A MODIFICATION OF A SUGAR BEET DIGGER TO SUIT EGYPTIAN FIELD CONDITIONS

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Abstract

The main purpose of the present work is to modify a sugar beet digger to suit the Egyptian working conditions using a primary digging tool with a special design (under root) to assist the main harvesting unit to pull the roots from the soil with the following criteria: -

- The modification should be simple and constructed from cheap row material locally available.
- The modification should be made from standard components to save the time and money for mass production if possible.
- It must be designed to attach to the most available tractors.

A comparison between the number of un-harvested roots, injured roots and harvested roots were determined before and after modification of the machine. The results indicated that the percentage of un-harvested roots was 16.3 % and 20.4 % compared with 5.7% and 4.5% before and after the modification, respectively, at the same tractor speed. While the injured roots were 42.9% and 49.3% compared with 10.2% and 8.2%. The pre-pulling device did not make any change in the machine field capacity but it had direct effect to decrease the number of injured sugar beet roots during the harvesting operation.

INTRODUCTION

Sugar beet became one of the most strategical crops in Egypt. Recently, sugar beet plantations expanded in the Delta and Upper Egypt .The planted area increased from 131323 feddan in year 2003 to140982 feddan in year 2004. (Annual publication of extensions service M.O.A 2005)

Meanwhile the annual productivity per feddan reached about 20 ton. The annual capacity of recent suger factories for extracting sugar from sugar beet needs about 200 thousands feddan to operate with full capacity.

The traditional way to harvest sugar beet depends on the availability of labors. Each feddan needs 3 men to pull the roots from the soil with a hand tool meanwhile another 4 females use scythe to top the green haulm and clean the root. These workers can harvest almost one feddan per day at a cost of 200 L.E/feddan . To speed up the harvesting operation with a mechanised technique, a digging machine is needed having high field capacity and low operating cost.

It is realized that, there are many types of sugar beet diggers which were tested under Egyptian agricultural conditions. Some of them were multi rows others were one or two rows. Field experiments indicated that one or two rows diggers have more maneuverability in small-scale prevailing farms and can easily deal with planting problems. The method of harvesting varied according to type. A two-row digger may be considered most suitable.

Smith and Wilkes (1994) reported that over the recent years a number of toppers and under root cutters have been designed and modified on the same design principles of the rotary beaters, or flail of forage harvesters. They concluded that the machine equipped with a pair of rotary cutters may reduce the overall labor requirements to a great extent. The rotary cutters rotate opposite each other, thus depositing the vegetative part of the plant in a narrow row on the field.

Bishop and Maunder (1980) stated that not only removing the above ground portion, but also necessary to cut the plant leaves by cutting under the tuber growing zone. This is needed before any machine can be used to uproot the root crop. A number of topping devices and root cutting definers have been tried with varied results.

Ibrahim et al (1989) modified and tested a sugar beet digger to be used under Egyptian conditions. They studied the effect of tilt angle, blade width, and forward speed on the damage caused by the modified harvester. Based on the evaluation of the damage and lifting efficiency they concluded that, best blade width was 20 cm, the optimum tilt angle was 20° while the optimum forward speed may be 3.5 km/h. They stated that the modified sugar beet digger was economic and it may save about 90% of total costs for the lifting operation compared with manual harvesting methods.

Lebicki (1987) reported that the pulling technique is a suitable method to be used for harvesting sugar beets. He showed that the number of picking units on the mechanism is depending on the distance between the plants and the operating speed.

El-Sahrigi (1985) indicated that the harvesting operations require extensive measurement before, during and after harvesting and may lead to high yields and low costs.

Dohi, *et al* (1995) modified a puller mechanism to be used as a holding type hands-on robot for harvesting some vegetable root crops. The machine consisted mainly of a DC motor, pulleys, tension roller and two timing belts. The DC motors rotated about 60 rpm of which the holding belts are moved at a speed of about 0.1

m/s. When the robot will be harvesting, the X-axis traveling speed of the manipulator is synchronizing the holding belt speed.

