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Factors related to mechanical cleaning of sugarcane stalks

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ABSTRACT

Sugarcane is an important cash crop in Egypt. The production cost of sugarcane is increasing year after year which reduces the profit margin of sugarcane growers, sugarcane harvesting in Egypt is done by manual labour. developing local machinery for sugarcane de-trashing is now necessity to overcome the specific problems of sugarcane production. For following reasons, (a) the price of the imported machinery is high that economical operation could not be achieved (b) the imported machines are designed according to criteria depending on agricultural systems different from that prevailing in Egyptian fields. The main aim of this research was study the factors related to mechanical de-trashing of sugarcane stalk as a data base to help design local machine for sugarcane crop de-trashing made of local materials to overcome this problem, at the lowest cost and fit conditions of the Egyptian agriculture. To provide information that help in designing a mechanism for handling, feeding and removing sugarcane leaves, the following parameters were taken, length, diameter, the number of internode, weight of the stalks, the weight of the green top and the weight of dry and green needs removed . Also, the required force to remove cane stalks leaf beside to penetration force, cutting force and crushing force were measured. The main results in this study can be summarized as follow: The maximum length of 322 cm, and diameter 26.1 mm and the number of internode 25 and the weight of stalk 2530 g, weight of the green top was 7.93 % and dry and green leaves 7.44 % percentage to total weight of the stalks. The maximum value of penetration force were 1916 N, 1686 N and 1205 N for bottom, middle and the top a part of the stalk respectively, for the cutting force were 1030 N, 627.8 N and 382.6 N for bottom, middle and the a part of the stalk respectively. Crushing force was 1226 N, 657.3 N and 510 N for bottom, middle and the top of stalk respectively. The required force to remove the leaves from the stalk has been recorded maximum values of 6.54 kg/ leaf and 11.76 kg /leaf and 13.57 kg /leaf for bottom, middle and top a part of stalks respectively, while minimum values were 0.340, 0.685 and 7.34 kg/leaf for both the base, middle and the top a part of the stalk respectively.

1. Introduction

Sugarcane is an important cash crop in all the world. Approximately 80% of the world's sugar is produced from sugarcane in tropical and subtropical climates, with the remaining 20% derived from sugar beet, which is grown mostly in the temperate zones of the northern hemisphere. Sugarcane is best established industrial crops that is efficiently grown and harvested to produce both food and bio-energy (Cane growers, 2012). In Egypt, sugarcane is considered as an important major sugar crop. Is a renewable, natural agricultural resource.

Providing sugar, the only resource for molasse which used in feed industry, plywood and paper pulp industries and besides a myriad of by-products like, fiber and fertilizer. Sugarcane crop plays a vital role in

