PERFORMANCE EVALUATION OF SUGAR BEET TWO SPLIT HARVESTERS UNDER EGYPTIAN CONDITIONS

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ABSTRACT

The main objectives of this study were to evaluate the performance of using two split of harvester for topping and lifting the sugar beet crop at the same time that means a complete harvesting process for sugar beet crop. Measuring indicators were tested for the two split harvester (Grimme BM300 and Rootster 604) at the tested forward speed (m/s), type of cleaning system (axial or turbine) and type of opal wheel driven (ground and hydraulically). It was found that using the tested harvester with turbine cleaning system and with hydraulically driven under forward speed of 5.8 km/h gave the best results in all treatments. Forward speed of 3.5 km/h gave desirable results with some measurements. Therefore it is advisable to use the harvester with hydraulically driven and turbine cleaning system with forward speed of 5.8 km/h that showed the best results while harvesting the sugar beet crop.

INTRODUCTION

Efforts have been exerted for increasing sugar production to overcome the gap between the people consumption and production. It has been recommended to increase beet production area because of the limitation of water sources required for increasing sugar cane production area. Although, sugar beet harvesting is one of the most labor consuming operations; yet harvesting machines are still not widely used in developing countries including Egypt. Mechanical sugar beet harvesters are not common in Egypt, and manual methods are exhaustive, and impractical. Sugar beet harvesting is carried out in Egypt manually by hand digging, pulling the roots out by shovel and hoe or by

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using a chisel plow and collecting the roots manually. In the recent time various types of machines are available for harvesting sugar beet crop. They are operated on entirely different principles to each other's. 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. This will normally be when the center point of any lifting unit is positioned in the ridge center. **Aly (1998)** explained that the maximum force needed to cut the beet in the upper part was 540 N, in the middle part of 430 N and the root part was 188 N and the cutting resistance was an inversely proportional of cutting velocity. **Kromer et, al. (1998)** found that the harvesters today have field capacities from 40 to 130 t/h , tank capacities from 5.5 (2-row) to 26 t (6-row) and average harvesting qualities of 5.8 % dirt tare, 1.9 % total mass loss and 75.1 % acceptable topping. **Ivancan et, al. (2002)** reported that losses due to the top root breakage amounted to 8.4% of yield at a speed of 1.2 km/h, and to 18.3% at a speed of 6.5% km/h. Surface and underground losses ranged from 2.3 to 4.1 % of yield. Underground losses were a consequence of the performance of the lifting mechanisms and, depending on the working speed, ranged from 1.4 to 2.6% of yield. The lowest underground losses were recorded at speed of 1.2 km/h, and the highest at the speed of 6.5 km/h.

Sharobeem et, al. (2003) developed and manufactured suitable equipment for lifting sugar beet roots. 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.Also, they added that 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. **Abd- Rabou (2004)** concluded that decreasing forward speed tended to

decrease total damaged roots. It is clear that, increasing forward speed from 0.55 to 1.06 m/s tends to increase the total damaged root from 4.51 to 5.4%. The highest value of the total damaged roots of 6.2% was obtained at forward speed of 1.6 m/s, the lowest value of the total damaged 3.4% was obtained at forward speed of 0.55m/s. **Awad (2006)** mentioned that using developed harvester decreased unit cost by decrement from 66.15 to 68.66% comparing by the digger techniques. **Khallil (2007)** mentioned that decreasing forward speed and increasing share depth tends to decrease total damage root at all types of lifting blades for mechanical and traditional planting methods. The minimum value of harvesting losses reach to 2% at lifting depth of 25 cm, forward speed of 1.2 km/h for mechanical planting by using fork lifter. He mentioned that the maximum harvesting eff. was reached to 95.1 % at 1.2 km/h by using the fabricated machine with fork lifter at mechanical planting methods.

Therefore, the main objective of the present investigation is to choose a suitable mechanism for topping and lifting sugar beet roots. To study the possibility of utilizing it under the Egyptian new reclaimed land and to suit large holding farms of investment companies using available power tiller on farms. Field experiments were carried out to evaluate the performance of two split harvesters at different forward speeds, two type of cleaning system and two type of opal wheel driver. Topping efficiency, the tare ratio, cleaning ratio, fuel consumption and the cost of harvesting operation were therefore studied.

MATERIALS AND METHODS

Al-Nouran advanced company decided planting of 6000 feddan sugar beet in land new reclaimed under pivot irrigation system to choose the suitable harvesting method from the harvesting system in the world. The main objective of this study is to evaluate the performance of using two split the first one defoliator (BM300) and the second one harvester (Rootster 604) for topping and lifting the sugar beet crop and to choose the suitable options for Egyptian sugar beet harvesting conditions. A field experiments were carried out in new reclaimed land under pivot

irrigation system in Al- Nouran advanced company in Salihia Sector, Al-Sharkia Governorate to harvest sugar beet in a large holding area (pivots) and evaluate machine performance during the harvesting operation for the first time in Egypt. The experimental crop of the present study was sugar beet monogermel (cesira) . The chosen variety was planted in an area of about 600 feddans. Measuring indicators were tested for the two split harvester (BM 300 and Rootster 604) at the tested forward speed (m/s), type of cleaning system (axial or turbine) and type of opal wheel (ground driven and hydraulically driven) for sugar beet.