MATERIALS AND METHODS

The original digger

The original digger is a 2-row sugar beet digger, Danish manufacturers Sammaka make. It is equipped with two root pulling devices. Each device consisted of two pulling discs. The vertical angle between each two disc is 60°.

The digger is equipped with a rotary elevator coated with rubber to avoid scratching the tubers. It transfers the roots to two cleaning turbine like dvices . The digger is also equipped with two depth wheels to control the digging depth.

The modified digger

The main modification was to provide a special tool in the front of each pulling unit of the original machine. Two shanks were fixed to the main frame by clamps.

The tool was pre- plowing underneath of the roots. This modification helps the main pulling machine to harvest the sugar beet roots by loosening the soil around the tuber. Fig. (1) shows a schematic diagram for the digger before and after development. Fig. (2) shows a photo of the sugar beet digger after modification.

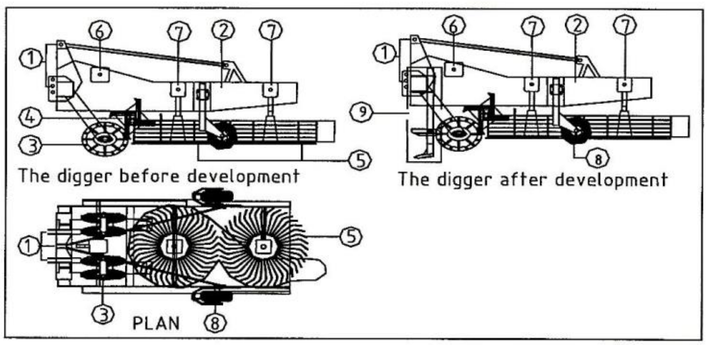
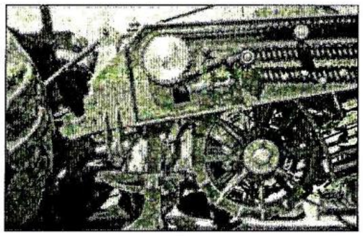


Fig. 1. Schematic diagram for the digger before and after development

(1) Three point hitch	(2) Chassis	(3) Pulling unit
(4) Rotary elevator	(5) Cleaning rotors	(6) Main gearbox
(7) Cleaning rotor gear box	(8) Depth control	(9) Underneath device



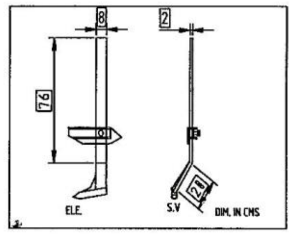


Fig. 2. (Left) The modified machine, (Right) The Underneath device in details

Planting system and area

A 4-row planter, Italian made, semi-mounted was used to plant a multi-germ seeds (Corolla variety) in Kafer-El Shiekh governorate in El-Hamool and El-Zawia. The distance between rows was 65 cm and the distance between plants in the row was 25-30 cm. After germination replanting of the missed plants and removal of the extra plants were done by hand.

Tractor

A Kubota tractor model M-110 equipped with 110 (SAE) Hp at 2400 r.p.m, 5 cylinders in line, direct injection, total displacement 5832 cm3 ,water cooled, power shift transmission,(16 F and 16 R) was used to operate the digger. The tractor was equipped with 440 kg front weight. Three forward speeds were selected during the experiments. Another tractor, Romanian made, UTB, was used during the draw bar experiments.

Dynamometer

A hydraulic type dynamometer (Erichsen, British made) mechanical indicator on a graduated scale in KN or printed on paper roll, equipped with hydraulic cylinder and two-drawbar collar Cat. II each side, was used to measure the required draw bar pull of the machine before and after modification.

Plants and roots calculation

Before operation, a common hand tool was used for topping the haulm of the plants. The total number of the plants was counted before harvesting. Also, the number of un-harvested roots, injured roots and harvested roots were recorded after operating the digger with and without modification.

Determination of some physical characteristics of sugar beet roots

Measurement of the axial dimensions

The measurements of the axial dimensions were done using micrometer and or vernier caliper.

Surface area calculations

The surface area and volume were calculated using the corresponding engineering shapes.