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nation's economy, being one of the most commercialized crops in Egypt (Tayel et at., 2015). The cultivated area in Egypt at growing season 2019/2020 A.D was about 325052 feddan with an average production of 46.728 Mg/fed (CCSC, 2020). Harvesting is the costliest operations responsible for increase in sugarcane production cost that needs more than operation being with cutting sugarcane stalks, windrowing the stalks, cleaning cane stalks from the dry and green leaves adding cutting the green tops (topping), load the cane from the field to store ending with transporting to mill. Sugarcane harvesting is one of the most time and labour consuming, arduous operation. Harvesting includes base cutting of standing cane stalks, de topping of green top and removal of dry trash, bundle making of cleaned cane stalks and loading to transport vehicles. In India, sugarcane harvesting is done by manual labour (Anonymous, 2013). In study on mechanical properties of the plant material were done prior to the design of sugarcane harvesting system and also significantly influence the performance of the different unit operations in combine harvester. The mechanical properties of sugarcane stalk viz., cutting resistance, penetration resistance and crushing resistance were studied in the laboratory. It is found that the specific cutting resistance varies between 1764.56 and 957.48 kNm-^{2}penetration resistance ranged from 29.74 kNm^{2} to 56.33 kNm-2 and the crushing force varied from 0.75 kN to 1.53 kN (Bastian and Shridar, 2014). Sugarcane is mainly used for sugar production so it is necessary to remove the trash (leaves and tops) from sugarcane stalk. One major reason is that the leafy portion absorbs sugarcane juice during milling operation so nearly 10% deduction in selling price is made if trash is not properly removed (Ashfaq et al., 2014). de-trashing of sugarcane is the costliest operation in sugarcane production. Sugarcane de-trashing in Egypt is done completely by manual labour. The harvesting sugarcane stalks requirement 16 man to harvesting cane stalk and de-trashing {cut the green tops (topping) and cleaning the dry leaves} that requirement 40 boys for one feddan (Abd El-Mawla and Hemeida, 2015). In the field study in India fined that the labour requirement for manual cutting and cleaning (removing the tops, dry and green leaves) of sugarcane required 157 man-h/ha and 395 man-h/ha, respectively. since about 70% of the labour is required for removing the trash from the harvesting cane (Shukla et al., 1991). The main components of the sugarcane plant are the stalk at the time of harvesting about 71 % stalks for milling 13% green leaves, 7% dry leaves, 8% cane-tops, and the remaining non-sugar bearing component of sugarcane called as sugarcane trash (Yadav et al., 1994). For getting a good quality sugar, the sugarcane stalks should be de-trashed because the trashes reduce the quality of sugar. Furthermore, the trashes absorb significant amount of juice during sugar extraction processes decreasing the quantity of sugar. The amount of trash removed from sugarcane depends on different factors such as topping height, harvesting system (burnt or unburned sugarcane (Paes and Oliveira, 2005). Sugarcane characteristics represented in stalks length and diameter of the joints vary widely with different varieties and growing conditions. In general, however the joints at the base are short and inter-nodal length gradually increases toward the top (Miller et al., 2009). Sugarcane trash be used as fertilizer of soil and a source of energy. Sugarcane leaf stripping is time consuming and labour -intensive procedure. Shortage of modern machinery also highlights this problem (Ikram et al., 2020). The stalk consists of segments called joints. Each joint is made up of a node and an internode. The node is where the leaf attaches to the stalk and where the buds and root primordia are found. A leaf scar can be found at the node when the leaf drops off the plant. The leaf of the sugarcane plant is divided into two parts: sheath and blade, separated by a blade joint. The sheath, as its name implies, completely sheaths the stalk, extending over at least one complete internode. The leaves are usually attached alternately to the nodes, thus forming two ranks on opposite sides (Hardev et al., 2019). The resistance for penetration of the stem, cutting and crushing. They concluded that the penetration resistance varies with node position from top to bottom in the range of 300 to 800 kgcm-^{2} were been measured. They also concluded that the flexural strength and stiffness increases from top to bottom. The crushing strength (80 to 140 kg) increases with the age of the cane and top to bottom (Miyabe and Abe, 1976). Mechanical properties of the sugarcane by compression tests using the universal testing machine and for leaves removal test by friction by a special apparatus designed to allow the registration of the normal and traction force. The sugarcane stalk can resist up to 4.9 MPa. With a normal pressure of 0.8MPa, which correspond to a friction force of 315N, it is possible to remove the leaves, independent of its location in the sugarcane stalk (Magalhães et al., 2004). Measurement of the pulling-force, which remove a leaf from the stem. This is the fundamental studies on the development of leaf stripping-machine for sugarcane. This machine is one part of the whole stalk sugarcane harvester. As test-instruments were used the tensile tester "Tension" and the pen-oscillograph. The result was as follows:

1. The pulling-force-values, under which a piece of leaf is removed from the stalk, were different in accordance with the position of the leaves-order from the apex and with the pulling direction to the stem.
2. The average pulling-force-value of the 8th leaf was 6.33 kg/leaf with standard deviation 0.90 kg/leaf at 45°- direction to the stem, and was 3.61 kg/leaf at 135 degree-direction to the stem.

3. The maximum pulling-force-value of the 8th leaf was 11.194 kg/leaf, at 45°-direction to the stem and was 7.70 kg/leaf at 135°-direction to the stem. 4- The pulling-force-value was apt to descend when the position of the leaves-order from the apex became lower and the pulling angle was extended to downward along the stem.
4. If a simple pulling-system is applied to the leaf stripping mechanism, removing the leaf to downward direction along the stem is assumed most effective.
5. Judging from the pulling-force properties of sugarcane leaves mentioned above, they conclude that removing-mechanism of the leaf-stripping-machine must be composed of more than one force; not only pulling but other valid forces must be put into consideration (Miyabe and Abe, 1976). To measuring the force required to remove leaves and sheath, the stalk was passed in a ring made of iron wire. The ring was attached to two ends of the rope and the rope passed through hook attacked to spring balance. The stalk was then pulled and the maximum deflection in spring balance was noted which gave this the required force. The method was used to measured force required for removing sheath and leaves (Project Report by Sanket Mane (NARI intern, 2016).

The present research aims to study some of physical and mechanical properties of sugarcane stalks to serve as a database to be used in the design and development of machines used in postharvest processes such as cleaning of sugarcane stalks.

