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DEVELOPMENT OF A MACHINE FOR CUTTING SUGAR CANE BUDS

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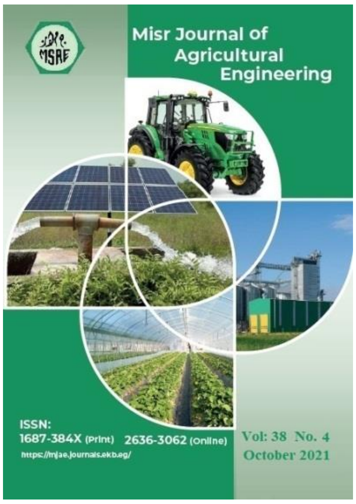


Keywords:
Cutting buds machine; Sugar cane buds; Cutting efficiency; Machine productivity

ABSTRACT

This research aims to manufacture and test a machine for cutting sugar cane buds to develop mechanization of the stage of preparing sugarcane seedlings in the nursery. The developed machine consists of a frame, cutting unite, electric motor, and power transmission system. This machine will save the time, effort and costs spent on cutting reeds by traditional methods at farmers. The machine cuts the sugarcane stalks that are used as seeds and which contain undamaged buds, the operator cuts the groups of sprouts by the bud cutting machine. The machine has been tested at three transmission ratios to cutting rate of R_1 = 22, R_2 = 32, and R_3 = 40 buds/min. The results of preliminary tests revealed that the machine achieved the skipping, percentage of damaged, cutting efficiency, and productivity was (4.09, 7.19, 11%), (2.37, 5.39, and 8.99%), (97.63, 94.61, 91%), (1266, 1782, 2136 bud/hr.) at the cutting rate R_1, R_2, and R_3 respectively. The total costs for operating the machine are 50.3 L.E./h to at the highest cutting rate R_3.

1. INTRODUCTION

Sugar cane *(Saccharum officinarum L.)* is considered the main source of sugar production in Egypt and many countries around the world. The area of sugar cane in Egypt reached up to 332 thousand feddan, with an average production of 48.6 Mg/fed., **(CCSC, 2020).** The transplanting technique has been applied in several countries for reducing the duration of the sugarcane production season. Sugarcane seedling planting in the nursery is done using the single buds, the sugarcane buds it means excised axillary buds from cane stalk, these buds are less in size, easily transportable, fast-growing, and more economical seed material. Traditional hand-held cutting tools of sugarcane buds create a strain on the hands and thumb, cause wastage, and damage with slanting cuts, and are incapable of dealing with hard plant grafting. Sugarcane transplanting has been recommended as an alternative planting method for saving a considerable part of irrigation water that determines the expansion of the agricultural areas in the country. **(Drees, 2005)** recommended that sugarcane transplanting could be used as an alternative method of the sugarcane seedlings. The application of the transplanting technique to replace traditional planting of sugarcane saves up two months of the crop production season. **(Mahmoud, 2016)** mentioned the feddan (4200 m^2) is needed about 1600 kg from sugar cane stalks suitable for agriculture for obtaining bud sets. **(Abd El**

Mawla, et al., 2014) reported that the transplanting sugarcane saves a considerable amount of irrigation water determined as 2000 m^3/acre and the quantity of seed consumed when applying the transplanting technique is largely less than that of the traditional method**.** **(Ragupathi et al., 2017)** said that the traditional tools used for bud chipping of sugar cane are unsafe, messy, minimum productive, and need skill and training, the risk of injury is also too high, this necessitates the development of an automated sugarcane bud chipping machine. **(Suraj et. al., 2016)** designed and fabricated of a pedal operated sugarcane bud chipping machine where the sugarcane is fed to the cutting region manually, when the operator starts pedaling the cutting action starts and the sugarcane buds are cut along with the stalk. **(El-Nakib et al., 1996)** performed tests on the Egyptian sugar cane variety C-9 and they found that the average diameter of the stalk was 2.3 cm, and the cane stalk hardness was 775 N. **(Abarna et al., 2017)** designed machine cutting buds from sugarcane stalk consists of a platform, hemisphere chipping knife, sphere chipping knife, linkage system, and handle, it is used to chip out the bud from sugarcane for sowing purpose and for tissue culture that, this machine can remove buds from the sugarcane for the plantation purpose to minimize losses as well as time, money, and seeds, with this implement. **(Mahesh et al., 2017)** mentioned that the bud chip technology could be one of the most viable and economical alternatives for a manually operated machine and can be converted manually operated machines into automatic ones by using an electric motor. **(Rahul A. et al., 2017)** developed a machine is semi-automatic with pedal-operated to the sugarcane is cut in curve shape, where the only bud is cut, therefore remaining sugarcane is reuse.