Machine used:
Technical data of the used defoliators (BM300) (first split)

	BM300
Length **Width** **Height**	5,600 mm (6,700mm*) 3,600 mm 1,300 mm
Weight	2,300 kg (2,700 kg*)
Row width	Adjustable between 45 and 56 cm
Flail shaft	Continuous flail shaft with spirally arranged steel flails
1st cleaning shaft	Rubber flails above beet row, row width mechanically and steplessly adjustable;
2nd cleaning shaft	Rubber flails above beet row, row width mechanically and steplessly adjustable,
Depth setting	Lifting cylinder with spindle adjustable end stop in front, tool-free adjustment of rear control wheels
Tires	4 x 7.5–20 TR 15 AS
Operating/Setting	1 double acting independent controller (+1 single acting controller with pressure-free return*)
Drive	Mechanically: PTO-shaft 1,000 rpm with freewheeling
Required power	At least: 60 kW/82 HP, Recommended: 90 KW/120 HP

Technical data of the used Grimme rootster 604) (second split)

	Rootster 604 (6-row)	
	Length 8,300mm Width 3,500 mm Height 4,000 mm	
Channel width	3,150 mm	
Row width	45–56 cm (18–22 inches) manual, steplessly adjustable	
Digging unit	Ground-driven Oppel shares Hydraulic wheel share drive with self-hydraulics (option)	
Depth setting	Lifting cylinder with spindle-adjustable end stop 2 additional support wheels for the depth guidance of the digging unit (option)	
1st cleaning unit	Cross roller table: 1 plain roller, 4 spiral rollers, 1 pair of centering rollers	
2nd cleaning unit	Short main web and axial roller table with 6 spiral rollers and 2 plain rollers can be added as extraction unit, or as an option: 3 mechanically driven turbine systems: 1st turbine 1,700 mm; 2nd and 3rd turbine 1,350 mm	
Bunker	Filling by means of ring elevator and fill auger Contents: 6 m³ (approx. 4.0 t) Transfer height: max. 380 cm Unloading web can be swiveled hydraulically from the transport to the transfer position Unloading web width: 100 cm	
Transfer	2 speed settings can be selected via the operating terminal Remote control LRC (Load Remote Control) to operate the unloading web for the transporters (option)	
Chassis	Axle steering with automatic centering function (option)	
Tires	Standard: 600/55–26.5, Option: 600/60–30.5	
Drive	Mechanical cleaning and bunker functions: PTO-shaft 1,000 rpm; Wide angle PTO-shaft Bunker emptying: hydraulically via tractor hydraulics	
Hydraulics	1 x controller (double acting) and 1 x pressure-free return	
Power requirement	At least: 99 kW/135 HP (6-rows) Recommended: 110 kW/150 HP; With hydraulic Oppel wheel share drive (option): 136 kW/185 HP	At least: 136 kW/185 HP (8-/9-rows) Recommended: 147 kW/200 HP; With hydraulic Oppel wheel share drive (option): 169 kW/230 HP

Measuring instruments:

1- Hand peeler: to remove a slice approximately 1.0 mm thick for damage classification.

2- Balance: to measure the mass of roots obtained from the plots of replicates an ordinary balance (accuracy of 1.0 g).

3- Vernier caliper: **t**o measure the dimension of roots size with accuracy 1/20 mm.

4- Stopwatch to record the time consumed through a travel of 10 meters length for different units during execution the different experiments. Range, min: 30, Sensitivity: 1

5- Steel tape: to measure the length of the replicate tracks and both length and width of plots.

7- Fuel consumption apparatus: the fuel consumed during the harvesting operation was measured by using a fuel consumption apparatus. Its capacity is of about 750 ml. It has a reading ruler divided into 15 divisions. Each of the division is reading 50 ml.

8- Tachometer: to measure the rotation speed of shafts.

Figure (1) : The BM 300 grimme defoliator machine while working .

Figure (2) : The Rootster 604 Grimme harvester while working

Design of the experiment:

In this research the experiments were carried out in an area pivot (each one pivot area 150 feddans). The dimension of every one pivot of about one km diameter and 3 km circumstance. Sugar beet seeds (cisera monogerme) variety was mechanically planted.

Test factors

The following parameters were studied to evaluate the performance of the harvester with four replicates for each parameter.

- Four forward speeds (3.5, 4.3, 5 and 5.8 km/h): Forward speed is calculated by measuring the necessary time to cover specified experiment and the travel distance

$$V = \frac{S}{T \ x \ 3.6} \ km/h$$

Where:

V = forward speed, km/h; S = travel distance, m and T = time of experiment, s.

- First split:

-Two types of rubber shaft (one rubber shaft 1S and two rubber shafts 2S).

