DEVELOPMENT PLANTING AND HARVESTING SUGAR BEET CROP MACHINE.

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ABSTRACT

The main goal of the present research is to develop a rationalized power, and operation cost combined machine suitable for sugar beet planting and harvesting operations, and to be suitable for the Egyptian agricultural conditions. The developing machine components can be summarized in two parts:

First component is planting unit: is planted two sugar seeds' rows with suitable depth at top of the middle center of the two row furrows, in the same time formed three cultivable rows. The formed three shares are seated after the two planting rows. Each formed row share is a consisted from a double mouldboard bottoms, at end of it whereas, the drop seeds is covered by the sliding soils path.

Second Component is sugar beet pulling unit: is involved three main sugar beet harvester components namely, two appropriate shares for loosing the ridge structure around the roots, pulling out belt mechanism with its proper power transmission system, and a proper disk knife as a topping mechanism.

The machine id performed 60-70 cm riders during planting two rows. Also harvester one sugar beet row through pulling out and topping mechanisms. Three proper ridges in shape of a double mouldboard were constructed one was fixed on the front machine frame and the other two ridges were fixed on the back frame. Also two proper shares form for loosing the ridge structure around the roots.

INTRODUCTION

The second major root crop grown in Egypt is sugar beet not only for sugar production, but also for producing animal fodder, and organic matter for fertilizing the soil. Over 40% of the world sugar production is produced from sugar beet. In Egypt the important of this crop as a source of sugar was increased to meet the increasing consumption of sugar by Egyptian population. Therefore cultivated area of sugar beet increased from 190,000 to 200,000 Feddans, within 2003 to 2004, (Anon, 2004) .

In the recent time various types of machines are available for planting and harvesting sugar beet crop. They are operated on entirely different principles to each other's. There are many planting machines on the market *all* over the world, started from early years with mechanical metric wheel devices to pneumatic metric devices. In this research a comparative studies took place between using peripheral metric wheel a brush disk for planting sugar beet crop. On the other hand, the range of the available harvesters all over the world may be included in three main harvester techniques namely:-bulk, vibrating, and pulling, harvester techniques. Whatever the harvester classification, it has to lift the sugar beet crop, out of the ridge and by passing them through different sections of the implement to separate them from loose soil, soil clods, tops and any other rubbish. Also whatever type of harvester is used, the same general principles apply when it comes to setting and using it. Whereas, the harvester should directed so that it lines up correctly with the

row of sugar beet crop to be lifted. This will normally be when the center point of any lifting unit is positioned in the ridge center.

In fact harvesting sugar beet crop in the developing countries especially in Egypt are often performed by using simple diggers and manual tools. So harvesting operation can be an expensive labor-consuming if not proper mechanized, (El–Sherief 1996). Hence, application of a developed sugar beet harvesters becomes one of the most essential target for minimizing both, production cost, and root damage. Subsequently, increasing the net income for sugar beet growers in Egypt.

Over the last two decades a number of pullers have been developed for harvesting beet-crops. Many authors (Lebicki, 1987 and Srivastava *et al.*, 1995) reported that, puller mechanism is suitable method to be used for harvesting sugar beets. In fact there are different types of puller mechanisms that are harvested by engaging and holding the above ground plant portions that is to be harvested. Hence the plants with both above ground and the root portions are lifting together by the pulling action.

In general the sugar beet pullers are favorable if the soil conditions are dry and weak. Then the front end of the harvester will easily fracture that soil and the sugar beet crop is extracted free or nearly so of soil. But unfortunately, most of the available pulling beet harvesters are not developed to suit the wet and cohesive soil conditions.

Finally confiding that rationalized power requirement, and minimizing both operation cost and beet damage are the umpires goals of developing sugar beet seeder and harvester in Egypt. Hence the aim of the present study is to develop an economical drilling and pulling out sugar beet machine. The suggested seeder and harvester was planned to perform these subsequence functions: planting two rows and harvesting one row of sugar beet crop throughout :(1) losing the ridge around the growing roots, (2) pulling the bulk of leave cervixes to lift the roots from the ridge with its leaves and vines, (3) Topping the leaves, and then (4) Directing the roots back to the ground surface to be picked up by hand.

REVIEW OF LITERATURE

Sugar Beet Physical and Mechanical Properties

Buyanov and Voronyuk (1985) found that the forces required to shear the topes of sugar beet were determined by using the dynamometer cutting speed 0.1 m/s, a knife thickness of 1.5 mm, a blade angle of 0.17 rad (10^0), and knife set at 1.57 rad (90^0), relative to the line motion of the root, the

Table (1): Shearing force of topping sugar beet.

Thickness of the shearing layer (mm)	Diameter of root, (mm)	Diameter of sheared section, (mm)	Shearing force(N)
5	78	41	101.03
10	74	48	113.39
20	80	56	141.26

The tenacity force (S) of the lower beet leaves bunch (sheaf) section (at average height of 22 cm above ground surface) may be considered as 1900- 2200 N. That force magnitude did not cause leafs sheaf cutting and it is four times approximately higher than the required uprooting force (P=560-720 N) for an individual beet plant. {That value is in accordance to the statements of Klenin *et al.* (1984)}. The friction angle of a sheaf of beet leaves and a beet root against a rubber belt surface depends on the respective leaf sheaf beet properties, and also on the smoothness of the surface over belt sides. But, it can be considered {according to Bernacki *et al* (1987)} that the coefficient of friction of the leave bunch against smooth rubber belt was about 0.4-0.5. While, coefficient of friction of the leave bunch against belt covered with sackcloth was 0.5-0.6 (Hence , the average of friction angle of beet leaf sheaf against smooth rubber belt may be about 25°, and against belt covered with sackcloth may be considered about 27°

Ismail *et al.* (1989) reported that the most important factor affecting the design of a digger for beet is the root length (L). The less important factor is the minimum diameter of beet (Min. diam.). The maximum diameter of beet (Max. diam.) effect was found to be in a middle position. An exponentially relationship between correlated roots of beet mass (m), length and diameter are as indicated: M= 0.118 kg; L= 1.11 cm; max. Diam = 11.0 cm and min. Diam. = 8.52cm they also concluded that, the optimum parameter for digging blade are tilt angle, t ranged from 15 to 25°, lifting angle d= 35 to 40° and inclination angle & = 52.5 to 58.75° when operating in different types of soil with "u" ranging from 0.55 to 0.79.

Gorzelany and Bakalury (1999) measured the force necessary for extracting sugar beet roots from the soil. The effect of selected geometric characteristics of the roots (length, diameter) and their depth in the soil on the force necessary for removal of roots from the soil was determined. The variation of force necessary for root extracting was analyzed with reference to beet variety, soil compactness and soil moisture content. Irrespective of the root size, variety and field (plantation), the recorded average values of force were found to vary widely in the range of 297.9-669.0 N. In some cases forces up to 1000 N were recorded.

Sugar Beet Harvesting Machines:

Bernacki and Karwowski (1976) stated that the first step towards sugar beet harvest mechanization was done to ease the manual drudgery of lifting the roots by the leaves and cutting the tops. After that in (1961) the Sieder Leben Company constructed a two-Row beet harvester. This implement had two curved chisels lifters. The spaces between them could be adapted to the width of adjacent inter-row, The chisels were attached by hinges to a main frame supported on a four- wheel cart.

Shippen *et al.* (1980) illustrated that the most of the beet harvesters available to the farmer are P.T.O driven types, which all operate in basically the same way, but self-propelled types are also available. The latter machines have built-in self-unloading tanks, which can eliminate the use of an additional tractor and trailer for carting the sugar beet. The complete operation is done by a beet harvester as follows.

A pair of lifting shares or wheels lift a previously topped row of beet on to a chain elevator which carries the beet to a cross elevator which in turn delivers the beet into a trailer running alongside the harvester. Where a self-propelled tanker machine is used, this elevating arrangement is modified. Whilst the lifting of one row of beet is taking place, another row is clear for the lifting share on the next time round.