2. Materials and methods

Experiments were carried out at in Upper Egypt in Farshout city - Qena governorate during the years 2019-2020 A.D. Physiology of sugarcane at the time of harvest is very important for the development of a prototype de-topper and de-trasher mechanism. Sugarcane stalks represented the raw material supposed to be fed into the machine for de-trashing. The following properties of individual cane stalks was included in this study:

Physical characteristics represented in stalks length (L_s), dimeter (D_s), internode number, weight of stalk (W_s), weight of green top (W_t), weight of dry leaves and green leaves supposed to removed ($W_{d\&g}$).

1. Mechanical characteristics such as penetration force (F_P), cutting force (F_c) and crushing force (F_{Cr}).
2. Required force to remove sugarcane leaves (F_r).

2.1. Material

2.1.1. Sugarcane stalks

Sugarcane is planted in upper Egypt, Variety Giza (G.T.54/9) was known C9. Thirty-five stalks were randomly chosen to determine the properties of cane stalk. All sample was token from the first ratoon form one field, with average moisture content 75.56 % wet basis. To determine the average moisture content of the cane stalk, the random sample were weighed and but in oven-dried at 103° c for 72 hours and weighed again to determine moisture contents (Taghijarah el at., 2011).

2.1.2. Digital balance

More than digital balance was used in this study.

- Digital balance with accuracy of 0.005. With maximum weighting capacity 40 kg was used to weight the mass of the sugarcane stalks during the experiments.
- Digital balance with accuracy of 0.05. With maximum weighting capacity 10 kg was used to weight the mass of the sugarcane leaves during the experiments.
- digital force gauge 50 kg, capacity: 0. 1 g sensitivity used to measure the required forces to remove the cane stalk leaf

2.1.3. Digital force gauge

Digital force gauge, models DF-FG 5 with capacity 2200 g and ± 0.2 % of F.S. The test was carried out using the apparatus designed by (Zaalouk and Ghanem, 2003), was shown in Fig. 1, after modifying it by fixing a plate at the head of its plunger to adapt it to fracture a sugarcane sample. Force "F" of a digital force gauge (of magnitude of 2200 g) was magnified using a lever to measure the required force for cutting sugarcane stalks.

2.2. Methods

2.2.1. Same Physical characteristics of sugarcane stalks

Physical and mechanical properties of sugarcane stalks at the time of harvest is very important for design and development of a prototype de-topper and de-thrasher machine. Hence, the various physical parameters such as length and diameter of mill-able cane, node characteristics, leaf characteristics and amount of trash.

2.2.1.1. Stalks Length (L_s)

Length of mature sugarcane stalk (L_s) was determining in (cm), using a measuring tape (5 m) length. The length of mature sugarcane stalks was measured form the bottom of the stalk (the cut position) to the tip of the upper leaves, before cutting the green tops and after cutting the green tops. Fig. 2 shows the length of harvested cane stalks measuring.

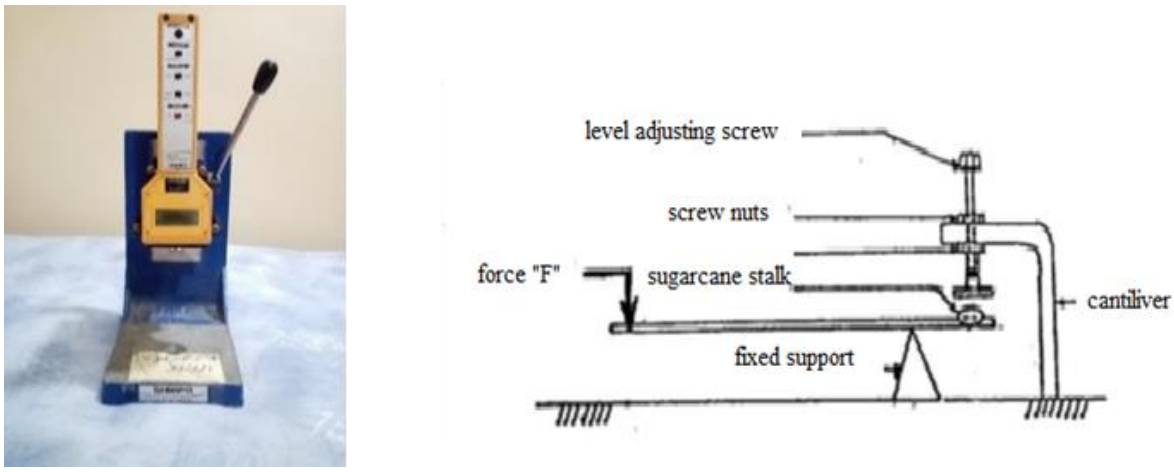

Fig. 1. Digital force gauge models DF-FG 5, and apparatus designed by (Zaalouk and Ghanem, 2003).