(1)Prolate spheroid (2) Oblate spheroid (3) Right circular cone

The sugar beet root resembles the right circular cone or cylinder. This can be formed by rotating the (b) axis as shown in Fig (3). The volume (V) and the surface area (S) were calculated using the following formula: -

$$V = 3/4h(r_1^2 + r_1r_2 + r_2^2)$$

$$S = \pi(r_1 + r_2)\left[h^2 + (r_1 + r_2)^2\right]^{1/2}$$

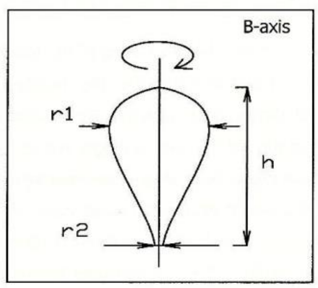


Fig 3. Calculations of the surface area of a sugar beet

where:-

r_1 = the max. horizontal radius of cone.

r_2 = the min. horizontal radius of cone.

h = height of the cone.

RESULTS AND DISCUSSION

Machine field capacity calculations

Original and modified sugar beet digger field capacity

The original digger was tested before and after modification in El- Hamoul village in Kafr El- Sheikh Governorate in a heavy clayy soil. The digger was tested at speeds of 3 and 4 km/hr only and the test could not be followed up due to the high number of the injured roots at higher speeds. Table (1) shows the original digger performance during experiments before and after modification.

Table 1. Sugar beet digger field capacity before and after modification

Average speed (Km/hr)	*Digger field capacity (feddan/hr)*	
	Before modification	*After modification*
3	3.15	3.19
4	4.20	4.26
5	-	5.73
6	-	6.90

From Table (1) it is realized that increasing of the forward speed increases the digger field capacity. Also, it also indicated that the modified digger field capacity is very near to the original digger field capacity. This indicates that, the pre-pulling device dose not affect operation of the original digger and its field capacity.

Performance of original sugar beet digger on root injuring

The percentage of the unharvested and injured roots at different tractor speeds using the original digger before modification are given in Table (2).

Table 2. Performance test results of the original digger before modification.

Average Speed (Km/hr)	*Average total number of roots before harvesting*	*Average number and percentage of root condition after harvesting*				
		losses				*Total losses %*
		Unharvested	*%*	*Injured*	*%*	
3	240	39	16.3%	103	42.9%	59.2
4	201	41	20.4%	99	49.3%	69.7
5	-	-	-	-	-	-
6	-	-	-	-	-	-

The percentage of unharvested and injured roots at different tractor speeds for the modified digger are given in Table 3.

Table 3. Performance test results of the modified digger.

Average Speed (Km/hr)	Average total number of roots before harvesting	Average number of roots after harvesting				
		Losses				Total losses %
		Unharvested	%	Injured	%	
3	176	10	5.7%	18	10.2%	15.9
4	268	12	4.5%	22	8.2%	12.7
5	119	2	1.7%	8	6.7%	8.4
6	167	10	6.0%	12	7.2%	13.2

From Table (3), it is realized that, increasing the forward speed results in a low total loss ratio. The total loss ratio was 15.9 %, 12.7%, 8.4% and 13.2% at average speeds of 3, 4, 5 and 6 Km/hr respectively. Also, it is realized that increasing the speed from 3 to 5 km/hr, the un-harvested root ratio and the injured plants were decreased. Meanwhile, at speed 6 km/hr the un-harvested plants ratio increased to 6.0% and the injured roots ratio re-increased up to 7.2%. Hence, the optimum forward speed may be cosidered 5km/ hr. Fig (4) shows the effect of the forward speed on the root losses.