Ibrahim *et al.* (1989) developed a two-row tractor drawn sugar beet digger and used a sweep share with a fork shape including two wings with a flat cutter. There is no need to increase blade width more than 20 cm because there is no corresponding increase in lifting efficiency or decrease in roots damage. Root damage reached its minimum value at till angle of 20°. the optimum parameters which achieved maximum lifting efficiency and minimum damage are : φ=20°, w=20 cm and S= 3.5 km/h. The cost of lift sugar beet roots using the developed blades was compared with manual methods. The results showed that the blade was more economic and reduce the cost from 90 to 6 LE/Fadden.

Sugar beet crop harvesting machines Features.

The recent sugar beet crop harvesting machines are operated on entirely different principles to each other. In fact they are differing in these mechanisms which are working in the area of lifting the crops from the ridge and separating them from foreign materials. Hence according to the lifting principles the range of sugar beet crop harvesters which are available allover the world may be classified under the three following headings: (a- Bulk harvesting, b- Vibrating harvesting and c- Pulling harvesting).

The bulk harvesting machinery.

Kepner *et al.* (1982) noted that most harvesting of sugar beet crop is commercially achieved by bulk harvesting machinery techniques. Whatever machine classification it has carry out a number of tasks, which are common to all harvester types. All types aim to lift the roots out of the ridge then passing them either through different sections of the harvester itself or through an individual separating mechanisms to carry out the separation from soil, tops and any other rubbish.

Nasr (1992) showed that there are many more components on the digger as compared to the spinner. These components come in contact with the soil and this inevitably means that more wear can take place. He added that one main advantage of the elevator digger over the spinner is that it deposits the crop in a narrow row on the field and this eases considerably the work of the hand pickers. The complete harvester digs, separates and delivers into sacks, boxes or trailers during one pass of the machine over the field.

Sharobeem *et al.* (2003) developed and manufactured suitable equipment for lifting sugar beet roots. The experiments were carried out to evaluate the performance of the constructed lifter compared with the traditional chisel plow. Three traveling speeds (2, 3, and 3.8 km/h.) were used. The results showed that, for the developed lifter, the maximum a lifting efficiency was about 84% at 2 km/h forward speed and the minimum damage roots was about 4.5 % at the same speed. The maximum percentage of lifted roots was about 88.5 % with the developed lifter, while that obtained with

chiseling was 76.4 %. The actual field capacities were 0.6, 0.9 and 1.14 fed/h at forward speeds of 2, 3 and 3.8 km/h respectively for the developed lifter. In case of using the developed lifter, the minimum power required was 13.16 kW at forward speed of 2 km/h. while the maximum power required was about 25.96 kW at 3.8 km/h forward speed. The energy requirement for the developed lifter was about 22.77 kW.h/Fed.

Vibratory harvesters' machines:

Kang and Halderson (1991) designed a two-row, three-point-hitch vibrating. Each row was composed of a pair of four-bar linkages to which two side plates are attached. A bottom plate for each row was composed of a soil-cutting blade with points (0) followed by soil-sieving bars. Those bars were rigidly attached to the bottom of each pair of side plates to cut and lift the soil and also allow for soil separation. The motion of the bottom plate was also designed to assist with soil flow. The oscillating assemblies were PTO driven by a cam through by roller chain drive such that one moved forward, while the other moved backward.

They tested the vibratory digger for the effects of amplitude of vibration, frequency of vibration and travel speed on root crop damage, uncovered root crop, and draft requirements. they showed that the greatest amount (24.9%) of root damage was observed at highest frequency (1227 rpm), and slowest travel speed (1.7 km/h). They added that the unrecovered root crop significantly increased (7.2-24.0%) as the travel speed increased from 1.7-3.3 km/h. They indicated that the average draft requirements per unit area of the furrow were 3.3 and 4.2 N/cm2 for 1.7 and 3.3 km/h. operation speed respectively. They concluded that draft/area is about 35-80% of that required for commercial non-vibrated harvesters, they added that the blacks pot increased as frequency increased. The greatest amount of blacks pot (24.9%) was observed at high frequency (1227 rpm) and slowest travel speed [1.7 km/h (1.05 mph)]. Un recovered sugar beet significantly increased (7.2-24.0%), as travel speed increased from 1.7-3.3 km/h. draft force decreased as vibrational frequency increased and travel speed decreased. draft varied from about 7.9-12.2 kN over the range of combinations of frequency and travel speed levels.

Pulling harvesters machine:

Srivastava *et al.* (1995) cleared that the pulling mechanism in Fig. (1B) is the common for harvesting the sugar beet crop. They showed that it has two important implemented functions. Top removal is desired at the lowest point on the plant with respect to the top of the harvested roots. They added that interior surface (2) of the elevating part (1) grasp and continues to elevate the crop until the top portion of the sugar beet crop engages the counter-rotating toppers (3). This counter-rotation of the topper elements further ensures that the top of the plant is pulled up to the desired height.

Lebicki (1987) reported that the pulling techniques are suitable method to be used for harvesting beets for sugar. He mentioned that introducing the puller mechanism that shown in Fig. (1B) started the movement towards that technique. He showed that the number of picking units on the shown mechanism is depending on the distance between the plants and the operated speed of the driven. The pulling units are traveled in a circular path

opposite to the machine travel. As a pulling unit is passed over the plant potion the two grips engages around the beet to pick it. Then they grasp and elevate it by the continual rotating action. With further movement the crop tuber passes the pulling mechanism until the grippers is opened. Hence the beet crop is either thrown on the ground surface or ejected to a transport mean. The gripping spring mechanism must be opened and closed in the proper time.
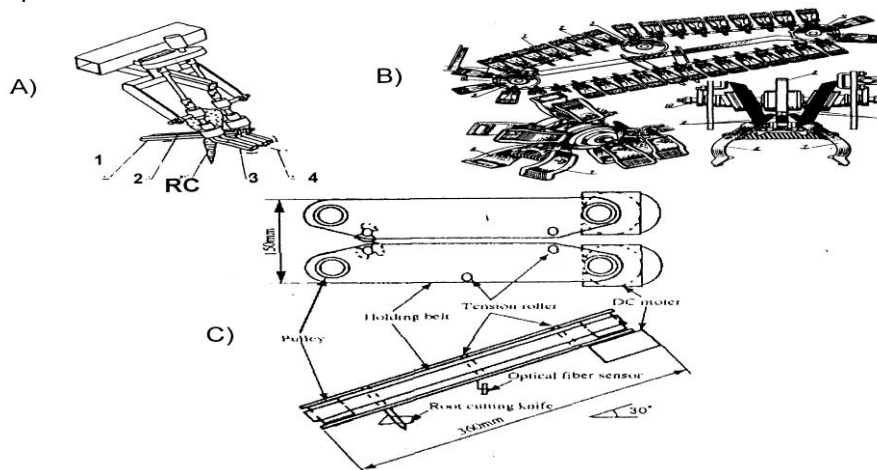

Fig. (1): Three pullers mechanism versions for harvesting root-crops A) for Carrot harvesting B) for beet harvesting C) for the potherbs harvesting (Srivastava *et al.* (1995)

Abou-Elmagd (2002) reported that the efficiency of pulling harvesting machinery during operation is directly related to the time of engaging, and releasing the harvested object. Hence the spring of the gripping mechanism must be calibrated to open and close in the proper time. From that point of view the recognizing process of a mechanical mechanism is not so easy to do. That is may be due to the wide variations of shape, size, and location in field of the sugar beet crop. In addition the need to exchange of the shape of gripping mechanism to suit each product properties is required a numerous of trails and research efforts to be developed. Worthwhile under certain conditions particularly where gripping part (the stem) is not strongly attached to the object, that part can not draw object into the grippers or the rollers causing law pulling efficiency.

Sugar beet topping

Lebicki (1987) reported that most topping mechanisms can be operated as individual topping machine or mounted on its own harvester. Most of such machines in use now are tractor-mounted or semi- mounted and operated by the power take-off (P.T.O.) as shown in Fig (2a). These types are suitable for row widths from 650 mm to 900 mm. They are made to fit cut the contours of the bed row as shown in Fig (2b). The flail toppers Fig. (2C), often has flail vertical type knives, and full width adjustable gage roller located at immediately behind the rotor to provide cutting heights control.