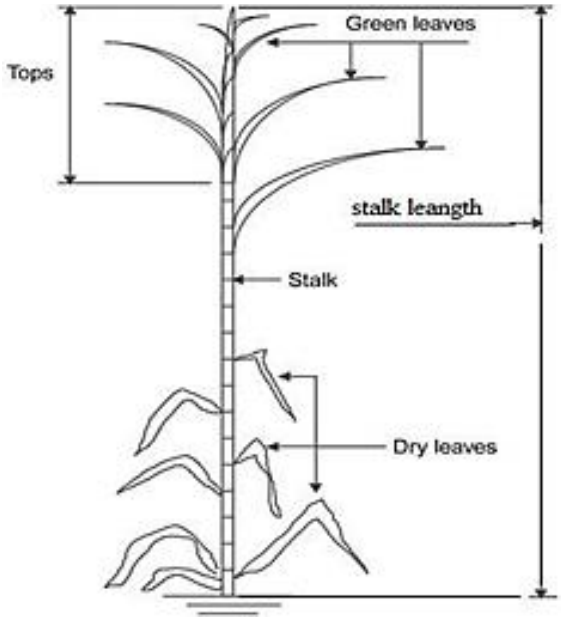

Fig. 2. Length of sugarcane stalks.

2.2.1.2. Stalks diameter (Ds)

Sugarcane diameter usually varies from top to bottom and the variations depending upon the variety or ratoon, and the climatic conditions which prevailed in the phase of the sugarcane growth. Sugarcane stalks diameter was determined in (mm) using an electronic digital measuring caliper with measuring range 0 -150 mm, resolution 0.01 mm, accuracy ± 0.02 mm, repeatability. The diameter was measured at three different positionsbottom, middle and top. viz., Fig. 3 shows the stalk diameter measuring at three different positions. diameter has an important role in designing de toping unit.

2.2.1.3. Stalks mass (Ws)

Mass of cane stalks is one of the important parameters for selection distance between drum roller. the stalks weight, was determined in (gm).

2.2.1.4. Number of nodes on the stalks (Ns)

Numbers of internodes on the sugarcane stalk were counted physically.

2.2.1.5. Content trash

Trash content of the cane at time harvest varies depending upon the variety or ratoon and the agricultural practices adopted. The content of trash and density of leaves were measured for cane stalk already harvested, through manual cleaning and weight of the green and dry leaves after cleaning (gm / stalks).

2.2.2. Mechanical characteristics in sugarcane stalk

2.2.2.1. Penetration force of the cane stalks (FP)

The penetration (vertical) force acting on the cane stalk by cleaning elements is to be lesser than the penetration resistance to avoid the damage of the cane stalks.

Fig. 3. Sugarcane stalk diameter measuring at three different positions.

2.2.2.2. Cutting force of the cane stalk (Fc)

The cutting force are measured at the nodes and internodes of the sugarcane where the de-topping and cutting at the bottom of stalks (cut position) are to be performed. Hence the cutting force required at top and bottom is measured.

2.2.2.3. Crushing force of the cane stalks (Fcr)

The crushing force was measured at node and internode at the bottom middle and the top of the sugarcane stalks.

2.3. Required force for removing sheath and leaves (F_r)

During the preliminary test, wide variation of required force was detected according to the part of cane stalk. There for the stalk was divided in to three zones as bottom and middle, which bears the dry leaves, while the top zone bears the green leaves. A sample of 35 stalks were studied where the data of each individual stalk was recorded. The balance was connected to the leaf using a thin wire and pulled back toward the bottom of the stalks, the device holds the force peak value when each leaf removed. The digital force gauge 50 kg, capacity 0.1 g sensitivity respectively, Fig. 4 shows measurement the force required for removing sheath and leaves.