The main objective of this research is the development and performance evaluation of a machine for cutting sugar cane buds to increase the efficiency of the buds cutting process, reduce the muscular effort exerted by the laborers, and replacing the manual method of cutting buds with semi- Automatic.

2. MATERIAL AND METHODS

The prototype of the cutting buds machine was constructed in the workshop of the Faculty of Agricultural Engineering, Al-Azhar University, Assiut. All the experiments were carried out during November 2020. to study the possibility development of mechanical cutting to stem sugarcane buds and used in planting instead of using full lengths of sugarcane.

2.1 Sugarcane stalks characteristics.

The source of the sugarcane stalks used in this research was from the Sugarcane crops Research Institute, ARC, Egypt, Sohag, Shandawill (شندويل). The samples were selected, cleaned, and shelled manually. The measurements and tests were carried out in the Fac. of Agri. Eng., Al-Azhar U., Assiut. Characteristics of sugarcane C-9 variety stalk before buds separation to use for obtaining of buds are presented in Table (1), the obtained data is approximately compatible with **(Mahmoud, 2016)**:

2.2 Sugarcane buds cutting machine.

Frame of the machine:

The frame was fabricated from square welded iron sections 50 × 50 mm, thickness 3 mm. The frame shape was formed with certain dimensions 500 mm width, 900 mm length, and 900 mm height. To mount various components of the machine such as power transmission system, cutting unite, electric motor (1400 rpm), and other components. The components of the sugarcane buds cutting machine are shown in Fig. (1).

Table (1): Average characteristics of sugarcane C-9 variety stalk before buds separation:

Characteristics	Averages	± S.D*
Stalk length "L" cm.	295.3	± 9.13
Stalk diameter "D" cm.	2.35	± 0.15
Stalk mass "M" kg.	1.97	± 0.11
Number of buds on the stalk.	16.33	± 1.80

*S.D. is the standard deviation.

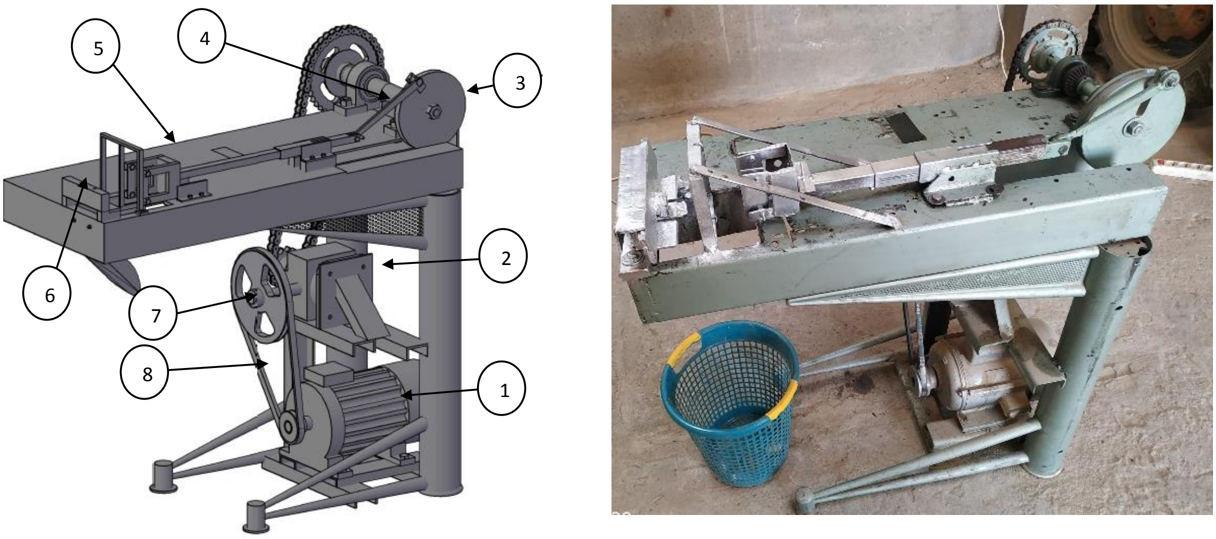
Cutting unite.

The cutting unite consists of as shown in Fig. (2) a plunger, eccentric wheel, and connecting rod. plunger made of square shaft of 30 mm and length of 320 mm. The eccentric wheel is made of iron with a diameter of 200 mm and a thickness of 10 mm. the connecting rod is made of an iron plate with dimensions of 180 mm in length, 20 mm width, and 10 mm in thickness. The connecting rod is connected with the plunger and eccentric wheel by two hinges.

Cutting Blade.

The cutting blade consists of two knives from stainless steel with dimensions are (100 × 20 × 3 mm) and parallels, the distance between them is the length of 50 mm.

The knife was used with three cutting angles 15, 30, 45 degrees, the knife was sharpened by the laser iron cutting machine.