Smith and Wikers (1994) reported that over the recent years a number of toppers and under root cutters have been designed and developed on the same design principles of the rotary beaters, or flail of forage harvesters. They concluded that the machine which is equipped with pair of rotary cutters reduces the overall labor requirements to a great extent. That is because pair of rotary cutters rotates opposite each others. Thus it deposits the vegetative in a narrow rowan the field. Fig (3) shows the available features of topping mechanisms.
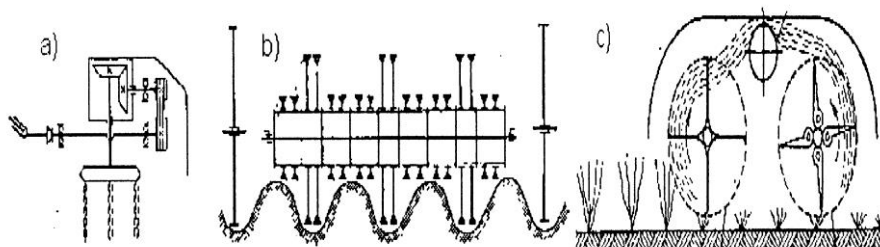

Fig (2): The operating principles of the toppers (Lebicki (1987)

It can be seen that most of them are rotary toppers, which have high-speed disc, and lower drum. They added that, the rotary cutters or pasture clipper equipped with gage wheels does a good job of shaving off the tops of the bed row. But the success in performing topping is depending on the matching between of the vegetative properties, and each of number, diameter, and revolution speed of topping mechanism.
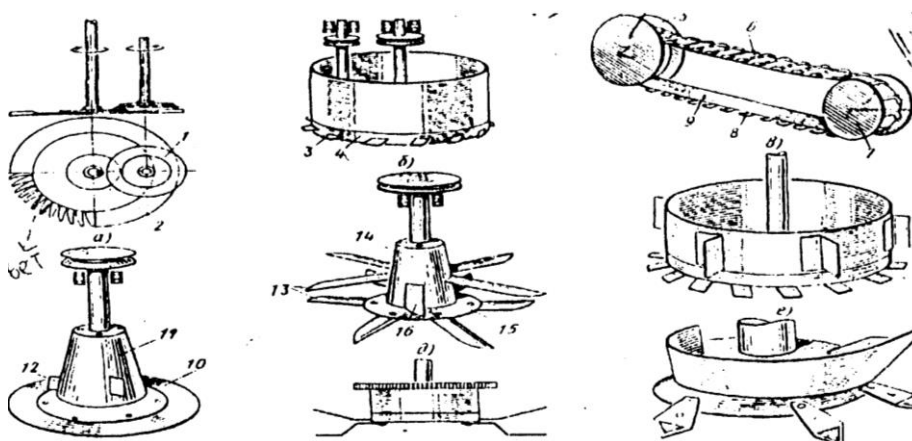

Fig (3): The Essential features of the available topping mechanisms (Smith and Wikers (1994)

Ridge geometric

Determinations of the shape and dimensions of the sugar beet crop ridge at time of harvesting allow for tractors and harvesting machines to securely travel between the rows to harvest without causing damage for the

crop. Abou Elmagd (2001) indicated that to detect of the geometric of the root crop ridge, the measurements should be run in the two perpendicular directions of the ridge. The lateral direction is considered as X-axis, and the ridge height as Y-axis. That measure should be done for hilled and non- hilled zones.

From that point of view the locally made, ridge drawing profile-meter which is shown in Fig (4) can be used as a proper instrumentation for Egyptian conditions.

1-Iron L shape support.
2-Wooden board
3-Graph paper.
4- Double rings sliding
5-Horizontal steel rod.
6- Vertical steel rod
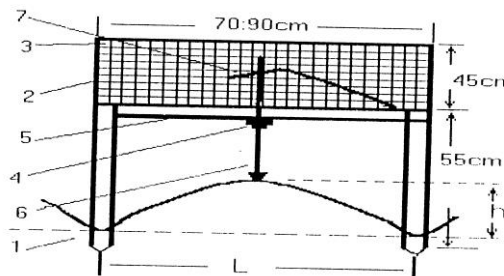7-Drawing pencil

Fig. (4): The locally made ridge drawing profile-meter (Abou-Elmagd 2002)

However, Elbanna (2001) found a general relationship between, cone index, proctor needle and vane shear reading as:
Cone index = 10* vane shear readings and   Proctor needle = 1.5 * cone index

The three readings of these instruments can be calculated using the cone penetrometer equation (Elbanna, 2001 and 2002) as in the form:

$$CI = [3.62 Cr \cdot e^{-0.01\theta(1+Cr)} + 0.0066 \frac{\gamma}{(1+2Cr)}] e^{\pi \tan\phi}$$

where θ= soil moisture content, %;
ϕ= soil internal friction angle; γ=soil specific weight, kN/m^3;
Cr=%clay/(%silt+sand).and tan$^{-1}\phi$= 1/*1+2Cr).

(i) cone penetrometer (ELE20-088 British standard).
(ii) proctor penetrometer (ELE 24-651 British standard)
(c) vane shear strength; (GeoNorA/S Vane tester H-60).

MATERIALS AND METHODS

The main goal of the present research is to develop a rationalized power, and operation cost combined machine suitable for sugar beet planting and harvesting operations, and to be suitable for the Egyptian agricultural conditions. and study the possibility of utilizing it under Egyptian conditions to replace the traditional methods in both planting harvesting operations. The developing machine components can be summarized in two parts:

First component is planting unit: this unit is planted two sugar seeds' rows with suitable depth at top of the middle center of the two furrows, in the same time formed three cultivable rows. The formed three shares are seated after the two planting rows. Each formed row share is a consisted from a double mouldboard bottoms, at end of it whereas, the drop seeds is covered by the sliding soils path.

Second Component is sugar beet pulling unit: this unit is involved three main sugar beet harvester components namely, two appropriate shares for loosing the ridge structure around the roots, pulling out belt mechanism with its proper power transmission system, and a proper disk knife topping mechanism.

Planting and Harvesting/ Date: The planting season begins in September and continues until mid-October. Harvest starts roughly April 15 and ideally ends by the 1st of August. Late-planted fields tend to be more expensive due to additional costs for irrigation, additional pest control, and for losses due to root rots and sugar beet cyst nematode. However, sometimes the greater expenses on late fields are often offset by higher beet yields.

Seeding rate: Sugar beets are grown single line on 75 cm rows. Some early season fields are planted at a 5 to 7.5 cm spacing; later fields are precision planted with seed spaced 10 to 15 cm apart. Seed is now sold in units of 100,000 seed. Seed prices depend upon fungicide and insecticide treatments, seed size, seed quality, variety and quick prime treatment. Precision planting improves the overall stand by reducing the need for thinning and increases overall plant uniformity and population.

Field observations indicate that yield is reduced more by too few plants than too many plants per Fed. Planting depth is normally 0.6 to 1.25 cm. Many kinds of planters are used including vacuum planters. Early plantings during extremely hot weather will require a higher seeding rate to achieve the proper stand. Planting when soil temperatures are high greatly increases the incidence of seed rot, damping-off and insect injury. However, new seed treatments have reduced the problem significantly.

The main technical components (planting and harvesting units), and each unit parts can be described, in general parts e.g. Frame, hitching system and transpiration power unit, and two machine components (e.g. Seeding and harvesting mechanisms), as are explained by:

General Parts

Main Frame: Machine frame was constructed and manufacturing as U shape from steal iron (5*10*0.5 cm) with dimensions 160 cm of length and 162 cm width, other machine parts were fixed and fitted on it and the machine frame was carried on two tyres (Fig. 5). It was provided with some special bearings for the transmission system elements. The hitching system, gearbox, rarefaction mechanism, the pulling mechanism, and two there tracing wheels

Hitching system: The front end of the frame has three points. The hitching system was constructed locally from steel bars of 10 mm thickness and width of 5 cm. The hitching system was built according to the ASAE (1992). The dimension of the system is hitching point diameter of 25 mm, max height of 60 cm, and lower hitch point spread of 65 cm, by means of using three bins to

fix   or carrying the machine by the three beams of the tractor hydraulic system**.**

Power transmission unit: In fact a two power transmission systems were being used:

1- Indirect transmission system was designed to supply the metric seeding system from machine ground wheel throughout a chain and a group of gears, as shown in Fig (5).

2- Direct transmission system consists of a gear box which is transfers the suitable speed of the tractor PTO shaft to pulling machine unit, as shown in Fig. (5).