-Two types of rear cleaning (without scraper Ds1 and with scraper Ds2)

- Second split:

- Two types of opal wheel driver (ground driver TW_1 and hydraulically driver TW2).

- Two types of cleaning system (axial system, CS_1 and turbine system, CS_2).

These measuring indicators were tested for the two split harvester (Grimme BM 300 and Rootster 604) at the tested forward speed (m/s), type of driven of opal wheel (ground and hydraulically) and type of cleaning system (axial or turbine) for sugar beet. The row width was adjusted at 45 cm, the spaces between seeds were adjusted at 20 cm and the depth at 3 cm for sugar beet planting.

Measurements:

1- Un topping beet (%)

The topping performance was evaluated by observing the sugar beet toper through, correct topped beet, un-topped beet, and topping

efficiency. During the experimental work, the performance of topper assessed by taking randomly selected 30 m of work length, lifting the beet and collecting the tops. So untopped can be estimated easily. The percentage of the items, which are used to control topper performance, can be calculated as the following **(Richey et al., 1961).**

$$Untopped\ beet = \frac{No.\ of\ untopped\ beet}{Total\ No.\ of\ topped\ beet + No\ of\ untopped\ beet} x100$$

$$Topping\ efficiency\ = 100 - (untopped\ beet, \% + broken\ beet, \%)$$

2- Tare ratio (%)

The tare ratio (Tr.) was calculated by the following equation:

$$T_r = \frac{M_{tare}}{M_{total}} x100$$

Where:

Tr: tare ratio (%), M_{tare}**:** mass of tare in simple M_{total}: total weight of sample

3- Cleaning ratio (%)

The cleaning ratio calculated by the following equation:

$$C_1 = \frac{M_c}{M_t} x100$$

Where:

C_1: cleaning ratio (%), M_c: mass of the sample after cleaning.
M_t: total mass of sample.

4- Fuel consumption (l/h)

Fuel consumption was experimental determined by using a fuel consumption apparatus its capacity of about 750 ml. It has a reading scale divided into 15 sections with accuracy of 50 ml. The rate of fuel consumption was calculated as quantity per unit time, as show in the following formula **(Suliman et al., 1993).**

$$C.F. = \frac{f}{t} x\ 3.6\ (l/h)$$

Where:

C.F. = Fuel consumption, l/h;   f = volume of fuel consumption, cm^3 and,   t = time, s.

The specific fuel consumption (S.F.C.) calculated by using the following formula **(Suliman et al., 1993).**

$$S.F.C = \frac{Fuel\ consumption}{Power\ consumed}\ (l\,/\,kW.h)$$

The statistical analysis:

The experiments were arranged in split plot design with three replicates by using Minitab software (Regression analysis and ANOVA). The analysis of variance was done to investigate the significance of the studied variables. Also, the best fit multiple linear regression equations and Regression Coefficient, R^2 were developed for each variable.

RESULTS AND DISCUSSION

Untopped beets for two split harvester at the tested forward speed (km/h), number of rubber flails shaft (1S and 2S) and attached rear scraper DS_1 and DS_2) for sugar beet (Cesira).

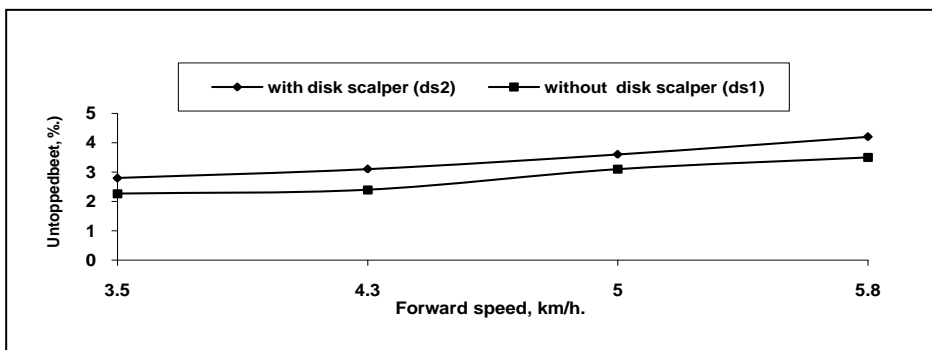The untopped beets percentage for the two split harvester at the tested forward speed (km/h), type of rubber flails shaft and attached disk scraper for sugar beet (Cesira) is presented on Figure (3). The achieved results revealed that both type of rubber flails and type of attached disk scalper for sugar beet harvester affected deeply the topped beets percentage at constant forward speed. The results showed that increasing forward speed resulted in decreasing topped beets percentage. The overall data showed that, with the two rubber flails shaft and attached disk scraper (with and without) under forward speed of 3.5, 4.3, 5 and 5.8 km/h, average of untopped beets percentage was 2.85, 3.28, 3.68 and 4.0, respectively. From the figures, it was clear that the untopped beets percentage was higher at ds_2 than ds1 attached disk scraper. The highest value of untopped beets percentage 4.27 with ds_1 was obtained under forward speed of 5.8 km/h while the lowest value of untopped beets percentage under the same conditions was 3.17 under forward speed of