1. Electric motor 2. Gearbox. 3. Eccentric wheel. 4. Connected rod.
5. Cutting Blade. 6. Barrier. 7. Pulley. 8. V-Belt.

Fig. 1: The sugarcane bud cutting machine.

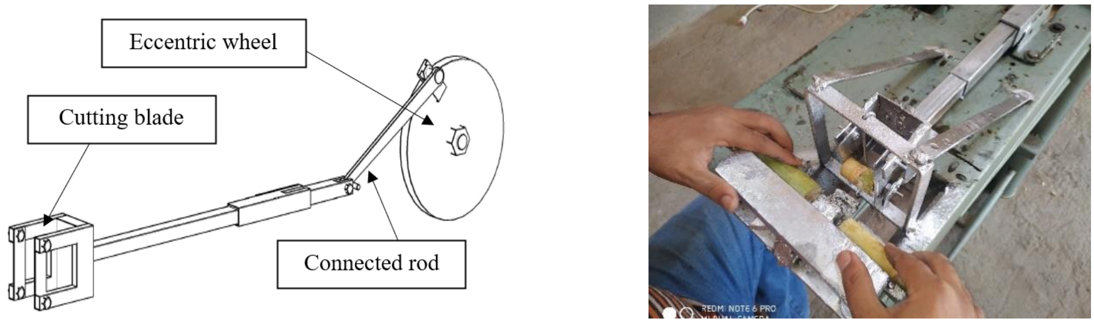
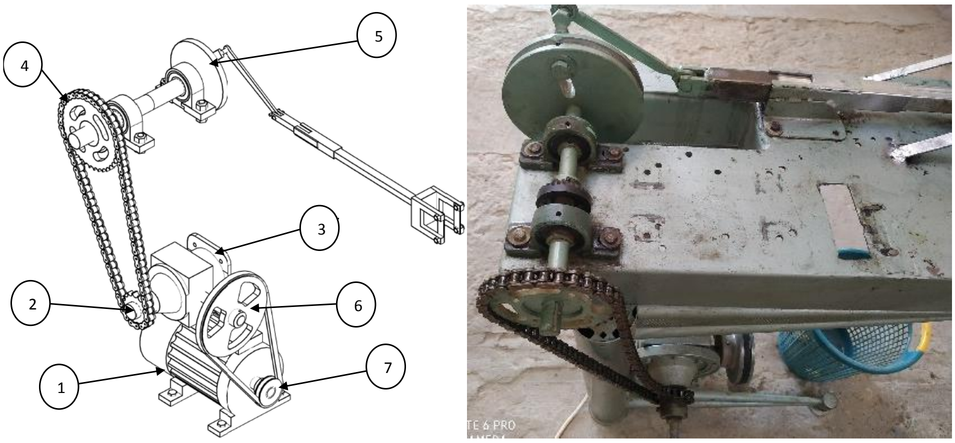


Fig. 2: The cutting unit.

Transmission system.

The power transmission of the cutting buds machine is shown in Fig. (3). The power is transmitted from the electric motor 1400 rpm to the cutting unit by a gearbox with a speed ratio of 35:1, by two pulleys, diameters of the pulley (1) = 14, 12 and 15 cm on the motor shaft, and diameters of the pulley (2) = 12 and 7 cm on the gearbox shaft. The different diameters were used to obtain the variable for a cutting rate of R_1 = 22, R_2 = 32 and R_3 = 40 buds/min. as shown in Table (2). The power is transmitted from the gearbox to the cutting unit by two sprockets (15 and 32 teeth) and a chine.



1. Electric motor 2. Gearbox. 3. Sprocket 15 Teeth. 4. Sprocket, 32 Teeth.
5. Eccentric wheel 6. Pulley (2). 7. Pulley of motor (1). 8. V-Belt.

Fig. 3: Detailed descriptions of the power transmission system.

Table 2: The power transmission.

Number of transmission tools.	Cutting rate, bud/min.		
	R1	R2	R3
Diameters of pulley (1), mm.	140	120	150
Diameters of pulley (2), mm.	120	70	70
Rotation speed of pulley (1), rpm.	1400	1400	1400
Input gear box, rpm.	1633	2400	3000
Output gear box (on sprocket 15 teeth), rpm.	46.7	68.6	85.7
Sprocket 32 teeth, rpm.	22	32	40
Eccentric wheel, rpm.	22	32	40

Power and torque calculations.

The force required to cut the sugarcane bud is 697.2 N. from two blades. according to **(Ali, 2012):**

T = $F \times r$ …………………………..(1)

Where:

T= Torque in N.m

F= the force required to cut the sugarcane bud.

T = $697.2 \times 0.08 = 55.78\ N.m$

P = $\frac{2\pi NT}{60}, \dots \dots ..$Watt. ………………..(2)

Where:

P = Power of motor in Watt.