Tracing wheels. Two wheels with diameter of 50 cm were used for machine to control of the rarefaction depth and it should be remembered that the width of tires on land wheels is usually restricted by the width of inter-rows. Only in one-row and self-propelled harvesters the wheels of which travel over the field from which beets have been lifted, the problem of the width of tires may not be really important, but when the tracing wheels run even between rows of topped beets, widths of their tires cannot exceed the value defined by inequality

$$w \leq S_m - (d_b + 2C_o)$$

where:-

w=Width of the tracing wheels (cm); S_m= width of interrows;

C_o=admissible deflection of roots from the row's axis; d_b = diameter of roots in the thickest place.

Planting units

Seeds tank

This unit is consisted from two seed boxes each 25 kg capacity, constructed from 1.5 mm a sheet of steel (Fig. 6) and fitted by 1.5 cm steel bars on top of the planting unit. At the bottom of each box there is a sliding control gate, to allowable the right seeds output to the metric device.

Metric devices

Two metric devices system were developed to be tested in the present study which can be explained as:

1- The brush-type metering device, Figs. 3.3a and 3.3b.

2- The type of repelled wheel, Figs. 3.4a and 3.4b

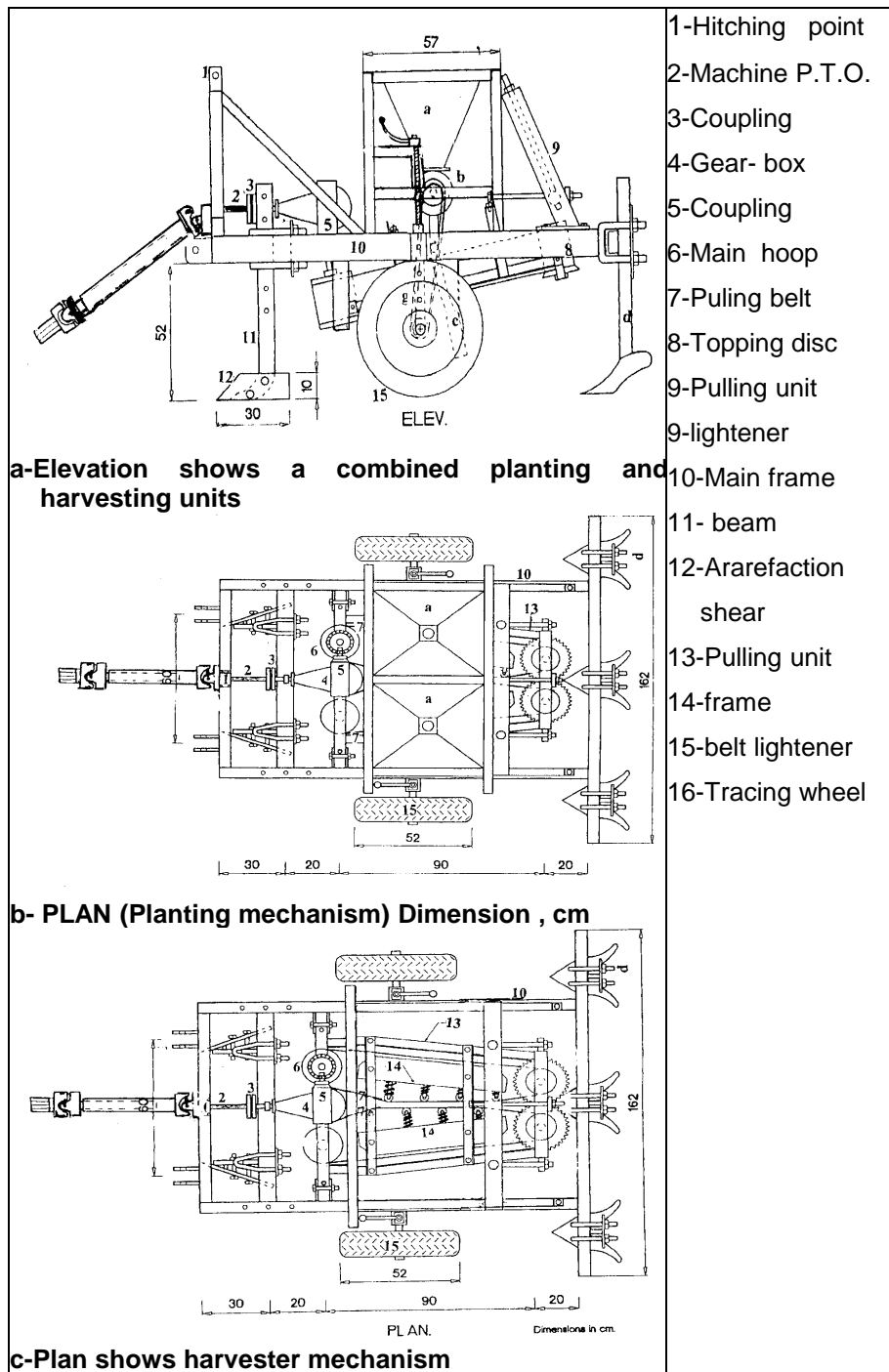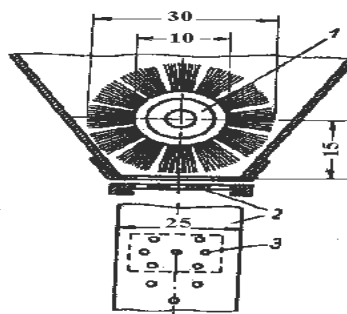**1-The brush-type metering device:** Figs. 7 and 8

1-Hitching point
2-Machine P.T.O.
3-Coupling
4-Gear- box
5-Coupling
6-Main hoop
7-Puling belt
8-Topping disc
9-Pulling unit
9-lightener
10-Main frame
11- beam
12-Ararefaction
   shear
13-Pulling unit
14-frame
15-belt lightener
16-Tracing wheel

a-Elevation shows a combined planting and harvesting units

b- PLAN (Planting mechanism) Dimension , cm

c-Plan shows harvester mechanism

Fig. (5): Sketched of elevation and plan views of the developed planting and harvester sugar beet machine.

Fig. (6):Constructed seeds box

1-brush roller; 2-siding plate for adjusting the rate of seeding; 3-openings releasing seeds

Fig. 7a: A brush-type device for sowing small seeds:

Fig. 3.3a is shown diagrammatically a brush-type sowing device. It embodies a revolving shaft on which are fitted at regular intervals wooden rollers having on their periphery rigid cylindrical brushes. The sheet-iron bottom of the box has rectangular openings, and underneath is a strip with round orifices which can be manually shifted along the box axis and which serves to control the rate of seeding. The strip orifices are so arranged that under the rectangular openings there can be found from one to six of such in sowing grass seeds, a mixture of different types and sorts of such is commonly employed and, it is required that the appropriate quantitative proportion between the individual components be possibly maintained during sowing. Grass seeds differ considerably, however, from one another as regards dimensions, weight and the type of cuticle.

Seeds may have a smooth and polished or a coarse and pily surface. For this reason, in a mixture of different seeds set in a rotary motion by revolving brushes, smooth and small seeds are a bit quickly to get to the bottom, while the larger and pily grains remain on the top. In consequence, a mixture of a considerably changed composition is sown. The use of some other types of elements revolving inside the box (such as, for example a "butterfly" rotor) exhibits a similar disadvantage.

