DEVELOPMENT OF A LEAFY CROPS HARVESTER

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ABSTRACT

Leafy crops harvester prototype was modifying depending on the leafy crops characteristic like crop height leaves surface area crop stems. The prototype included frame, conveyor, collection box, and transmission system. Results provided the suitability of the modifying prototype to transportation and collecting leafy crops, the suitability of the modifying prototype was judged through the removal percentage, un-damaged percentage and losses percentage.

INTRODUCTION

Vegetable is an important class of agricultural products at the national and international levels. They present core products that contribute to main food and drugs.

The economy of the leafy vegetable e.g. spinach, parsley, basil, dill, cabbage, celery, lemon grass, baby spinach and thyme has been growing during the last decades due to the increasing demand to industry. The national production of leafy vegetables in the years of 2010 was 37000 tons. Parsley represents an example of economically important leafy crops. Parsley has many benefits and uses in the area of health and drugs. It has culinary uses seems to help blend other flavours. It ameliorates strong odours like garlic and fish. It works well with most foods except sweets, Medicinal Uses: parsley can also provide dietary sources of calcium (Ca), potassium (K), phosphorus (P), magnesium (Mg), and iron (Fe), as well as vitamin A, vitamin C, and carotenoids (Rademaker, 2007). It is not worthy to mention that some medical Egypt companies produce some drugs from parsley. Mean while an important economic value of parsley is the exportation to international markets. One of the most important factors that guaranties good quality of the vegetable product is high performance of the harvesting techniques.

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This can aid in better competition for the international market and in reaching the international standards for the quality of those leafy crops. Parsley is locally harvested by manual technique and yet the mechanical methods are not widespread in Egypt. Current problems associated with the manual processes include unstable labor availability, high cost for labors and possible healthy problem, regarding transfer of diseases from labors to the end users.

Hanna and Suliman (1986) mentioned that the scythes and sickles have simply remained largely the same for literally thousands of years. They also added that the efficiency of hand tools, at best they place heavy demands, on human energy, increase work hours and are often responsible for low levels of production and increasing reluctance of labors to work in agricultural sectors.

Hegazy, *et al*. (2011) designed a new harvesting prototype for cutting and collecting different types of aromatic and medical plants. They showed that the main components of the experimental harvester are: engine with travelling mechanism, cutting unit and conveyor unit connected with storage tank. The design concepts were related to cultivation, environmental factors for these types of plants. The others observed that, The general performance of the prototype for harvesting three types of aromatic and medical plants showed that the working time taken by the machine to collect sage was higher than the time taken to collect rosemary and winter savory by 16 and 12%, respectively, where average values of fuel consumption for sage, rosemary and winter savory were 0.32, 0.27 and 0.30 kg kWh^{-1}, respectively. Machine working efficiency varied from 28.5 to 36.9 m^2 min^{-1} for all plants. Best working efficiency value obtained by using machine with rosemary. There were increasing in harvesting losses for sage and rosemary by 15.4 and 14% compared to winter savory, also number of transferred plants in case of winter savory was high and gave best transfer efficiency by 89.2%.

Celik (2006) tested a cutter bar mower for harvesting it wae mainly consisted of six main components including the cutting, transmission, power, handling, frame, and transporting units. A two cycle engine that produced 1.47 kW at 7000 rpm provided power for the cutting unit. Two skids were attached to the cutter bar unit, one on each side, to control cutting height. The total mass of the mower was 41kg. He resulted that, the effective field capacity 0.11 ha/h, 10 L/h fuel consumption, 0.875 field efficiency, 2.24 t/h effective wet grass harvesting capacity, 4.43 L/t wet grass specific fuel consumption, and 64 mm cutting height.

The aim of the present work is to develop a common reciprocated mower to mechanize the harvesting of locally produced leafy crops. This will help to get advantage of better performance, higher quality of the harvested vegetables and lower the cost at the whole harvesting process. One of the expected results is to spread this approach locally and to increase the possibility of exportation of leafy crops.

To achieve the objective it was required design and manufactures a belt conveyor attached behind the cutter bar of a side reciprocating.

MATERIALS AND METHODS

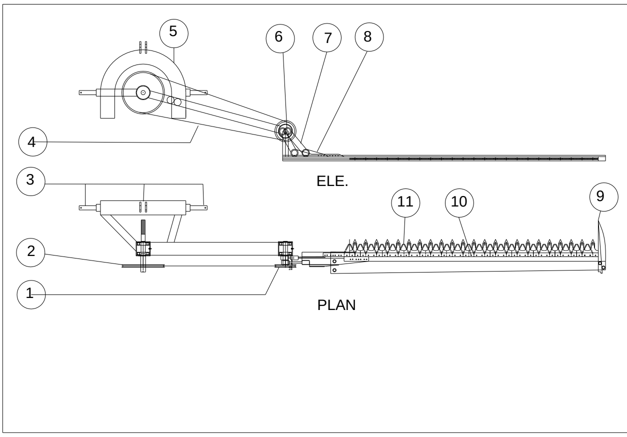
The designed conveyer transfers the harvested leafs to a collecting box located behind the tractor. This development needs to design and modify the transmission system to transmit the motion to the conveyer.

The plan of realizing the objective of this research was implemented through the following steps:-

(a) Determine some physical and mechanical characteristics of leafy crops.
(b) Select a common mower which has high productivity, simple design and suitability for cutting leafy crops.
(c) Test the original mower for determining the field performance parameters and its effect on the leafy crops.
(d) Modification of steps to equip the original mower with crop transportation unit and collection box.
(e) Evaluate the developed mower technically and economically and make the required manipulation.

