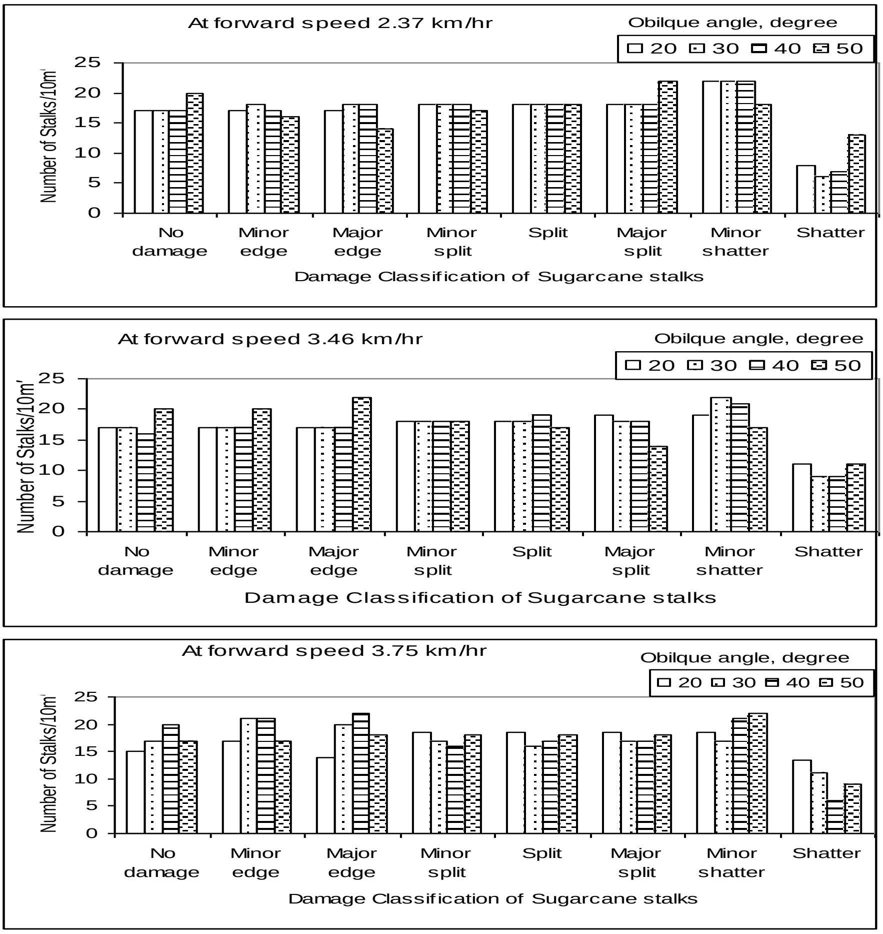

Fig. (8) Effect of forward speed on damage classification of sugarcane stalks

4. Collecting efficiency:

a.Effect of star wheel height on collecting efficiency

Fig. (9) show that decreasing the star wheel height from 125 cm to 105 cm, the collecting efficiency increased from 46.53 % to 70.69 %. At star wheel height from 125 cm, the collecting efficiency increased from 32.5 % at back direction to 58.44 % at right direction. At star wheel height from 115 cm, the collecting efficiency increased from 50 % at back direction to 71.21 % at toward direction. Also, at star wheel height from 105 cm, the collecting efficiency increased from 66.67 % at back direction to 76.83 % at right direction.

b. Effect of stalk direction on collecting efficiency:

Fig. (10) show that the lowest mean value of the collecting efficiency was 49.72 % at back direction of stalks and the biggest value of the collecting efficiency was 67.03 % at right direction of stalks. At back direction, the collecting efficiency increased from 32.5 % at star wheel height from 125 cm to 66.67 % at star wheel height from 105 cm. At left direction, the collecting efficiency increased from 46.67 % at star wheel height from 125 cm to 72.09 % at star wheel height from 105 cm.