T = Torque in N.m

N = Speed of motor in rpm.

P = $\frac{2 \times 3.14 \times 22 \times 55.78}{60}$ = 128.44 W.

It is clear from the previous equations that the required power when using speeds (22, 32, and 40 rpm) was (128.36, 186.83, and 233.53 W), respectively.

Electrical motor:

Based on the maximum mathematical power obtained (233.53 W) was chosen the electric motor of 0.75 kW (1 hp), 89 % effective load, and 1400 rpm (obtained from the nameplate), was used to move the cutting unit by the transmission system.

2.3 Process of bud cutting and preparation.

By used mature sugarcane stalks which using as seeds and that contain undamaged buds, the operator is cutting sets bud by cutting buds machine shown in Fig. 1.

The cutting machine produces equal sets in the length and contents one a bud and can be controlled in sets length (from 3 cm to 5 cm) by adjusting the distance between the pair cutting knife.

The products of cane buds cut fall down the machine into the allocated receptacle. The cutting products fall out of the machine as classified to:

- Sets with undamaged buds.
- Sets with damaged buds.
- Sets of internodes with no buds.

2.4 Measurements:

The developed prototype of the cutting buds machine was tested considering the measurements related to prototype performance to realize the purpose of this research. Measurements as following:

1. Actual number of buds per minutes (Nb_{actual}).

The actual number of buds that can be cut during feeding by the operator compared to the number of cuts calculated by the theoretical cutting rate ($N.b_{theo}$).

2. Skipping rate (Sr, %).

Skip rate refers to the number of cuts of the cutting knife without feeding by the operator which usually results from increasing the reciprocating speed of the cutting knife. Skip rate is useful for determining the optimum reciprocating speed of the cutting knife it can be calculated as a percentage of the number of skipped cuts divided by the theoretical number of cutting knife frequencies with each speed.

$$Sr, \% = \frac{Nb_{Theo} - Nb_{actu}}{Nb_{theo}} \times 100 \ldots\ldots\ldots\ldots\ldots..(3)$$

Where:

Nb_{Theo} = Number of theoretical cutting rate (bud/min.

Nb_{actu} = Number of actual cutting buds (bud/min).

3. The percentage of damaged buds (Nbd, %).

The damaged bud means mechanical damage to the bud scar due to the cutting process. decrease in the number of damaged buds indicates an increase in the percentage of cutting efficiency. The percentage of the damage was calculated by counting the damaged buds and relative to the actual number of buds that had been cut.

$$Nbd = \frac{Nbd}{Nb_{actu}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(4)$$

Where:

Nbd = Number of damaged buds.

4. Cutting efficiency *(ηc, %).*

Cutting efficiency refers to the number of healthy cut buds relative to the total actual number of cut buds.

$$\eta c, \% = \frac{Nb_{actu} - Nbd}{Nb_{actu}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(5)$$

Where:

ηc = Cutting efficiency.

5. Classification damage of cutting-edge buds:

The cutting-edge damage buds were inspected and classified according to the degree of damage following the classification of **Kroes (1997).** Fig. (4) show **Kroes's** classification of damage.

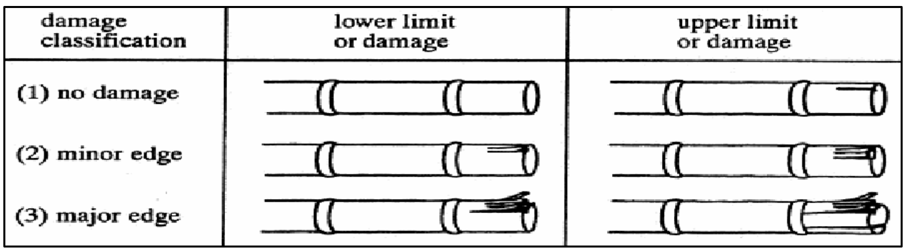


Fig. 4: Classification of sugarcane damage according to (kroes, 1997)

6. Machine productivity (Q, Nb/h).

Machine productivity was estimated by using the following equation:

$Q = \frac{Nb_{actual}}{t}$…………………..(6)

Where: Nb_{actual}= Actual number of buds per minutes at time t, (h).

2.5 Operation costs.

Cost of operation was calculated according to the equation given by **Awady (1978),** in the following form:

C=P/h (1/a + I/2 + t+ r) + (w.e) + m/144…………(7)

Where: C = hourly cost, LE/h, P = price of machine, (6000 LE), h = yearly working hours (1000 h), a = life expectancy of the machine (10 year), i = interest rate/year (9.75), t = taxes (0.20), r = overheads and indirect cost ratio (0.06), w = electrical power consumed to charge the battery, kW, e = electrical price, and m= monthly wage rate. "1.2" is a factor (upper limit) to take lubrication and greasing into account. "144" is estimated monthly working hours. Notice that all units must be consistent to result in L.E/h.