Fig. 7b: A Complete installation of brush metering device

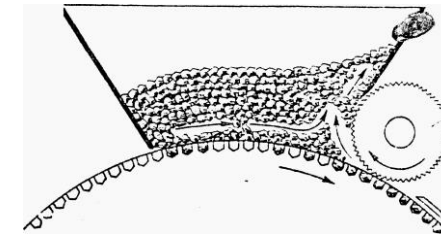2-The type of repelled wheel, Figs. 3.4a and 3.4b

Fig. 8a: A repeller wheel of metering device of sowing small seeds

Instead of the baffle can he used a repelled wheel revolving in the opposite direction to the vertical rotor's revolutions (Fig. 8). Underneath are situated two electors which thrust out seeds from cells. The ejectors tapering ends, enter into the grooves in between the cells. The vertical rotor with cells is similarly as in the previously described types, driven by the pressing wheel through a V-belt transmission and a toothed gear. At the back of the opener is, as usual, placed a pressing wheel together with a furrow coverer. The axle of this wheel is connected with that of the supporting wheel by means of two flat bars forming together a frame. Inside this frame is placed the sowing unit, the manner in which this unit is connected with the frame enabling the alteration of the level of setting of the opener and, thus, of the depth of sowing (20-55 mm).
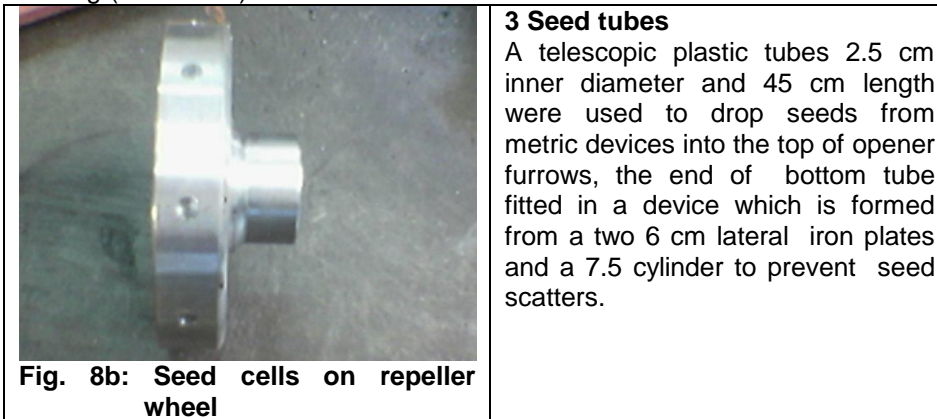
	3 Seed tubes
Fig. 8b: Seed cells on repeller wheel	A telescopic plastic tubes 2.5 cm inner diameter and 45 cm length were used to drop seeds from metric devices into the top of opener furrows, the end of bottom tube fitted in a device which is formed from a two 6 cm lateral iron plates and a 7.5 cylinder to prevent seed scatters.

Forming furrows shares

A three forming shares were constructed from a double a small mouldborad bodies. Each wide share has 3 cm at its top end and 15 cm wide ends has formed from two mouldboard. The formed share dimension is suited to make 3 furrows with 60 cm spacing in between. Whereas, each share ridged the furrows bottom and both its moulboard moves the soil 20 cm in each side of that furrows to form a wide furrows. At the end of each mouldboard path whereas seeds dropped in the top center of that furrows, where a little of the moving soil is covered the sugar beet seeds

Harvesting Unit

The developed harvester unit was constructed according to the theoretical relationship and its implement includes four main units namely: pulling unit, rarefaction unit, topping unit, and transmission systems. It also includes three secondary units such as the main frame, the hitching system, and the tracing wheel system, which were explained before first part, since these devices are used to serve the whole machine components (Fig. 5).

Pulling unit.

The puling unit was built and constructed locally according to the theoretical relationship and fitted to the developed harvester. It made from steel sheet and fixed on the machine frame. The pulling unit consists of three main parts fixed by especial frame used to contain these units and it as follows :

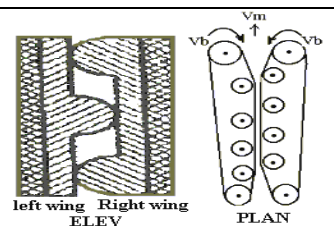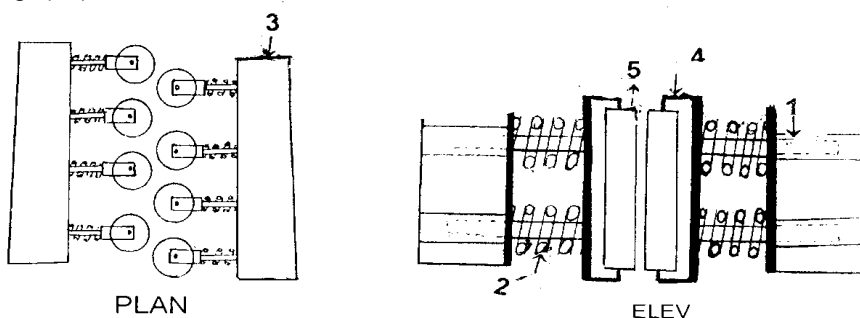| Fig. 9: Illustrates schematic of the main parts and operations consecution of developed pulling mechanism. It shows that the pulling belts are sat at a certain small angle (α) with respect to the horizontal, and at a certain aperture angle (2β°) in relation to the direction of machine travel.	
	Fig. (9): Pulling belt.

a-Pulling belt: Uprooting sugar beet in the present research is performed by picking up plant leaves in small gap between two parallel arranged gripping belts. The using pulling belt consists of two wings (Fig. (9) Each wing is of 250 cm length, and of 15 cm width. The belt constructed as (V) shape and covered with especial material to increase coefficient of friction between leaves and belt.

b- Hoops group: The hoops group was used to revolving the pulling belt, and it consists of four hoops, two with diameter of 17.5 cm and height of 20 cm fixed on shaft of 2.5 cm diameter and 40 cm length. The right shaft connected with gear-box by coupling. The other two hoops with diameter of 12.5 cm and height of 20 cm fixed on the back. The distance between the axis of the front and back hoops is 90 cm. When the universal joint is engaged between tractor P.T.O. shaft and gearbox shaft the motion transmit from gearbox to the right front hoop and consequently to the wing of right belt and by using gear fixed on the top shaft of the back hoop the motion can transmit to the lift belt wing.

c- Pulling tightened deliver: The tightened unit was used to control of pulling belt tightness. It consists from 8 hoops with lengths of 15 cm and diameter of 5 cm contact with the belt and two cases steel U shape 10 x 10 x 0.4 cm and with length of 80 cm contend springs and its shaft as shown in Fig. (10).

1-Shaft spring; 2-Spring;   3-Case steel;   4-Hoop bearer;   5-Hoop

Fig. 10: Pulling tightened.

Due to the combination of belt peripheral (V_b) motion and the forward speed (V_m) of the harvester, the punches of plant leaves are directed to the zone where the two belts are closely pressed together on them by means of two clamp spring sets, each consists of eight springs.

The previous parts are assembled on both puller belt mechanism sides and behind the belts along a distance of 80, cm each spring was 10 cm

length and 3 cm diameter and having stiffness coefficient of about 0.4 N/cm. These clamp spring sets are used to keep the two belts at the desired tension and gap clearances required for pulling up the plant. The desired tension and gap clearances between the two belts were adjusted by means of tighten box and guide, as illustrated in Figs (11 to 13).

Rarefaction unit, (Fig. 11)

The rarefaction unit were manufactured for loosen the bonds between soil and beet root surface (at front of the frame) by pulverizing both ridge sides. These units consists of two shears as shown in Fig. 8 of 10 cm height with base of 33 cm and top of 23 cm and it fixed in the two beam which move on a pare of 5x5 cm to control of the rarefaction distance (d_r) between the two shears. While, the control of the rarefaction depth was done by using two tracing wheels (with diameter of 30 cm) fixed with two guides,.
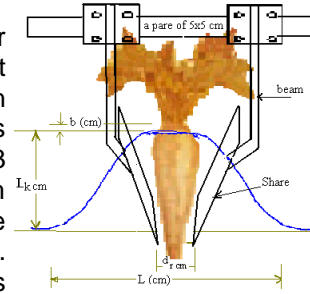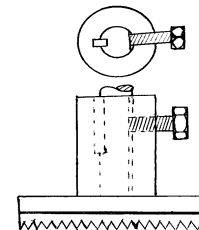

Fig. (11): A rarefaction shear

by these guides, it can be controlled the rarefaction depth by increasing or decreasing the guide height. The lower ends of two shares are shaped in a certain wedge form and assembled on the machine frame to help in guiding the up ground plant portion to enter the gripping zone

Topping unit.

Topping of sugar beets in the present research was selected to be performed to the picked up whole plant (after pulling). The topper mechanism is mainly consists of two topping disks each of the same diameter (D'). These disks are mounted below the rear idler belt pulleys as shown in Fig. (12). These disks are rotated opposite to each other, in a plane that is perpendicular to the plane of the belt motion.