3.5 km/h. Under DS_1, the highest value of untopped beets percentage 3.73 and the lowest value of topped beets percentage 2.53 was achieved under the same conditions of ds_2. Similar results and trends were observed under 2S system. With DS_2 system, the untopped beets percentage was less than using TW1 system. Also from the figure, untopped beets percentage was higher in DS_1 than DS_2 system. Data analyzed showed that there was a significant effect for using one shaft rubber flails and with using two shaft rubber flails ($p < 0.01$) under the same conditions of forward speed, number of rubber flail shaft and rear attached scraper systems.
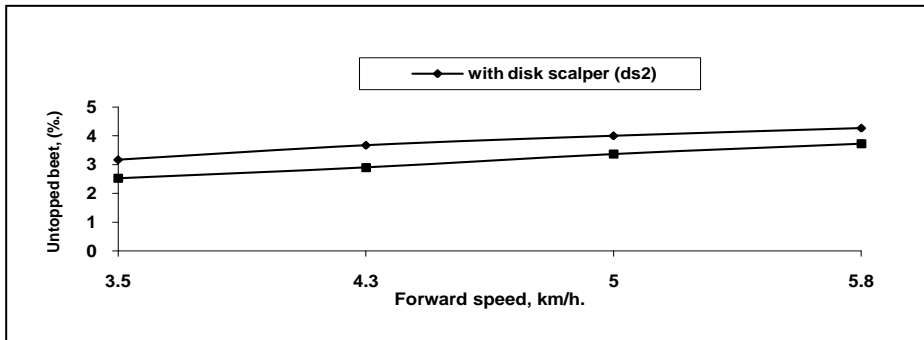
Figure. 3_a: The untopped beet (%) for the two split harvester at the tested forward speed (km/h), number of rubber flail shaft and rear attached scraper for sugar beet (Cesira).

Figure. 3_b: The topped beet %) for the two split harvester at the tested forward speed (km/h), type number of rubber flail shaft and rear attached scraper for sugar beet (Cesira).
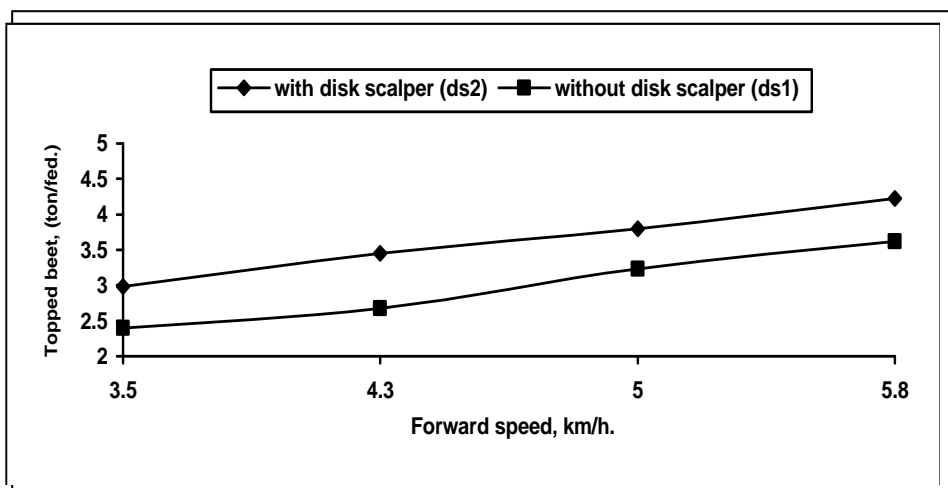
Figure. 3$_c$: Average of the untopped beet (%) for the two split harvester at the tested forward speed (km/h), number of rubber flail shaft and rear attached scraper for sugar beet (Cesira).

The tare ratio (%) for the two split harvester at the tested forward speed (km/h), type of cleaning system and type of opal wheel driver for sugar beet (Cesira).