3. RESULTS AND DISCUSSION

The working idea of the developed prototype of the cutting buds machine is based on cutting buds of sugarcane stalks through the clearance between the two cutting knives, which moves a horizontal reciprocating motion. Consequently, cut shoots can fall off through the blank under the cutting unit. The bud chips or short sets that include one bud by cutting machine were developed, which used to establish the sugarcane seedlings nursery were prepared where each bud chip includes a healthy bud and root band.

1. Effect of cutting rate on the skipping rate (S_r, %).

The cutting rate of the cutting unit determines the number of buds that can be cut per minute determine the optimum feeding speed by the operator. The rate of skipping the cutting unit and not utilizing it in cutting the buds is due to the increased reciprocating speed for the cutting unit. During the initial stages of selecting the transmission ratio, the theoretical rate of cutting buds was R_1 =22 buds per minute and it was found through experiments that there the skipping rate was 4.09 %. While the percentage of skipping rate was 7.19% at the theoretical rate of cutting buds R_2 = 32 buds per minute and the percentage of skipping rate was 11.00% at the theoretical rate of cutting buds R_3 = 40 buds per minute as shown in Table 3 and Fig. (5).

Table 3: Effect of cutting rate on the skipping rate (Sr), No. of damage buds (Nb.d), Cutting efficiency (η_c), % and Productivity, bud/hr.

Cutting rate, bud/min.		Ave. Perce. of skipping rate (Sr, %).	Ave. Perce. of damage buds (Nbd, %)	Cutting efficiency (ηc), %	Productivity, bud/hr.
$(N.b_{theo.})$*	Ave. $(N.b_{actu.})$**				
R_1 = 22	21.5	4.09	2.37	97.63	1266
R_2 = 32	29.7	7.19	5.39	94.61	1782
R_3 = 40	35.6	11	8.99	91.01	2136

* Theo. No. of bud per minutes. **Actu. No. of bud per minutes.

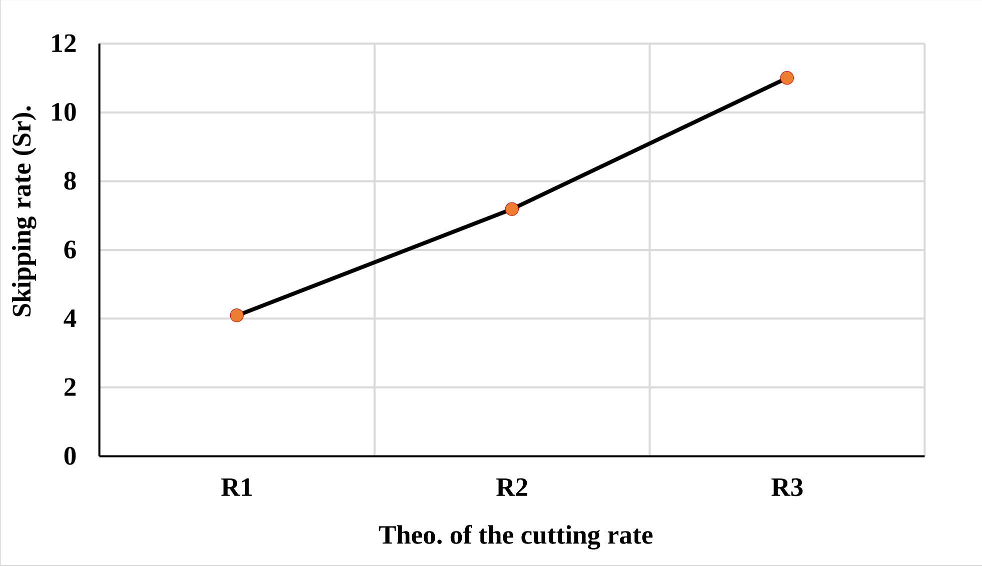


Fig. 5: Effect of cutting rate on the skipping rate (Sr,%).

2. Effect of cutting rate on the percentage of damaged buds (Nbd, %).

Mechanical damage to the buds may occur by the cutting knife due to the wrong feeding from the laborer, by the higher the reciprocating speed of the cutting knife, increased the percentage of damaged buds. Fig. (6) shows that by increasing cutting rate R_1, R_2, and R_3 increased to percentage of damaged buds. When increase of cutting rate from R_1, R_2, and R_3 increased of percentage of damaged from 2.37, 5.39, and 8.99% respectively.