The used topping unit.

To ensure proper topping (cut of the upper plant portion), it was regarded that the two disks is transmitted its motion from the same power source of the belts by means of pulleys and belts. Whereas, the linear speed of these disks was regarded to be 1.25 times the belt speed.

This pair of discs were used to topping sugar beet plant one pair is smooth disc, whilst the other is toothed disc. These units made from iron steel with thickness of 5 mm and serrated diameter of 230 mm the clearance (H) between the two discs ranged from 1 to 2 cm. The rotational speed of these units is changed with the change of belt speed. The disc speed was 1.25, 1.6 and 1.9 m/s.
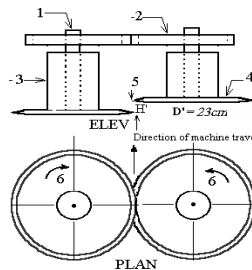

1- Shaft; 2- Gear; 3- Hoop;
4- disc; 5- disc clearance;
6- disc move direction
Fig. 12: Topping unit

Power transmission system

The developed harvester is a semi-mounted machine. Its transmission system was designed to give the same ratios from tractor to the pulling belt. The designed transmission system is shown in Fig. (13). It consists of gear-box, main hoops, rear hoop, two gears, and puling belts
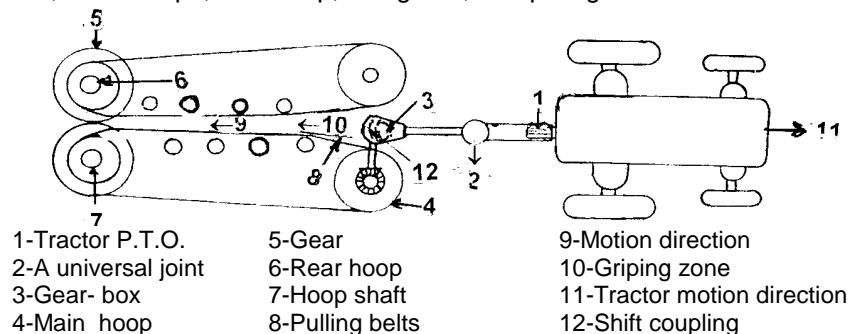

1-Tractor P.T.O.	5-Gear	9-Motion direction
2-A universal joint	6-Rear hoop	10-Griping zone
3-Gear- box	7-Hoop shaft	11-Tractor motion direction
4-Main hoop	8-Pulling belts	12-Shift coupling

Fig. 13: Transmission system of the developed harvester.

The transmission mechanism has four main shafts for hoops. The shaft fixed on the right front hoop takes its motion from gear box by coupling. The motion was transmitted from the right belt wing to the left belt wing by using two gears fixed over the rear hoops**.**
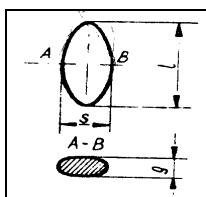

a-View of application points and 3 forming furrows' spacing | b-View of ply rolling and Pulling belt (harvester unit)

Fig. 14: Photo of (planting and harvesting) sugar beet machine

RESULTS AND DISCUSSION

Sugar Beet Seeds Technical Properties

The specific sugar beet seeds dimension is very importance for designing and manufacturer seed metric devices. Tables 21 and 3.2 explain the overall average seeds' dimension of three seed verities, which are grown in Egypt for the present two years. The mean overall average mean of five randomize replication samples each 20 seeds.

Table (2): Mean dimension of sugar beet 100 seeds of three crop verities				
Mean 1000 grain, gm	Thickness, mm	Width, mm	Length, mm	Variety
22.65	6.00	6.45	7.11	Voro
22.50	5.95	6.80	7.65	Ospar Poly
22.05	5.90	6.84	6.43	Raspoly

Table 3 shows the planting seed rate of these verities, metric spacing in furrow, furrow width, and soil cover layer for each variety. It can be seen the physical properties such as angle of repose, bulk density and number grains in1 cm3.

Table (3): Physical properties of sugar beet seeds, rate of planting and planting spaces

Sowing space in furrow (cover layer), cm	Planting rate,kg/Fed.	Number of seeds in 1 cm^3	Angle of repose, deg	Bulk density, gm/cm^3	Crop variety
40-45 (1.5-4)	4	6-8	45	0.70	Voro
40-45 (1.5-3.5)	4	6-9	45	0.66	Ospar Poly
40-45 (1.5-3.0)	4	6-10	45	0.63	Raspoly

In three experimental laboratory and field trails at 75-Village, Kafr El-Sheikh Governorate, 2008/2009 season, planting one Fed. with the above three varieties (Voro, Ospar poly and Raspoly. In Laboratory from all adjustments and testes seeding metric (gears and chain) the distance was 8 cm between seeds on the row with 91, 88 and 93 uniformity, whilst the percent planting seeds scatter were 2-5 cm from the meddle of the row 25, 28 and 24% of the above three varieties. In longitude distance of 5 meters, in laboratory, peripheral wheel cells and brush disk metric planting devices were tested. The peripheral wheel cells and brush disk gave an average of five replications of 18 and 49 seeds/ 5m that is means and average spaces of 28.8cm and 10.20 cm using peripheral wheel cells and brush disk, respectively. Because of the peripheral cells was rejected to be used in field trails, hence, seeds are being compacted inside the cells and closed its opened. The brush metric device was tested in three field trails and give high uniformity in plating and recommended seed rate required.

The fabricated formed share dimension is suited to make 3 furrows with 60 cm spacing in between. Whereas, each share ridged the furrows bottom and both its moulboard moves the soil 20 cm in each side of that furrows to form a wide furrow. At the end of each mouldboard path whereas seeds dropped in the top center of both furrow sides before the back two furrow completed formed furrows shape whereas a little of the moving soil is covered the sugar beet seeds.

Using the brush metric device, two rows of seeding can be achieved with suitable depth at top of the middle center of the two furrows, in the same time formed three cultivable rows. The formed three shares are seated after the two planting rows. Each formed row share is a consisted from a double mouldboard bottoms, at end of it whereas, the drop seeds is covered by the sliding soils path. Lots of farmers preferred the planting unit since formed good furrows and gave high uniformity of planting sugar beet crop. With 3

km/h forward speed; this machine productivity was 0.8-0.85 Fed./hr. with cost of 70 LE/Fed

Physical properties of sugar beet roots.
Determining the dimensions of sugar beet plants:-

The dimension of root length, (L), leaves width, (W) and root maximum and medium diameter (d_M), (d_m), height of leaves (H) were measured and recorded for random samples of sugar beet plant before harvesting operating as shown in Fig (15). The length and height of leaves were measured by a steel tap with accuracy of 0.5 cm. while the diameter of root and diameter of leaf cluster were measured by digital venire caliper with accuracy of 0.01 mm. volume of sugar beet root was calculated from the difference between the two measured volumes of water.
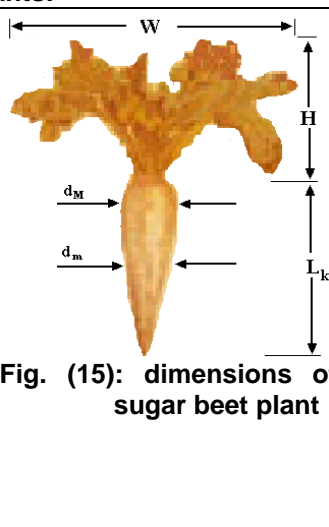
Technical length of root measured from the place where its diameter >10 mm, height and number of leaves, height of the cervixes, the force needing for cut the cervixes

Fig. (15): dimensions of sugar beet plant

Determine the actual volume of sugar beet roots

The actual volume of sugar beet crop was measure by using 20-liter capacity rectangular glass, the rectangular glass was file with water to a defined level, and then the sugar beet root was completely immersed in it. The actual volume of sugar beet root was calculated from the difference between the two calculated volume of water.

Determine the surface area of sugar beet roots

The reference method described by (Merriam, 1976) was used to determine the total lateral area of sugar beet crop. After determine the dimension of root lateral length (L), diameter (D), and height (H) the next equation was used to determine the lateral area of sugar beet crop.

Lateral area (cm^2) = π. D. L   whereas $L = \sqrt{D^2 + H^2}$

D = radius (cm) ؛ L = lateral length (cm) ؛ H = root height, cm.