Tare ratio (%) for the two split harvester at the tested forward speed (km/h), type of cleaning system and type of opal wheel driver for sugar beet (Cesira) is presented on Figures. 4. The results showed that increasing forward speed resulted in increasing tare ratio, % under different cleaning system and different opal wheel driver. It was found that increasing forward speed from 3.5 to 4.3 km/h resulted in increasing tare ratio from 4.37 to 4.95 % with TW1 system under axial. Similar trend was shown with forward speed of 5 and 5.8 km/h. Tare ratio was 5.34 and 6.31 % with TW1 system and axial cleaning. On the other hand with turbine cleaning and TW1 system, the tare ratio was 4.18, 4.47, 4.96 and 5.71 % under forward speed of 3.5, 4.3, 5 and 5.8 km/h, respectively. It was clear that the tare ratio was higher with axial than turbine. These results may be due to the excessive amount of yield on the belt.
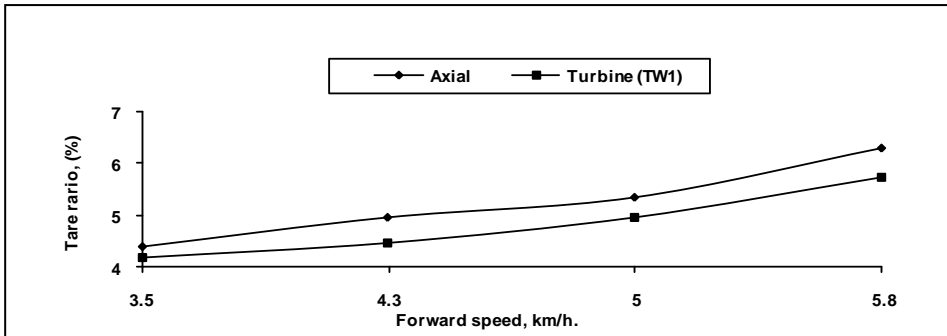
Figure. 4$_a$: The tare ratio (%) for the two split harvester at the tested forward speed (m/s), type of cleaning system and type ground driven opal wheel driver for sugar beet (Cesira monogerme seeds).
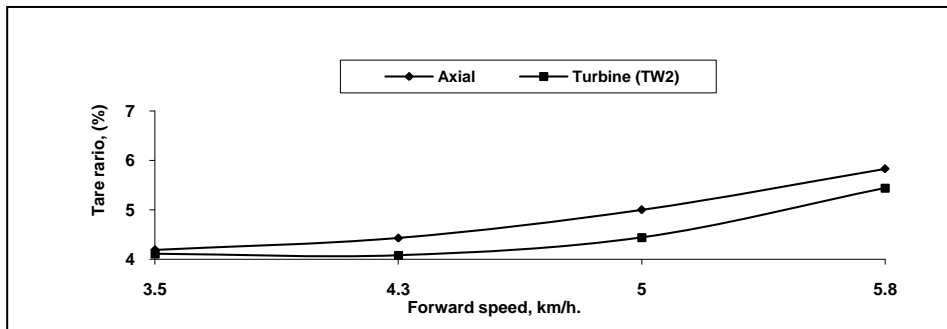

Figure. 4$_b$: The tare ratio (%) for the two split harvester at the tested forward speed (m/s), type of cleaning system and type with hydraulically driven opal wheel driver for sugar beet (Cesira monogerme seeds).
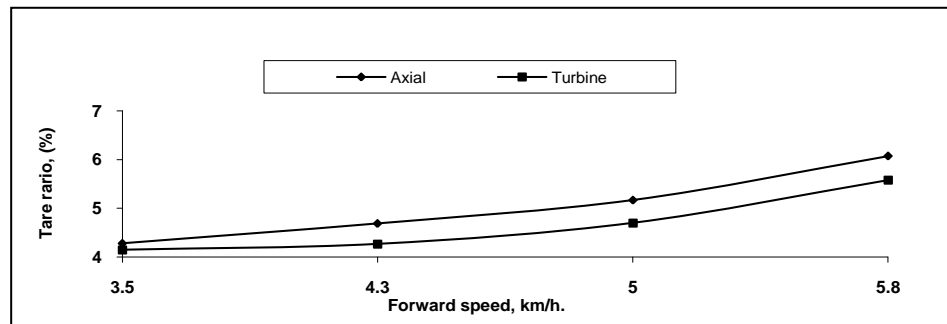

Figure. 4$_c$: Average of tare ratio (%) for the two split harvester at the tested forward speed (m/s), type of cleaning system and two types of opal wheel driver for sugar beet (Cesira monogerme seeds).

The highest value of tare ratio 6.31 % with axial cleaning was obtained under forward speed of 5.8 km/h while the lowest value of tare ratio

under the same conditions was 4.37 %. Under turbine cleaning system the highest value of tare ratio 5.71 % and the lowest value of tare ratio 4.18 % was observed under the same conditions of axial cleaning ratio. Similar results and trends were observed under TW2 system. The highest value of tare ratio 5.83 % and the lowest value of 4.19 was achieved under forward speed of 5.8 and 3.5 km/h respectively for the axial cleaning system. While the highest value of tare ratio for turbine cleaning system was 5.44 and lowest value was 4.11 % were obtained under forward speed of 5.8 and 3.5 km/h respectively. Generally , one can see that , there are a direct proportional between the tare ratio and tractor forward speed . Also, the minimum tare ratio achieved at turbine cleaning system and hydraulically driven of opal wheel.

The cleaning ratio (%) for the two split harvester at the tested forward speed (km/h), type of cleaning system and type of opal wheel driver for sugar beet (Cesira).