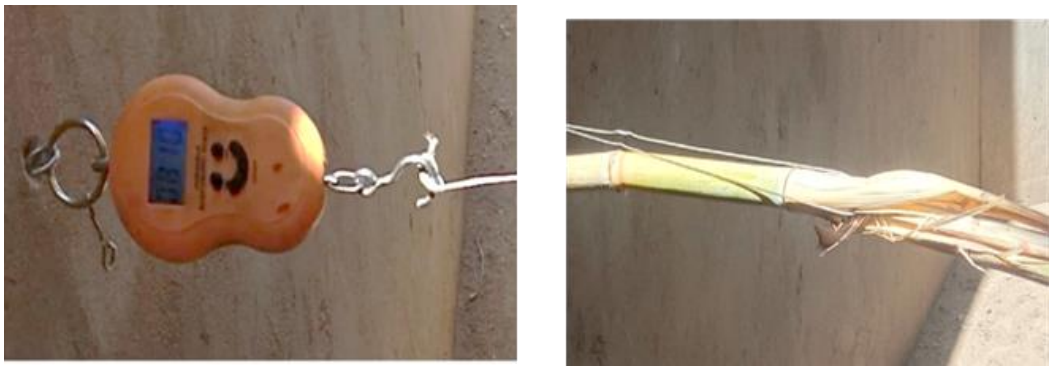

Fig. 4. Measurement the force required for removing sheath and leaves.

3. Results and discussions

3.1. Same physical properties of sugarcane stalks

Sugarcane stalk properties expected to have considerable effect on mechanical de-trashing are those related stalk dimensions and leaves condition. Internode numbers of may represented the same number of leaves on the stalk. Diameter and length of the stalks are the major factors affecting crop handling through any mechanism of de-trashing. Weight of sugarcane stalks, weight of green top and weight of leaves supposed to be important data for mechanical dr-trashing. In case of these above-mentioned properties a sample of 35 cane stalks were considered. The propertied of each individual stalk was measured. Table 1 shows maximum, minimum and average of sugarcane properties related to cane mechanical cleaning.

Maximum length, diameter and weight were 322 cm, 16.7 mm and 2030 g respectively the average minimum values were 212 cm, 26.1 mm and 720 g. Average values appear in the table represent the average of 35

reading. So that it doesn't represent the average internode number the minimum and maximum values. According maximum number of internodes was 25 mm and minimum number of internodes is 13 mm, internodes while the average was 19.9 mm internode on the stalks. For all commercial de-trasher of sugarcane the green top cut firstly. The table show the weight of green tops and its percentage to total weight of the stalks. Maximum and minimum weight of green tops were 161g and 31 g with average value for 35 stalks of 96.4 g that represent from 7.95 % to 4.31 % of the weight of the stalk and general average 7.45 %. the principle function of the de-trasher is to remove leaves on the stalks. The average weight of leaves supposed the removed was 80.4 g 6.22 % with maximum and minimum value of 151g and 30 within the tested sample of 35 stalks.

Table 1
Maximum, minimum and average of sugarcane properties.

	L_s (cm)	D_s (mm)	N_n (mm)	W_s (g)	W_t (g)	% W_t	$W_{d\&g}$ (g)	% $W_{d\&g}$
Max	322	26.1	25	2030	161.0	7.95	151.0	7.44
Min	212	16.7	13	720	31.0	4.31	30.0	4.17
Avg	288.4	20.7	19.9	1293	96.4	7.45	80.4	6.22
SD	31	2.1	3	318	33		28	

3.2. Some mechanical properties of sugarcane stalks

Mechanical properties of sugarcane stalks material that included in experiments were, penetration force, cutting force and crushing force. these parameters are important for the design of handling mechanism of the de-trasher supposed to handle sugarcane stalks with minimum damage and losses. Exploring each properties provide the basic information that determine holding force during handing.

3.2.1. Penetration force (F_p)

Penetration force was found to be variable according to position on the stalks. Fig. 5 show that the values of penetration force. Maximum values were 1916 N, 1686 N and 1205 N for the bottom, middle and top a part of the stalks respectively. Average value for the 15 stalks of the studied sample were 1615 N, 1377 N and 1014 N for the bottom, middle and the top part of the stalks respectively.