A 10 randomized samples (each average of 5 replications) of two sites were carried out for measuring of mean dimensions' of sugar beet plants. The pre-tests results showed the mean dimensions' of sugar beet plants as represented in Table (4)

Table 3: The mean dimension of sugar beet plants, cm		
Dimension	**Average value, cm**	**S.d, cm**
L_k	28	±3
L_1	44.80	±4.4
dm	11.86	±0.84
H	3.93	±0.70
h_a	2.41	±0.33
D_1	2.43	±0.33

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From surveying 100 randomized sugar beet roots it can be concluded that the individual root mass is ranged from 1000 to 2500 g; root cone angle (γ) is ranged from 20 to 28°.; the height of the above ground plant portions (leaves portion) of sugar beet was ranged between 40 -49 cm.;

Figs 3.4 to 3.9 clarified normal distribution of sugar beet mass, diameter, length, leaves height and and root volume. e.g Fig. 3.4 clarifying the normal distribution and the prevalen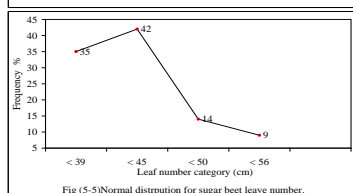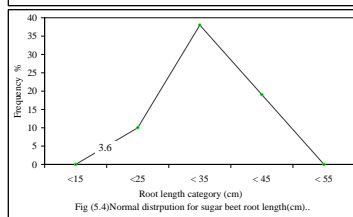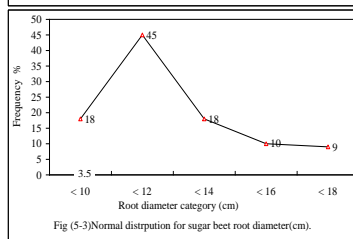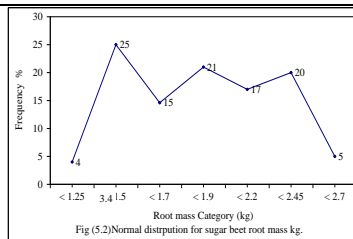t category for sugar beet root mass. From this figure the prevalent category was (1.3-1.5) kg its value was 25 % fold by category (1.75-1.9 kg) its value was 21 %. While Fig. 3.5 clarifying the normal distribution and the prevalent category for sugar beet root diameters from figure the prevalent category was (10-12) cm its value was 45 %. However, Fig. 3.6 Clarify the normal distribution and the prevalent category for sugar beet root length (cm). From figure the prevalent category was (25-35) cm its value was 38 % followed by category (35-45cm) its value was 19 %. But Fig. 3.7 clarify the normal distribution and the prevalent category for sugar beet leave number from fig the prevalent category was (40-45) its value was 42 % followed by category (30-39) its value was 35 %.

On the other side Fig 3.8 clarify the normal distribution and the prevalent category for sugar beet leave height (cm). From figure the prevalent category was (46-50cm) its value was 37 % followed by category (51-59) its value was 19 %. While Fig. 3.9 clarifying the normal distribution and the prevalent category for sugar beet root volume from figure the prevalent category was (100-120) cm^3 its value was 44 %.

Soil properties and ridge profile.

Soil strength (cone penetrometer), soil specific weight and moisture content were measured before the day of planting and

Fig (5.2)Normal distrpution for sugar beet root mass kg.

Fig (5-3)Normal distrpution for sugar beet root diameter(cm).

Fig (5.4)Normal distrpution for sugar beet root length(cm)..

Fig (5-5)Normal distrpution for sugar beet leave number.

Fig (5-..)Normal distrpution for sugar beet root volume (cm)

Fig (5-6)Normal distrpution for sugar beet leaf hight (cm).

harvesting. All field experimental tests were carried out at 75-village Kafr El-Sheikh Governorate. whereas, soil textures was clay loam soil. Most of that areas were grown sugar beet crop yearly, the soil mechanical analysis and its

properties are given by Elbanna *et al.* (2010). Table 5 showed soil properties, soil strength forces at the the day before planting and harvesting

Table 5a: 75-Village, El-Hamool soil mechanical analysis

Site	Sand, %			Silt, %	Clay,%	C_r,	φ, deg
	Coarse	Fine	total				
75-Village	4.95	10.48	15.43	30.77	53.80	1.165	16.70

Table 5b: Average values of soil strength (measured with cone penetrometer) soil moisture content and specific weight at the previous day of planting and harvesting (Cr=1.165 clay loam).

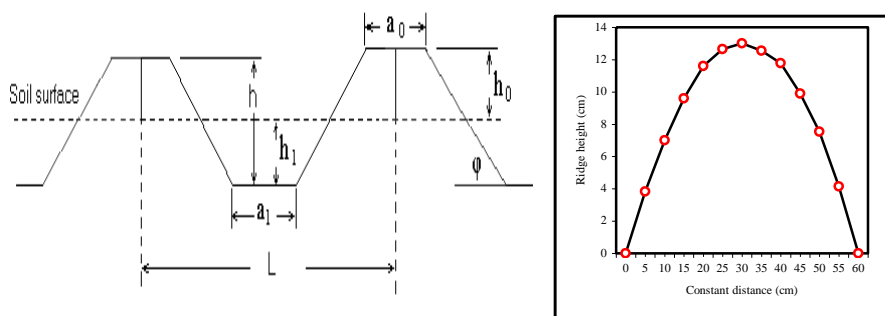| Profile depth, cm	Soil specific weight, kN/m³	Soil moisture content, % Planting day Harvesting day		Cone index, MPa, Before: Planting day Harvesting day	
5	14.04	26.02	23.02	1.449	1.955
10	13.99	27.04	22.04	1.487	2.135
15	13.64	27.60	23.60	1.509	2607
20	13.44	28.50	24.50	1.559	2.405
25	14.07	28.54	25.54	1.561	2.514
30	13.84	29.23	25.9	1.513	2.133

Fig. (16a): the general geometry of sugar beet ridge. **Fig. (16b): sugar beet ridge profile**

Figs 16a and 3.10b clarify the general geometry of sugar beet ridge and ridge width of 60 cm while ridge height before harvesting,
was approximately 13.7cm. by using local manufacturing ridge profile (after El-Sheikha, (2000), (Fig. 4-11) to determine ridge rows of planting sugar beet roots

Tables 6 to 10 reveal the physical and mechanical properties of sugar beet root leaves before harvesting at clay loam soil. Pulling force required with and without rarefaction as an average all of 100 randomized samples with other. Finally, Factor affected ridge refraction performance and topping and uptopping sugar beet roots and leaves.

Table 6: Physical and mechanical properties of sugar beet root before harvesting at clay loam and clay soils

100 Samples	Pull force , N without A*	Pull force, N with A*	Decr., %	Mass, kg	Length, cm	Diam.**, cm	Surface Area, cm²	Adhesion, N/cm²	Root Volume, cm³	Real Denisty, g/cm³
Clay soil										
Ave.	701.42	510.6	27.2	1.55	29.5	12.8	592.8	1.18	1104	1.404
s.d.	79.55	61.10	2.32	0.39	3.0	0.84	68.2	0.18	192	0.35
Clay loam soil										
Ave.	437.3	329.2	24.8	1.76	24.7	11.7	451.80	0.98	885	1.99
Sd.	45.8	40.5	3.9	0.4	2.8	0.9	43.0	0.2	139	0.4

A* = A rarefaction   **= Maximum diameter

Table 7: Physical and mechanical properties of sugar beet leaves Before harvesting at loaming clay soil.

100 Samples	Leaves cutting force, N	cutting height, cm	Leaves height, cm	Leaves number	Knife height,cm	Leaves Weight, N
Clay loam soil						
aver	2155	12.0	47.0	29.5	21.7	13.0
Sd.	90.1	1.3	4.8	4.3	2.6	2.5
Silty clay loam						
Aver.	2192	11.5	45.5	28.5	29.6	12.9
Sd.	67.4	1.3	4.8	4.3	3.1	2.5

Table 8: The mechanical performances as affected by traveling speed (Vm), and space between the bottom edges of rarefaction shares (dr) at Clay loam soil.