The chief reason for cleaning sugar beet is to remove the undesired materials such as clods and stones. Cleaning ratio (%) for the two split harvester at the tested forward speed (m/s), type of cleaning system and type of opal wheel driver for sugar beet (Cesira) is presented on Figures. 5. The results showed that increasing forward speed resulted in decreasing cleaning ratio, %. The overall data showed that, with the two cleaning system (axial and turbine) with TW1 system under forward speed of 3.5, 4.3, 5 and 5.8 km/h, average of cleaning ratio was 95.723, 95.292, 94.85 and 93.99 %, respectively. From the figures, it was clear that the cleaning ratio was higher with turbine cleaning than axial cleaning. The highest value of cleaning ratio 95.817 % with turbine cleaning system was obtained under forward speed of 3.5 km/h while the lowest value of cleaning ratio under the same conditions was 94.287 %. Under axial cleaning system the highest value of cleaning ratio 95.63 % and the lowest value of cleaning ratio 93.693 % was observed under the same conditions of turbine cleaning system. Similar results and trends were observed under TW2 system. Obviously, it was clear that with TW2 system, the cleaning ratio was higher than using TW1 system. Also from the figure cleaning ratio was lower in axial cleaning than turbine cleaning system. From the obtained data, the highest value of cleaning ratio was 95.89 % and 95.81 % for TW2 system and TW1 system, respectively under the same conditions of forward speed 3.5 km/h and turbine cleaning system. All these results may be according to the increase in belts movement speed which resulted in transmit beets with cleaning that

led to beet stuffed on the belt and consequently decreased the cleaning ratio. Data analyzed showed that there was a significant effect without using hydraulic system and with using hydraulic system ($p < 0.01$) under the same conditions of forward speed and cleaning systems.
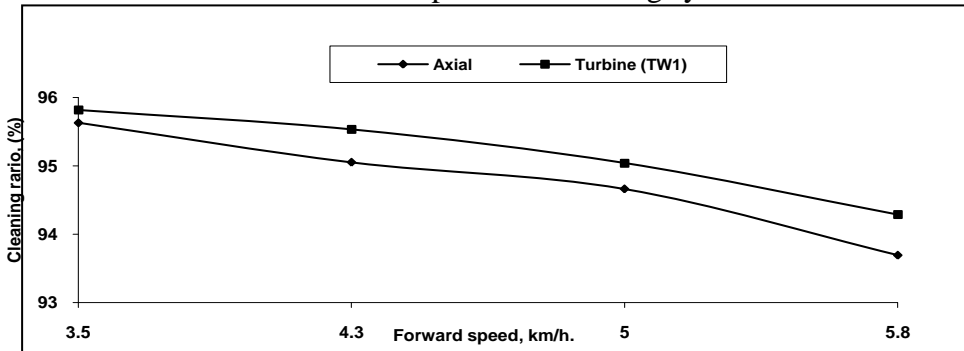

Figure. 5_a: The cleaning ratio (%) for the two split harvester at the tested forward speed (km/h), type of cleaning system and type without opal wheel driver for sugar beet (Cesira).
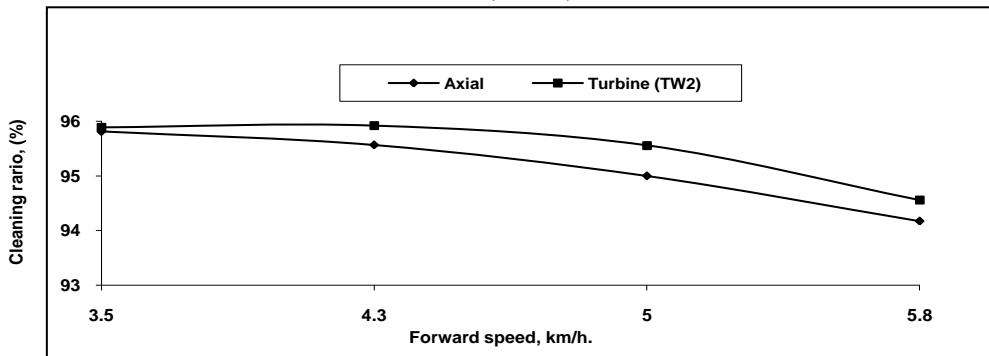

Figure. 5_b: The cleaning ratio (%) for the two split harvester at the tested forward speed (km/h), type of cleaning system and type with opal wheel driver for sugar beet (Cesira).
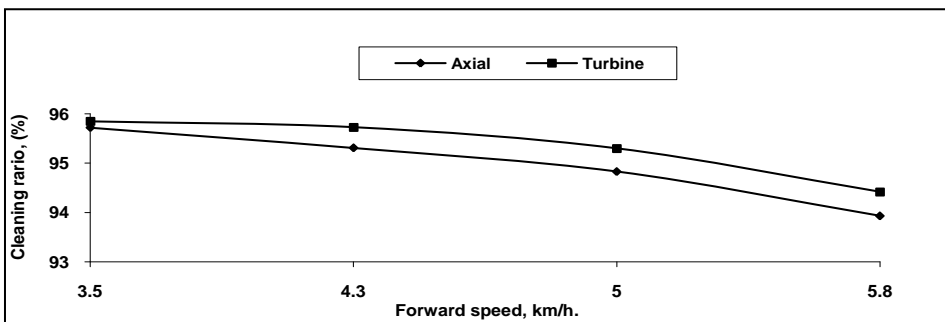

Figure.5_c: Average of the cleaning ratio (%) for the two split harvester at the tested forward speed (km/h), type of cleaning system and types of opal wheel driver for sugar beet (Cesira).