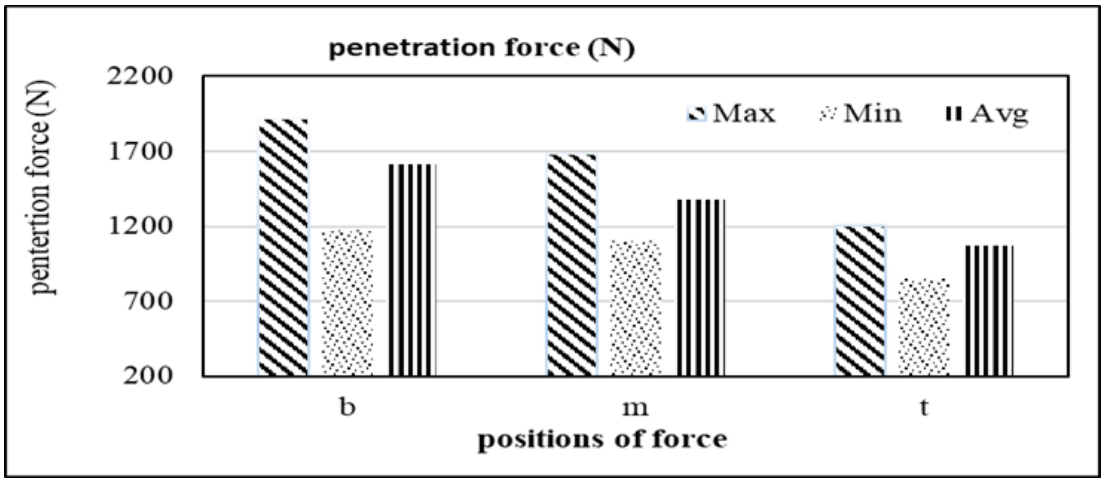

Fig. 5. Penetration force of sugarcane.

3.2.2. Cutting force (F_c)

Fig. 6 shows that the cutting force were 687 N, 432 N and 265 N, for the bottom, middle and top a part of the cane stalks respectively.

3.2.3. Crashing force (F_{cr})

Fig. 7 shows the average value of the crushing force of the cane stalk (in the upper part of the stalk) was 436 N, 510 N and 235 N respectively. The holding the cane stalk should not exceed the force required to break it, so that the stalk does not crush before it breaks.

3.3. Leaf removing force (Fr)

A sample of 30 stalks were considered to measure sugarcane leaf removal force. as indicated in material & methods, number of nodes was firstly counted and ranked form bottom to top. The rank of the internode on the stalks represents the rank of the leaf it. The bottom third of the stalks usually included dry leaf that

shown to be easy to be removed. The middle third of the case stalk included mix of dry and hold dry leaves, while the top part of the stalk may have green leaves was holder to be removed. Average maximum and minimum required force to strip one of a leaf was computed for each part of the stalk. The average force for each part of the stalk was also computed. Fig. 8 indicate that of the force measured to remove cane leaf corresponded to leaf rank. Studying the data of Table 2 maximum force corresponded to each of the leaf ranked from 1 to 20 means the highest force recorded when removing considered in simian way where the value of the force recorded when removing the leaf certain rank. The maximum and the minimum force shown in Table 2.

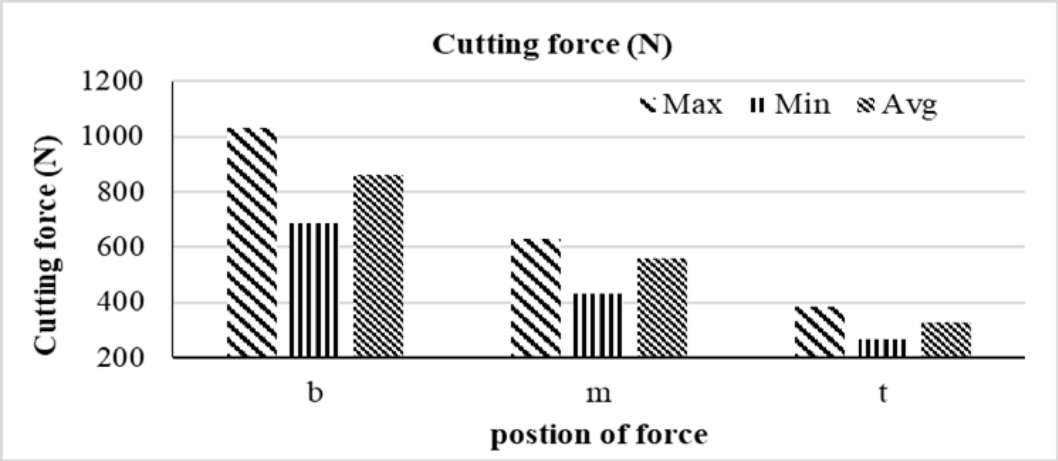

Fig. 6. Cutting force sugarcane stalks.