Studied variables	Measurements					Evaluating Parameters			
V_m, m (dr,cm)	draft force (kN)	draft force +RR	Slip %	Fuel (L/h)	Slip effort (kN)	Total effort (kN)	Traction power (kw)	specific fuel (L/kW)	stability factor (K)
1 (15)	7.43	7.56	18.51	2.86	1.42	8.97	9.47	0.30	2.58
1 (20)	7.26	7.39	17.28	2.73	1.29	8.68	9.17	0.30	2.89
1 (25)	6.57	6.70	16.50	2.52	1.13	7.83	8.34	0.30	3.29
1 (30)	6.33	6.46	15.06	2.38	0.99	7.45	7.90	0.30	3.36
Total	6.90	7.02	16.84	2.62	1.21	8.23	8.72	0.30	3.03

Table 9: The ridge refraction performances as affected by travel speed (Vm), and space between the bottom edges of rarefaction shares (dr).
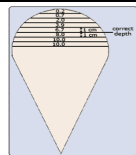
Studied variables	Evaluating Parameters ofClay soil			
V_m, m (dr, cm)	Root damge, %	Manual pulling force		
		pulling force, kN	Root mass, kg	P/M, kN/kg
1 (15)	16.95	0.4790	2.35	0.205
1 (20)	13.71	0.5347	2,50	0.209
1 (25)	8.43	0.5580	2.50	0.220
1 (30)	6.9	0.61	2.65	0.235

Table 10: The beet uprooting process as affected by speed ratio SR (between belt speed to tractor speed), and belt inclination angle (α). Clay loam soil

Studied variables		Evaluating parameters			
α, degree	S R	Lifting, %	Capacity, (t/h)	Fuel ,(L/h)	Power (kw)
20	1	73.84	14.09	1.90	4.67
	1.25	77.30	15.72	1.65	4.50
	1.5	78.59	19.01	1.40	4.10
	1.75	80.21	19.24	1.23	3.75
Average		77.48	17.01	1.55	4.25
25	1	77.57	14.72	1.75	3.77
	1.25	79.40	16.42	1.50	3.64
	1.5	80.74	19.86	1.30	3.31
	1.75	83.33	20.10	1.25	3.03
Average		80.26	17.78	1.45	3.44
30	1	77.32	15.83	1.50	3.20
	1.25	79.16	17.66	1.35	3.10
	1.5	83.5	21.4	1.3	2.8
	1.75	82.10	21.61	1.00	2.57
Average		80.52	19.11	1.28	2.92

2. Topping: A level field is the most importance in the topping process. A well topped beet will have the lower leaf scars visibly remaining. Topping is done with ridge or wheel. Great losses occur when topping is too deep. When topping is too shallow problems may occur in sugar extraction at the refinery.
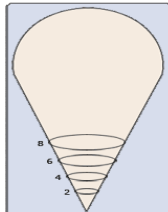
Losses from topping too deeply			
Too deep by:	**Loss**	**Yield at 60 t/ha**	
1 cm	8%	4.800 kg/Ha	
2 cm	18%	10.800 kg/Ha	
3 cm	28%	16.800 kg/Ha	

3. Lifting: Three types of lifting equipment are used:
a) disc lifters for light soil b) share lifters, which may be powered, for heavier soils   powered wheel lifters for both types of soils

Losses due to root point breaking		
Aver. Loss from Breaking	**Beet Loss**	
< 2 cm	0%	
2-4 cm	3%	
4-6 cm	10%	
6-8 cm	21%	
> 8 cm	35%	

The ease with which beets can be lifted depends on the shape of the beet, the type of soil and the harvesting conditions. The shape of the beet is dependent on the variety and can be further optimized by ensuring a uniform drilling of the crop. An optimal value ratio must be always being found between minimizing soil tare and root point breaking. On light, dry soils lifting

can take place up to a depth of approximately 6 cm. On heavier soils and under difficult conditions, lifting must take place from 3-4 cm.

Conclusion

An Economical sugar beet planting and harvesting machine was developed to a rationalized power, and operation cost combined and to be suitable for the Egyptian farm to replace the traditional methods in both planting harvesting operations. The developed machine has two components: **first component is planting** unit: which involves two seeder rows with suitable depth at top of the middle center of the two rows. Three formed furrows were developed, each is consists from two mouldboard bottoms. One furrow was fitted on the front frame as primary share moving soil in both sides and the other two shares seated after the two planting rows at back of the machine frame to completed the two formed rows and covering the dropping seeds.

Second Component is sugar beet pulling unit: this unit is involved three main sugar beet harvester components namely, two appropriate shares for loosing the ridge structure around the roots, pulling out belt mechanism and a proper disk knife as a topping mechanism. The machine performed 60-70 cm riders during planting two rows. Also harvester one sugar beet row through pulling out and topping mechanisms. Also two proper shares form for loosing the ridge structure around the roots. These components were equipped on a proper mounted one–row harvester frame. Field experiments were carried out to test and evaluate the performance efficiency of the developed planting and harvesting machine under different operating parameters and conditions.

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Annon (2004) وزارة الزراعة المصرية ، الجهاز المركزى للتعبئة والاحصاء نشرة انتاج محصول البنجر مرجع رقم 879.

تطوير آلة لزراعة وحصاد محصول بنجر السكر
الشحات بركات البنا ، زكريا إبراهيم إسماعيل وعلى السيد أبو المجد
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- تم تطوير آلة لزراعة خطين ببذور محصول بنجر السكر، وفى نفس الوقت لحصاد خط واحد من محصور بنجر السكر فى الجرة الواحدة.
- **بالنسبة لوحدة الزراعة** ينصح بإستخدام أقراص البذر ذات الفرشاه حيث من الإختبـارات أعطت نتائج عالية بكفاءة زراعة 95% وتشتت 5% عن منتصف الخط، بالمقارنة بالعجلـة ذات الخلايـا المحيطية التى أعطت نتائج منخفضة فى انتظام الزراعة 25% وتشتت أكثر من 7-8%.
- وحدة تشكيل الخطوط قبل نزول البذور من أنابيب البذر أعطت تشكيل خطوط أكثر انتظامـا بالمقارنة بأى آلة زراعة أخرى، حيث يعمل الفجاج المثبت فى منتصف مقدمة الإطار على إزاحـة الأتربة للخارج حيث تسقط البذور من أنبوتى البذور على الأتربة المزاحة، حيث يعمل الفجاجان المثبتان على الإطار من الخلف على تكملة تشكيل الخطوط بإزاحة الأتربة جزئيا لتغطية البذور بـالخطين التـى تـم زراعتهمـا وإزاحـة النصـف الأخـر للخـارج للبـدء فـى تشـكيل خطـان جديدان...وهكذا. والفجاجات الثلاثة كل منها عبارة عن فجاج مشكل من مطرحيتان لمحراث مطرحى مقدمة كل منها 3 سم وعرضه بالمؤخرة 20 سم.
وحدة الحصاد: عبارة سلاحان لمحراث حفار يستخدمان لخلخلة خط محصول البنجر لتسهيل عملية الملخ (الشد)، سيران عرض 12 سم مقويان بمادة معامل إحتكاك عالى، ينضغطان على بعضهما بمجموعة من السوست والبكرات، يقوم السيران بالقبض (الضغط على المجموع الخضرى للنبات) الذى تم خلخلة جذوره، ونتيجة تقدم الآلة يقتلع نبات البنجر وفى نهاية السير يقوم زوج من السكاكين القرصـة ذات الدوران العكسـى بفصل المجموع الخضرى عن جذور البنجر وبعدها تسقط جذور وأوراق محصول بنجر السكر على سطح الأرض خلف الآلة.
استخدام الآلة: الآلة يمكن إستخدامها لزراعة محصول بنجر السكر بمعدل 1 فدان/سـاعة، بسـرعة 2-3 كم/س، بتكلفة 60 جنية لزراعة الفدان، وحصـاد محصـول بنجر السكر بواقع خط فى الجرة الواحدة، حيث يتم حصاد الفدان فى 3 ساعات بتكلفة 180 جنبة/للفدان وينصح تعمق أسلحة الخلخة لعمق 30 لتفادى خدش الجذور، وضبط مستوى سير الشد وسكاكين التطويش بعجلتى الآلة (ضبط العمق).

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