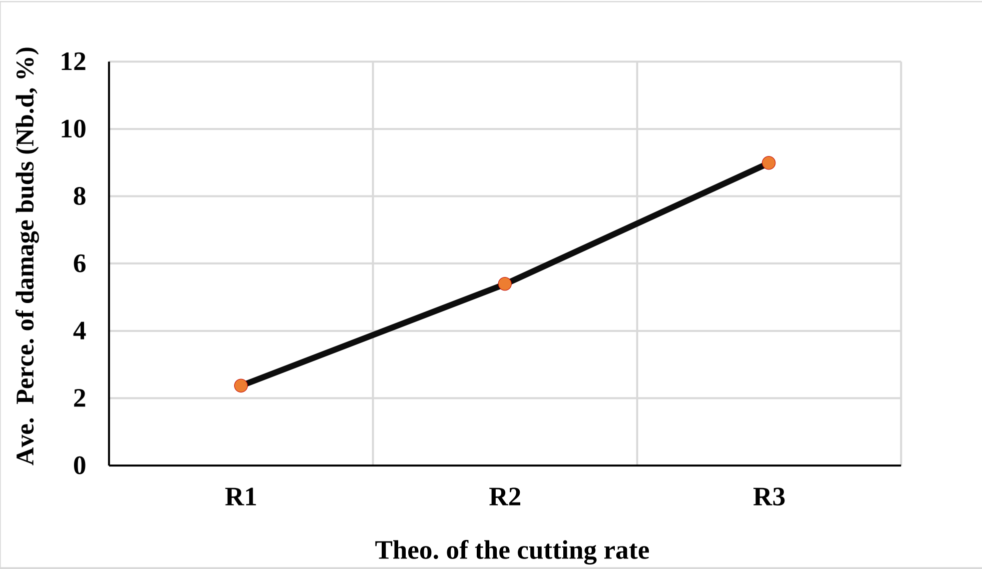


Fig. 6: Effect of the cutting rate on the percentage of damaged buds (Nbd, %).

3. Classification damage of cutting-edge buds:

Fig. (7) shows that increasing cutting rate R_1, R_2, and R_3 decreased the classification of damage (No damage) from 93.49, 92.95 and 86.28 %, 96.52, 94.84 and 93.88 and 98.27%, 95.27 and 94.15 % at cutting angles of knife 15, 30, and 45 degrees, respectively. While increasing the classification of damage (minor edge) from 4.57, 5.04 and10.08 %, 2.47, 3.70 and 4.55 and 1.08, 3.60 and 4.78 % at cutting angles of knife 15, 30, and 45 degrees, respectively.