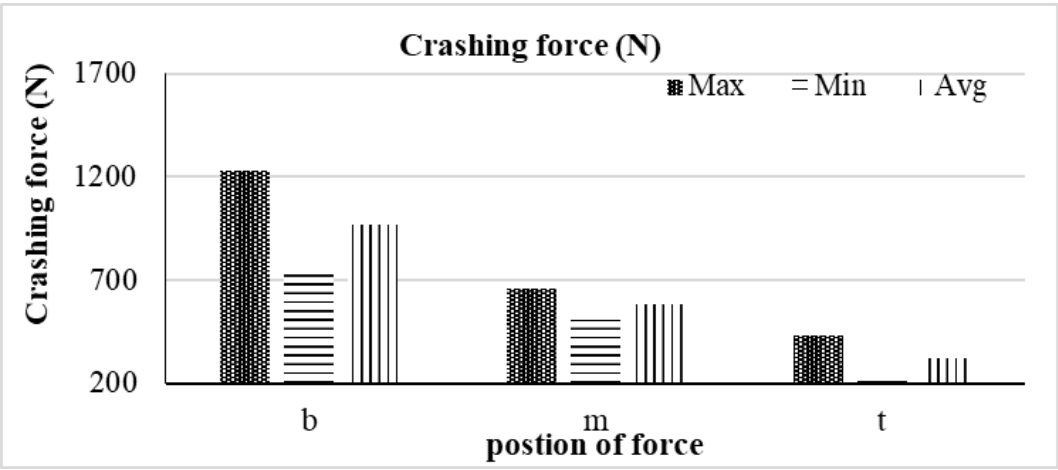

Fig. 7. Crashing force of sugarcane stalks.

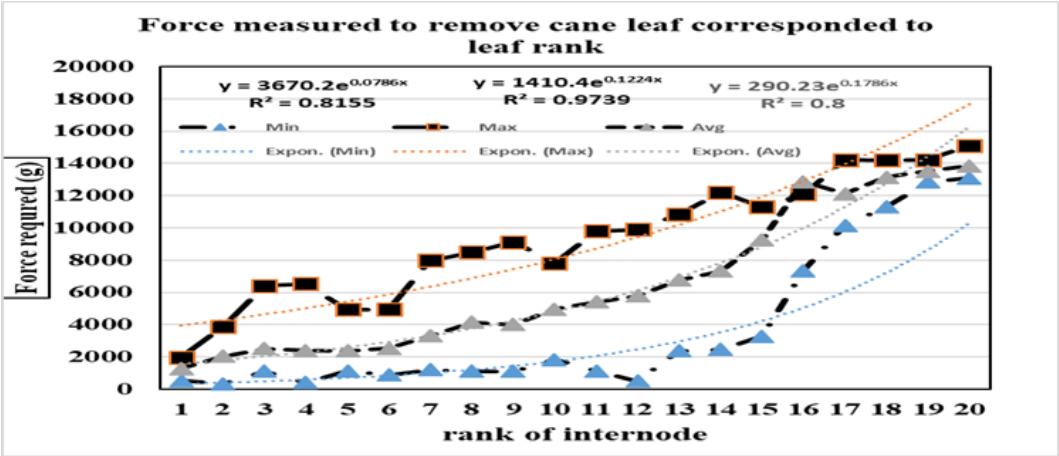

Figure 8. Force measured to remove cane leaf corresponded to leaf rank.

Table 2
The force measured to remove cane leaf corresponded to leaf rank (Kg/ leaf).

	Min	Avg	Max
bottom	0.34	2.117	6.54
middle	0.685	5.351	11.76
top	7.34	7.86	13.57

Fig. 9 shows that the means, highest and lower reading of certain leaf rang (kg/leaf) in the sample of 15 stalks included in the experiments. So that minimum force ranged from 0.34 kg to up to 7.34 kg, and maximum force ranged from 6.54 kg to up to 13.57 kg.

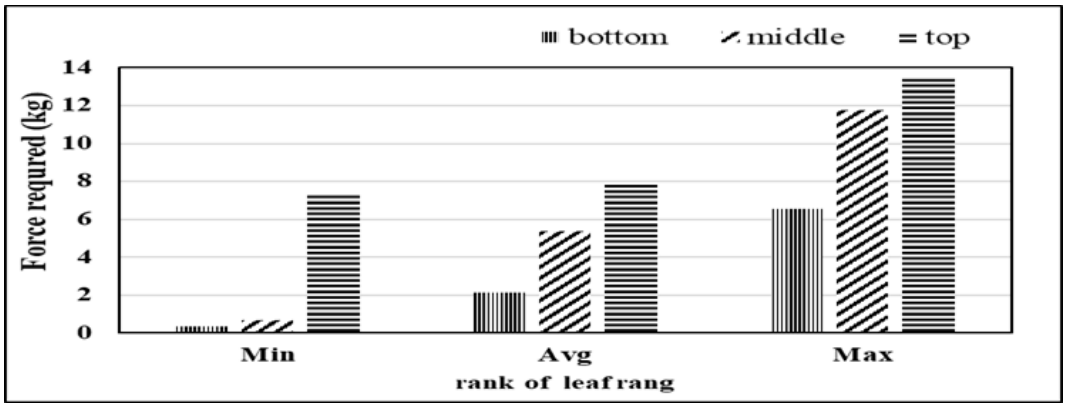

Fig. 9. Means, highest and lower reading of certain leaf.