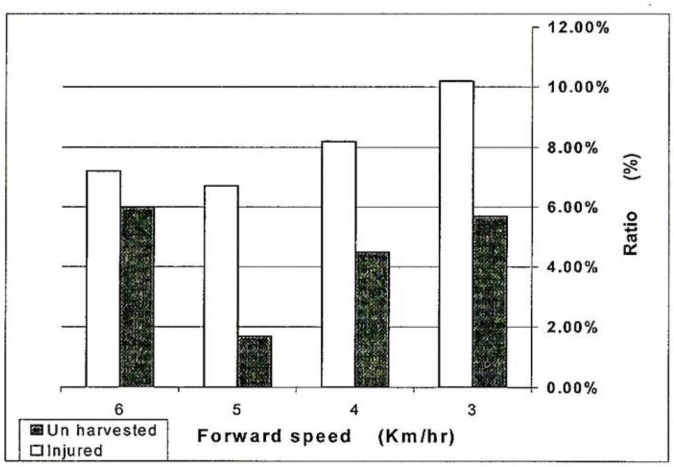


Fig 4.The effect of the forward speed on root losses.

Using Microsoft Excel program to determine a predicted equation to find the relationship between the speed and the losses ratio. The best fit relation has the following form: -

$$L = AV^3 - BV^2 + CV + D \qquad (R^2 \approx 1)$$

where:

L = Losses ratio.

V = the forward speed km/hr $(1 \le V \le 6)$

A, B, C and D = constants (A= 0.0169, B=0.1064, C =0.1691, D=0.0796).

The relationship between the losses and the forward speed follows a quadratic function. The comparison between the actual losses and predicted losses is shown in Fig. 5. It is clear that, the actual losses are very close to the predicted losses.

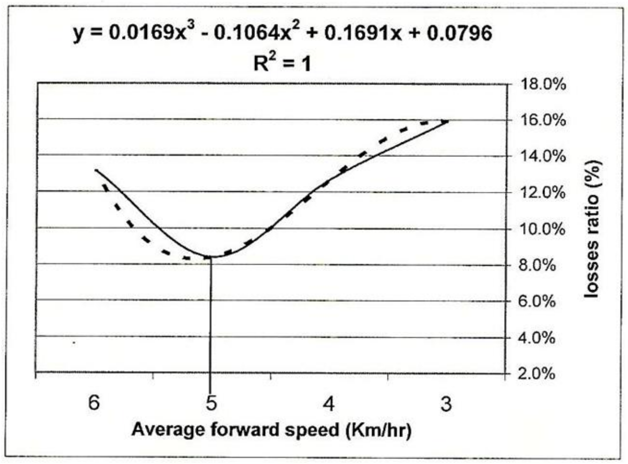


Fig 5. Actual and predicted relation for the modified digger between the root losses and the forward speed.

Measurment of the required drawbar pull

It was necessary to measure the draw bar pull on the four tested speeds. A hydraulic dynamometer was connected between two tractors. The first tractor was used to pull the digger . The second tractor transmission was on the neutral gear and the machine was attached to its three-point hitch. The measurements were taken twice. The first measure was taken while the digger was lifted off the ground. The second measure was taken on the same field and the digger was in operating position. The difference gives the draft of the implements, Smith *et al.* (1994).

Table 4. The required draw bar pull after digger modification

Average Speed (Km/hr)	*Draw bar pull with digger out of operation position (N)*	*Draw bar pull with digger in operation position (N)*	*Required draw bar pull (N)*
3	3362	5460	2098
4	2988	4706	1718
5	2490	3981	1491
6	2223	3685	1462

Study of some physical characteristics of sugar beet and its relation to harvesting losses

Some physical characteristics of sugar beet

The measurements of sugar beet, Corolla variety, were taken in from the field where the machine was operated. After harvesting, a ten meter long row was taken, the roots dominions were measured and inspected for injured. Some physical characteristics of sugar beet after harvesting are given in Table 5. The results showed that the roots may be categorized in five categories.

Table 5. Some physical characteristics of sugar beet after harvesting.

Category	*Dimensions (cm)*			Average volume (cm^3)	Average surface area (cm^2)
	h	r_1	r_2		
A	≤ 10	≤ 8	≤ 1	*548*	*2558*
B	*>10-20*	*>8-12*	*>1-2*	*1395*	*6952*
C	*>20-25*	*>12-13*	*>1-2*	*3126*	*16311*
D	*>25-35*	*>13-15*	*>1-2*	*5130*	*29039*
E	*>35*	*>20*	*>3*	*12311*	*63337*

The relationship between some physical characteristics of sugar beet and root injured

Comparing the root category (volume and the surface area) with the injured roots condition, the results showed that the injured roots increased with increasing the volume of roots. Table 6. shows the condition of injured roots in the five root categories

Table 6. Condition of injured roots in the five root categories.