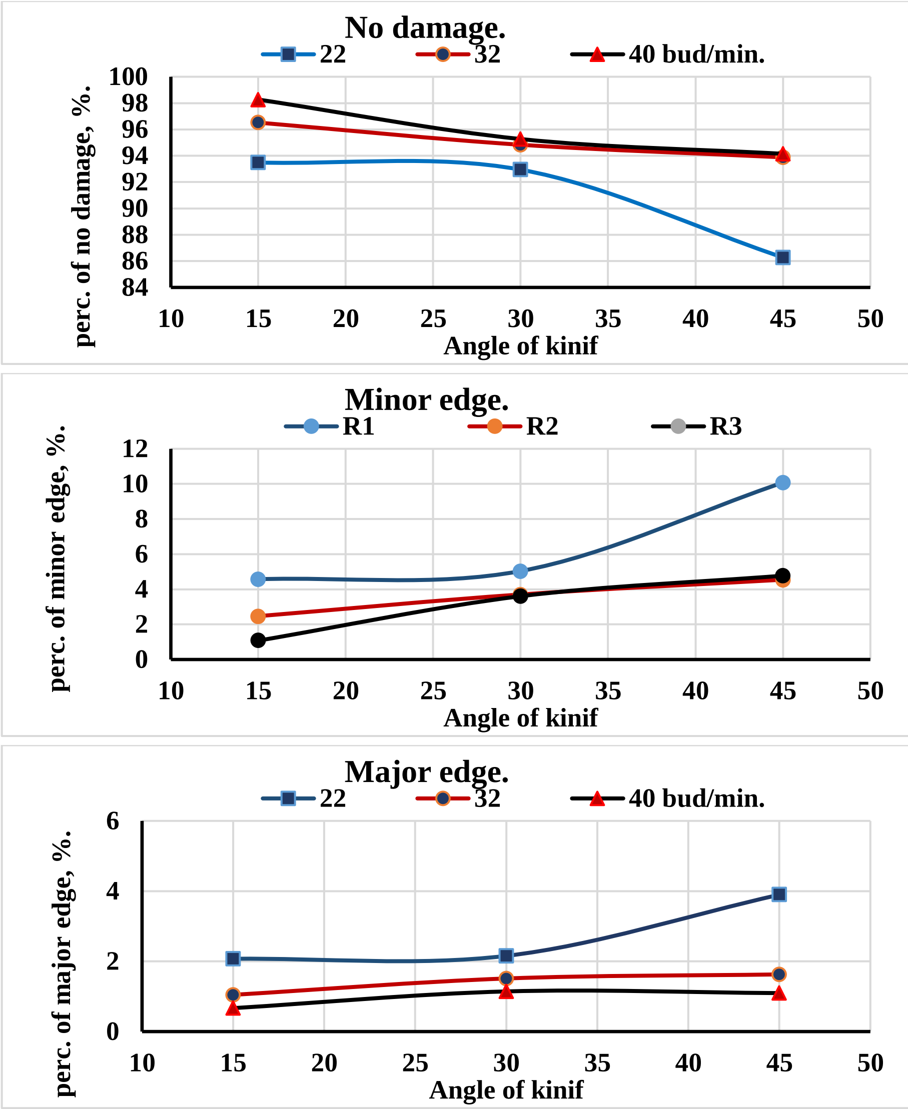


Fig. 7: Effect of the cutting rate on damage classification of the buds.

And increased the classification of damage (minor edge) from 2.07, 2.16, and 3.90 %, 1.05, 1.51 and1.63 and 0.67 and 1.14 and1.10 % at cutting angles of knife 15, 30, and 45 degrees, respectively. The classification damage of cutting-edge was calculated for buds according to actual productivity.

4. Effect of cutting rate on cutting efficiency (ηc, %).

Table (3) and Fig. (8) illustrate decreasing of the cutting efficiency with increasing of the theoretical cutting rate. The highest of cutting efficiency was 97.63% when the theoretical cutting rate 22 buds/min., and lowest of cutting efficiency was 91.01% when the theoretical cutting rate 40 buds/min.

5. Effect of cutting rate on the productivity (Q, Nb/h).

Table (3) and Fig. (9) shown that the lowest productivity was 1266 Nb/h when using a cutting rate R_1, while the highest productivity was 2136 Nb/h when using a cutting rate R_3.

6. Cost estimation:

Production cost was calculated by the maximum value of the machine productivity 2136 bud/h that it was obtained with the maximum value of the power required. Accordingly, the maximum operation production cost will be 50.3 L.E./h.

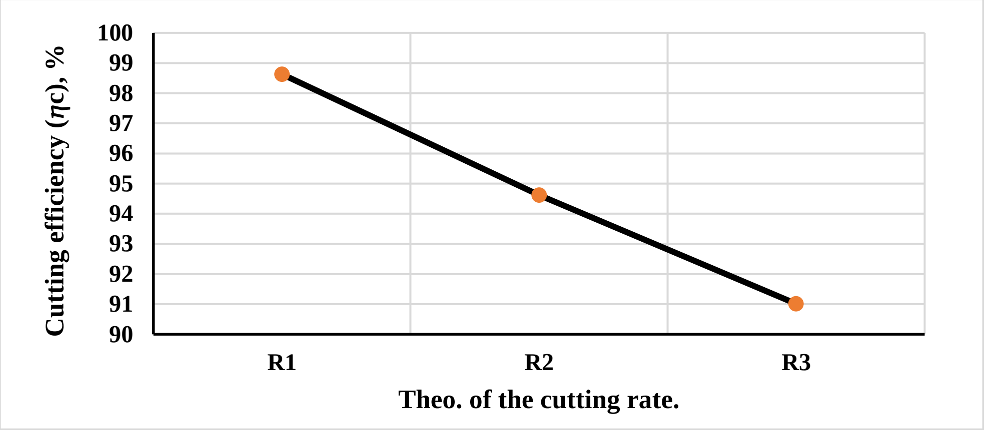


Fig. 8: Effect of cutting rate on the cutting efficiency (ηc, %).

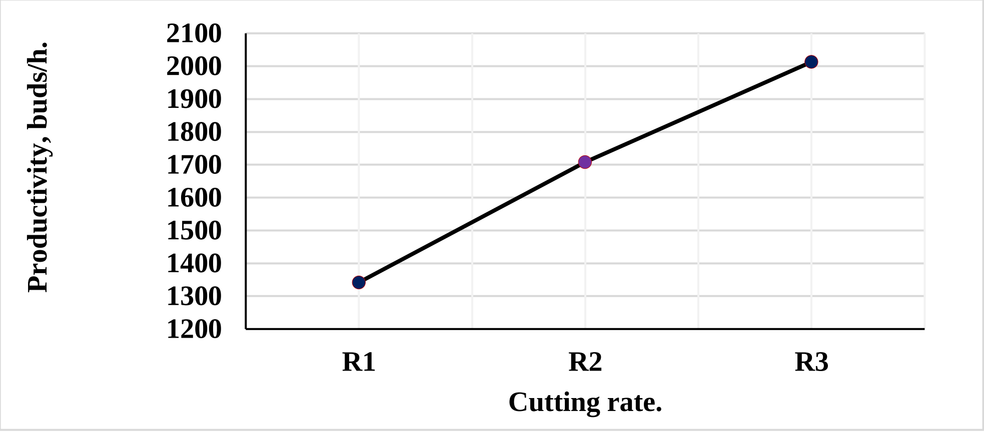


Fig. 9: Effect of cutting rate on the productivity (Q, Nb/h).