4. Conclusions

The conclusion of the present study may be summarized as follows:

1. Identify the characteristics of cane stalk that have a great effect on the process of mechanical de-trashing, namely length, diameter, number of nodes, weight of stalk, weight of green top, weight of green and dry leaves
2. Maximum values of penetration force, cutting force and crashing force were determined 1916, 1686 and 1205, 1030 N, 627.8, and 382.6 N and 1226, 657.3 and 431.6 N for bottom, middle and top a part of the stalks respectively. This data useful in design of handling and cutting mechanisms of the detraher.
3. The maximum required force to removes the leaves from sugarcane stalks were 6.54 kg, 11.96 kg and 13.57 kg for bottom, middle and top a part of the stalks respectively.

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العوامل المتعلقة بالتنظيف الميكانيكي لأعواد قصب السكر

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الملخص العربي

تنتشـر زراعة محصول قصب السكر في صعيد مصر بالطرق التقليديـة وفي حيازات صغيرة ومتفرقة تجعل استخدام الميكنة الكاملة لحصاد القصب شبه مستحيلة وبالتالي فان تكاليف الانتاج تزداد عام بعد اخر خاصة لعدم انتاج الات محلية الصنع تقوم بعمليات الحصاد والتنظيف.

يواجـه المزارع المصري بشكل خاص صعوبات بالغة لعملية الحصاد بشكل عام وعملية تنظيف أعواد القصب وإزالة القمة الخضراء بشكل خاص ولعل من أهم تلك الصعوبات عدم توفر آلات التنظيف التي تلبى الاحتياجات وتناسب الظروف الاقتصادية للمزارعين، كذلك نقص الأيدي العاملة وارتفاع أجورها والمجهود الشاق المبذول لأداء تلك العملية مما يجعل تكاليف الانتاج مرتفعة.

بناء عليه فقد تم دراسة بعض العوامل التي تؤثر على التنظيف الميكانيكي لعيدان قصب السكر كقاعدة بيانات ضرورية تساعد في تصميم هذه الآلات محليا وحل هذه المشكلة وتقليل تكاليف الانتاج ومن هذه المعلومات الخواص المتعلقة بالمحصول التي تشمل الطول، القطر، وعدد العقل، ووزن العود، ووزن القمة الخضراء، ووزن الاوراق الجافة والخضراء اللازم ازالتها آليا.

وكانت النتائج كالتالي:

أقصي طول ٣٢٢ سم، والقطر ٢٦,١ مم وعدد العقل ٢٥ ووزن العود ٢٠٣٠ جرام ونسبة وزن القمة الخضراء ٧,٩٣٪ ونسبة الأوراق الجافة والخضراء ٧,٤٤٪ وهذه المعلومات تفيد في تصميم اليات التداول والتغذية والطرد لآلات التنظيف.

وتم قياس قوة الاختراق للعيدان وقوة القطع وقوه السحق وكانت أقصي قيمة ١٩١٦ نيوتن، ١٦٨٦ نيوتن و١٢٠٥ نيوتن لكلا من قاعدة ومنتصف وقمة العود لقوة الاختراق على التوالي وكانت قوة القطع ١٣٣٠، ٦٢٧,٨ و٣٨٢,٦ نيوتن لكلا من القاعد والمنتصف وقمة العود وقوة السحق كانت ١٢٢٦، ٦٥٧,٣ ٥١٠ نيوتن لكلا من القاعد والمنتصف وقمة العود.

وتم أيضا قياس القوة اللازمة لإزالة الأوراق من عيدان قصب السكر وكانت أقصي قيمة متحصل عليها ٦,٥٤ كجم / ورقة و١١,٧٦ كجم / ورقة و١٣,٥٧ كجم لكل ورقة لكلا من قاعدة ومنتصف وقمة العود وأدني قيمة ٠,٣٤٠ و٠,٦٨٥ و٧,٣٤كجم/ورقة لكلا من القاعدة والمنتصف وقمة العود على التوالي.