The fuel consumption (l/h) for the two split harvester at the tested forward speed (km/h), type of cleaning system and type of opal wheel driver for sugar beet (Cesira).

Figures 6 revealed that both type of cleaning system and type of opal wheel driver for sugar beet harvester affected deeply on the fuel consumption at constant forward speed. The results showed that increasing forward speed resulted in increasing fuel consumption (l/h). It was found that increasing forward speed from 3.5 to 4.3 km/h resulted in increasing fuel consumption (l/h) from 17.19 to 18.17 with TW1 system under axial cleaning system. Similar trend was shown with forward speed of 5 and 5.8 km/h. The overall data showed that, with the two cleaning system (axial and turbine) with TW1 system under forward speed of 3.5, 4.3, 5 and 5.8 km/h, average of fuel consumption (l/h) was 17.51, 17.78, 18.13 and 18.57, respectively. From the figures, it was clear that the fuel consumption (l/h) was higher with axial cleaning system than turbine cleaning system. The highest value of fuel consumption (l/h) 18.97 with axial cleaning was obtained at forward speed of 5.8 km/h while the lowest value of fuel consumption (l/h) under the same conditions was 17.19. Under turbine cleaning system the highest value of fuel consumption (l/h) 18.17 and the lowest value of fuel consumption (l/h) 17.10 was observed under the same conditions of axial cleaning ratio. Similar results and trends were observed under TW_2 system. Obviously, it was clear that with TW_2 system, the fuel consumption (l/h) was less than using TW_1 system. Data analyzed showed that there was a significant effect for without using hydraulic system and with using hydraulic system ($p < 0.01$) under the same conditions of forward speed and cleaning systems. Also, there was a significant effect by decreasing forward speed from 5.8 to 3.5 km/h.
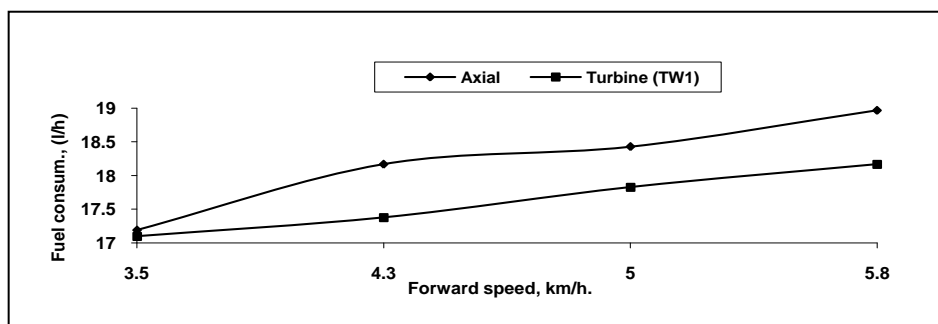

Figure. 6_a: Fuel consumption (l/h) for the two split harvester at the tested forward speed (km/h), type of cleaning system and type without opal wheel driver for sugar beet (Cesira).

Figure. 6$_b$: Fuel consumption (l/h) for the two split harvester at the tested forward speed (km/h), type of cleaning system and type with opal wheel driver for sugar beet (Cesira).

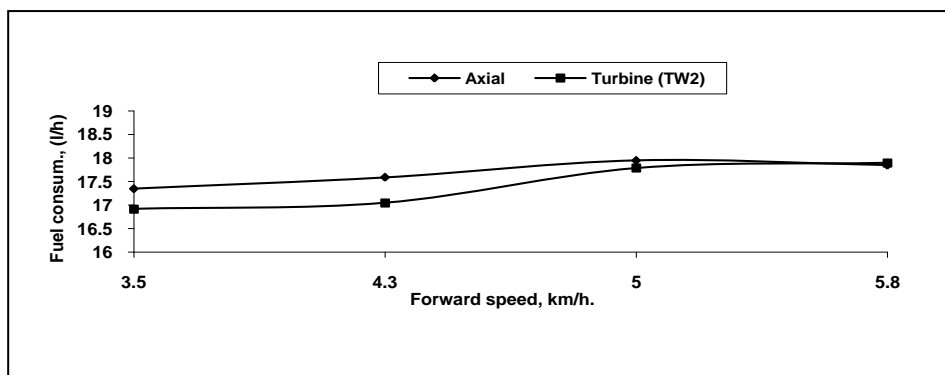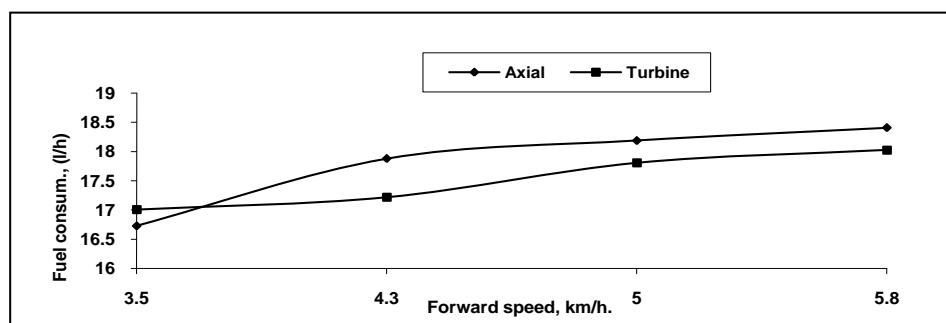
Figure 6$_c$: Average of fuel consumption (l/h) for the two split harvester at the tested forward speed (km/h), type of cleaning system and two types of opal wheel driver for sugar beet (Cesira).