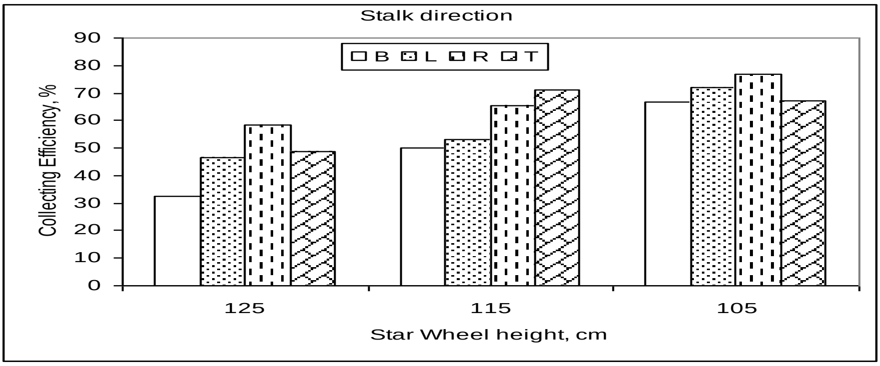

Fig. (9): Effect of star wheel height on collecting efficiency

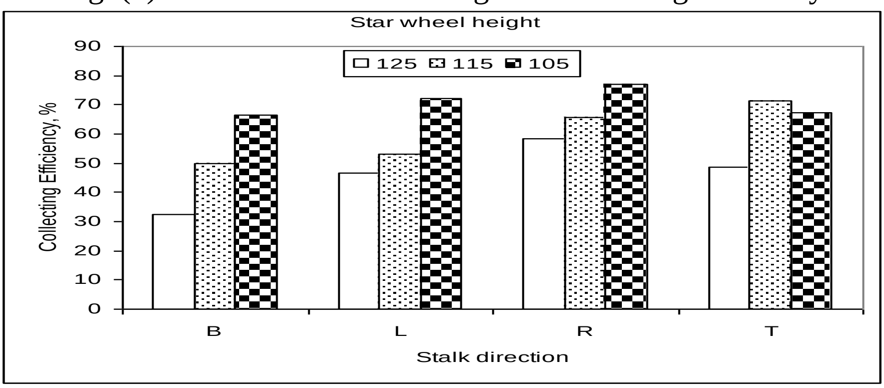

Fig. (10): Effect of stalk direction on collecting efficiency

CONCLUSIONS

The developed sugarcane harvester was tested at variable forward speed and angle oblique of knife. Cutting efficiency, harvesting efficiency, field efficiency, and losses were determined.

The results may be concluded as follows:

1-High cutting efficiency of 98.46 % was detected at forward speed 2.37 km/h and same knife angle.

2-Harvesting efficiency reached 98.86 % at same conditions.

3-Minimum losses were 8.313 ton/fed. recorded at forward speed 2.37 km/h and oblique angle of knife on bas cutter 30°.

4-High collecting efficiency was 70.69 % at star wheel height 105 cm.

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الملخص العربى

أداء آلة حصاد قصب سكر معلقة خلف الجرار

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تعتبر عملية حصاد قصب السكر من أكثر العمليات استهلاكا للعمالة فى منظومة إنتاج قصب السكر ونظرا للطلب المتزايد من الزراع لإيجاد أو تطوير آلة حصاد قصب السكر تعمل بكفاءة مرضية فقد تم تطوير الآلة موضوع البحث واختبارها بحقول قصب السكر بالمزرعة البحثية بمحطة بحوث شندويل محافظة سوهاج. وقد روعى أن تكون الآلة معلقة على الجرار للاستفادة من قدرات الجرار المتوفرة لدى المزارع وتقليل تكاليف تصنيع الآلة.

أجريت التجربة خلال موسم ٢٠٠٩/٢٠١٠ فى مساحة فدان فى أرض طميية تحت ظروف التشغيل المختلفة:

١- السرعة الأمامية :٢,٣٧, ٣,٤٦ و٣,٧٥ كم/س.

٢- زاوية انحراف السلاح على القرص:٢٠° و٣٠°و ٤٠°و ٥٠°.

٣- ارتفاع نجمة التكويم للعيدان: ١٢٥ و١١٥ و١٠٥ سم.

وتمت دراسة هذه المتغيرات على كفاءتى القطع والحصاد وكمية الفواقد الكلية وكفاءة التكويم للعيدان.

وأوضحت النتائج إلى إمكانية استخدام الآلة بكفاءة عالية عند سرعة أمامية ٢,٣٧ كم/س وزاوية انحراف السلاح على القرص ٣٠° و ٤٠° وارتفاع نجمة التكويم ١٠٥ سم حيث أعطت أعلى كفاءة قطع ٩٨,٤٦ و٩٨,٣١ % وأعلى كفاءة حصاد ٩٨,٨٦ و ٩٨,٧٦ % وأقل كمية فواقد كلية 9.062, 8.313 طن/ فدان وكفاءة تكويم للعيدان ٧٠,٦٩ % .

* هذه الدراسة جزء من النتائج المتحصل عليها من رسالة دكتوراه.

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