CONCLUSION.

Overall results of this applied research may be concluded as follow:

1- Design a prototype for sugarcane buds cutting machine to develop mechanization of the stage of preparing sugarcane seedlings in the nursery. The machine is characterized by a simple design and local materials, that can be manufactured in rural workshops. This machine will save the time, effort and costs spent on cutting reeds by traditional methods at farmers.
2- Using lower cutting rate R_1 given cutting rate theoretical of cutting buds was 22 buds per minutes, the skipping rate was 4.09 %, while the highest skipping rate was 11% using cutting rate R_3 which the theoretical rate of cutting buds was 40 buds per minutes.
3- By increasing the cutting rate from R1, R2, to R3 increased the percentage of damaged buds from 2.37, 5.39, to 8.99% respectively.
4- Highest cutting efficiency was 97.63 % when cutting rate R_1 and the lowest of cutting efficiency was 91 % when cutting rate R_3.
5- The highest productivity was 2136 bud/h. when using a cutting rate R_3, while the lowest productivity was 1266 bud/h. when using a cutting rate R_1.
6- The total costs for the machine operation are 50.3 L.E./h. to the maximum value of the machine productivity 2136 bud/h at cutting rate R_3.

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تطوير آلة لتقطيع براعم قصب السكر

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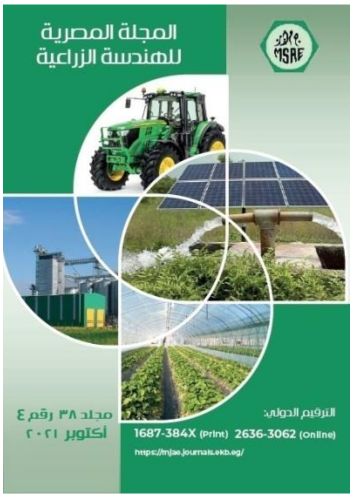

الكلمات المفتاحية:

آلة قطع البراعم، براعم قصب السكر، كفاءة القطع، إنتاجية الآلة.

الملخص العربي

يهدف هذا البحث إلى تطوير آلة ميكانيكية لقطع براعم قصب السكر، لتطوير ميكنة مراحل إعداد وتحضير شتلات قصب السكر في المشتل. تتميز الآلة بتصميم بسيط وخامات محلية يمكن تصنيعها في ورش ريفية. ستوفر هذه الآلة الوقت والجهد والتكاليف التي يتم إنفاقها على قص عقل القصب بالطرق التقليدية لدى المزارعين. تم التصنيع وإجراء القياسات والاختبارات بورشة كلية الهندسة الزراعية - جامعة الازهر - فرع أسيوط. المكونات الرئيسية للآلة تشمل الهيكل الرئيسي، موتور كهربي، جهاز نقل الحركة، وحدة قطع البراعم، سكاكين القطع.

اختبرت الآلة عند معدلات قطع نظرية ($R_1 = 22$، $R_2 = 32$، $R_3 = 40$ برعم/دقيقة) ودراسة تأثيرها على كل من معدل القطع الفعلي ومعدل التفويت، والنسبة المئوية للبراعم المصابة، وكفاءة القطع، وإنتاجية الآلة وحساب التكاليف.

وكانت النتائج المتحصل عليها كما يلي:

١- أقل معدل تفويت كان ٤,٠٩ % عند استخدام معدل التقطيع ($R1 =$ ٢٢ برعم / دقيقة)، بينما كان أعلى معدل تفويت ١١٪ عند استخدام معدل التقطيع (٤٠ $=R3$ برعم / دقيقة).

٢- عند زيادة معدل القطع من R_1 وR_2 إلى R_3 زادت نسبة البراعم التالفة من ٢,٣٧ و٥,٣٩ إلى ٨,٩٩٪ على التوالي.

٣- أعلى إنتاجية كانت ٢١٣٦ برعم / ساعة. عند استخدام معدل القطع R_3، بينما كانت أقل إنتاجية ١٢٩٠ برعم / ساعة. عند استخدام معدل القطعR_1 .

٤- أعلى كفاءة قطع كانت ٩٧,٦٧٪ عند معدل القطع R_1 وأقل كفاءة قطع كانت ٩١٪ عند معدل القطع R_3 .

٥- إجمالي تكاليف تشغيل الآلة ٥٠,٣ جنيه / ساعة، عند أقصى إنتاجية للآلة ٢١٣٦ برعم/ساعة وذلك عند أعلى معدل قطع للبراعم R_3.