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<u>الملخص العربى</u>

تقييم الات حصاد بنجر السكر ثنائية المرحلة تحت الظروف المصرية

حسنى الشبراوي[1]   رضا سالم[2]   ريهام رمضان[3]

أجريت هذه التجربة على مساحة ٦٠٠ فدان فى شركة النوران بالصالحية بمحافظة الشرقية بهدف تقييم أداء حاصدة آلية متكاملة ثنائية المرحلة two split وذلك تحت سرعات تقدم مختلفة للحاصدة لحصاد محصول بنجر السكر. وقد تم تحديد أربعة عوامل للدراسة لاختبار تأثيرها على أداء آلة الحصاد وهى أربعة سرعات تقدم مختلفة للحاصدة ٣٫٥ ، ٤٫٣ ، ٥٫٠ ، ٥٫٨ ، ٥٫٨

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[2]ـ باحث أول ــ معهد بحوث الهندسة الزراعية ــ مركز البحوث الزراعية ــ الدقي ـ مصر

[3]ـ معاون خبير زراعى- وزارة العدل

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كم/ساعة. وكذلك نظامان مختلفان للسكاكين الكاوتشوك (one flail shaft and two flail shaft) بالإضافة لعمود الساكين الصلب وكذلك وجود نظامين للأقراص الخلفية الملحقة (with Scraper and without scraper) وكذلك نظامين لاقراص التقليع ground driven (and hydraulically driven) مع نظامان مختلفان لعملية التنظيف (Axial-turbine) ، وقد تم قياس كل من النسبة المئوية للجذور الغير مطوشة والنسبة المئوية الشوائب و نسبة التنظيف واستهلاك الوقود (لتر/ساعة)

وقد خلصت الدراسة إلى انخفاض النسبة المئوية للجذور الغير المطوشة (%) بانخفاض سرعة التقدم من ٥.٨ إلى ٣.٥ كم/ساعة مع جميع المعاملات ، وكذلك أدي استخدام عمودين من السكاكين الكاوتشوك إلى انخفاض النسبة المئوية للجذور الغير المطوشة ٢.٥٣ (%) بينما كانت ٢.٨٥ (%) مع إستخدام عمود واحد من السكاكين الكوتشوك . كذلك أدى استخدام الأقراص الخلفية الملحقة إلى انخفاض النسبة المئوية للجذور الغير مطوشة ٢.٤٠ (%) عنه فى حالة عدم إستخدام الأقراص الخلفية حيث كانت النسبة المئوية للجذور الغير مطوشة ٢.٩٨ (%) وذلك عند نفس ظروف التشغيل. وقد أدى زيادة سرعة التقدم إلى زيادة نسبة الشوائب مع استخدام كلا النظامين فى عملية التنظيف وكذلك نظامى الاقراص (الهيدروليكي وغير الهيدروليكي) ، وكانت أقل نسبة شوائب ٤.١١ % باستخدام النظام التوربين في عملية التنظيف مع استخدام نظام القرص الهيدروليكي ، بينما كانت أعلى نسبة شوائب ٦.٣١ % مع نظام التنظيف المحوري ونظام العجل الغير هيدروليكي. وقد تحققت أعلى نسبة مئوية للتنظيف (٩٥.٩٢ %) مع نظام الاقراص الهيدروليكية واستخدام النظام التوربين في حين كانت أقل نسبة مئوية للتنظيف ٩٤.٢٨٧ مع نظام العجل الغير هيدروليكي والنظام الحصيرة فى التنظيف ،. أما بالنسبة لاستهلاك الوقود (لتر/ساعة) فقد انخفضت كمية الوقود المستهلكة فى حالة استخدام نظام العجل الهيدروليكي ١٧.١٤ (لتر/ساعة) عنه فى حالة النظام الغير هيدروليكي ١٧.٥٤ (لتر/ساعة) ، كذلك انخفضت كمية الوقود المستهلكة مع نظام التنظيف التوربين ١٧.٠١ (لتر/ساعة) عن النظام بالحصيرة ١٧.٦٣ (لتر/ساعة) عند سرعة تقدم ٣.٥ كم/ساعة.. وعموماً أعطى إستخدام عمودين من السكاكين الكاوتشوك بالإضافة لعمود من السكاكين الصلب وكذلك إستخدام السكاكين الخلفية الملحقة و نظام العجل الهيدروليكي وطريقة التنظيف التوربين أفضل النتائج مع جميع المعاملات.