Root Category	Root Average volume (cm^3)	Ave. surface area (m^2)	Forward speed (km/hr)							
			Injured root codition (%)							
			Scuffed				Severe			
			3	*4*	*5*	*6*	*3*	*4*	*5*	*6*
A	*548*	*0.2558*	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
B	*1395*	*0.6952*	12.5%	16.7%	0.0%	0.0%	10.0%	10.0%	0.0%	0.0%
C	*3126*	*0.16311*	25.0%	16.7%	16.7%	0.0%	20.0%	20.0%	0.0%	20.0%
D	*5130*	*0.29039*	25.0%	25.0%	33.3%	28.6%	30.0%	30.0%	50.0%	20.0%
E	*12311*	*0.63337*	37.5%	41.7%	50.0%	71.4%	40.0%	40.0%	50.0%	60.0%

CONCLUSIONS

1. The tested sugar beet digger has harvesting capacity of 5.7 feddan/h at optimum speed of 5 km/hr. (the desiged pre- pulling unit has no effect on the field capacity but it has a direct effect on decreasing the injured roots) .
2. The results indicated that the percentage of un-harvested roots was 16.3 % and 20.4 % in comparison with 5.7% and 4.5% before and after the modification respectively at the same tractor speed. Also the percentages of the injured roots were 42.9% and 49.3% compared with 10.2% and 8.2% before and after modification of the machine, respectively, at the same tractor speed.
3. The machine should be equipped with a suitable haulm topper.
4. Using the mechanical harvesting could save about 10 million Egyptian pounds compared with the manual harvesting on the same cultivated area in year 2004 with the injured root ratio.

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تطوير آله حصاد لبنجر السكر لتناسب الظروف الزراعيه المصريه

أســـــامه محــمــد كــامـــل

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يعتبر بنجر السكر من المحاصيل الاستيراتيجيه في جمهوريه مصر العربيه . وانتشرت المساحات المنزرعه به شمالا في الدلتا وجنوبا حتي الوجه القبلي حيث تحتاج مصانع استخلاص السكر حاليا الي مساحات اكثرمن ٢٠٠ الف فدان حتي تعمل بطاقه كامله . ولكي تعمل هذه المصانع بطريقه اقتصاديه لابد من تدارك حاجاتها من جذور بنجر السكر في وقت سريع حيث ان تكاليف تشغيل المصنع ثابته ولاتتأثر بكميه الجذور الداخله في خط الانتاج . وتحتاج الطريقه التقليديه في الحصاد الي ٧ عمال للتقليع بتكلفه ٢٠٠ جنيه / فدان بمعدل يصل الي فدان واحد يوميا . لذا فان السوق المحلي في اشد الحاجه الي معده تقوم بحصاد بنجر السكر بمعدلات سريعه لتفي بحاجات المصانع اليوميه . وتم عمل حصر للمعدات التي تم استخدامها في حصاد بنجر السكر آليا واتضح ان أهم أسباب عدم انتشارها زياده نسبه تجريح الدرنات . من هذا المنطلق تم اختيار اله لحصاد بنجر السكر واجراء التجارب المبدئيه عليها وتم تطويرها بإضافه وحده ابتدائيه لخلخله الدرنات وفك التربه من حولها قبل وحده النزع الرئيسيه . وبلغت نسبه الجذور الغيرمحصوده قبل التعديل ١٦,٣% و ٢٠,٤% بينما بلغت هذه النســـبه بعد التعــــــديل ٥,٧% و ٤,٥% عند نفس السرعات ٣ ، ٤ كم / ساعة علي الترتيب .

لم يؤثر التعديل علي السعه الحقليه للمعده بطريقه معنويه ولكن كان له اثر مباشر علي خفض نسبه التجريج من ٤٢,٩ % إلى ١٠,٢ % ، ٤٩,٢ % إلى ٨,٢ % عن نفس السرعات على الترتيب .