<u>Original mower:</u>

The original mower was one of the common mowers used to harvest leafy crops. Figure (1) shows the components of the selected mower. The original machine was a mower equipped with 180 cm cutter bar width with double reciprocating blades with knife spacing 7.6 cm.



No.	Main Parts
11	Blade
10	Cutter bar
9	External shoe
8	cutting bar support
7	Reciprocated arm
6	Crank shaft
5	Main frame
4	Rubber belt
3	Three point hitch
2	Main driven pulley
1	Main drive pulley

Fig. (1): The components of the original mower

The motion was transferred to cutter bar from the tractor power take off via universal joint at 540 rpm. A pulley of diameter 30 cm transform the motion directly from the universal joint and submits it to a pulley with diameter of 15 cm via rubber belt.

<u>The developed mower:</u>

A conveyer belt was attached to the original mower through extra frame. The conveyer belt transfers the harvested leafs from the outer mower's shoes to a collection box located behind the tractor at the distance between the rear wheels. This development secures harvesting leafy crops in a clean and well controlled system to suit the different condition of harvesting.

The modification was developed through three sub systems which are transportation, collection box and transmission system there were fabricated in Meet Khalaf workshop – Agricultural Engineering Unit – Ministry of Agriculture.

<u>Leaf transportation system:</u>

The leaf transportation system consisted of the following parts:-

a) Conveyer's frame:-

This frame was designed in order to keep enough stretching of the conveyor belt the conveyer's frame was manufactured from right angel steel 4×4 cm with thickness of 0.3 cm and Carbon steel sections

14×5×0.4 cm. all attached to the cutter bar with two plate steel having cross section of 5×0.4 cm for each.

b) Conveyer:

The conveyer was made of special plastic three ply rating and it was equipped with notched surface. The conveyer dimensions were (175 × 70 cm). Both ends of the conveyer were welded with laser ray by special instrument.

c) Drive and Driven drum:

Figure (2) shows the drive and driven drum and its components. The idler drive was made of steel pipe with diameter of 14 cm thickness of 4mm and length of 100 cm. Two flanges with diameter of 15 cm were welded at both edges of the drum to prevent the conveyer to slip. An axle of diameter 3.5 cm was fixed along the center of the drum and welded out of the two flanges. The drive drum axle was rolled on two ball bearing housing equipped with double ball bearing. The bearing housing was equipped with threaded bolt to adjust the tension of the conveyer**.** The motion was transferred to the drive drum via a pulley fixed at the end of the axle.

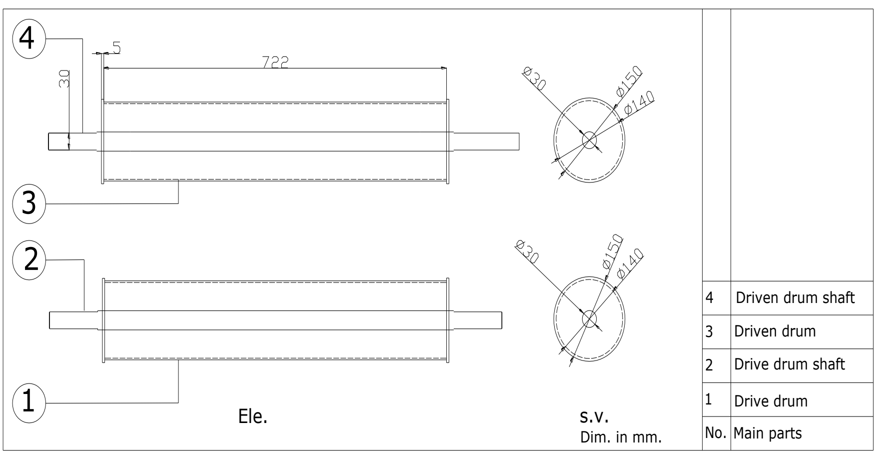


Fig. (2): The dimensions of the drive and driven drums

d) Collection box:

A Collection box made of steel sheet 0.2 cm thickness, length of 150 cm, width 80 and height 5 cm was fitted behind the mower between tracks of the tractor.

Transmission system:

It was necessary to transmit motion to the conveyer through a simple system. A pulley of 25 cm diameter was fixed on the same axel of the main original pulley. The pulley was rotated on 540 rpm. The motion was transferred to the idler drum through another pulley with 150 mm diameter via reversible rubber belt. Figure (3) shows the transmission system after development.

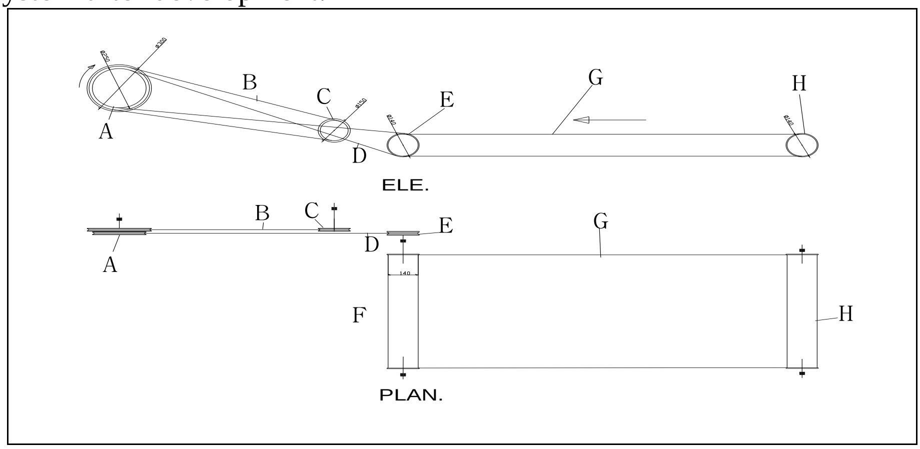
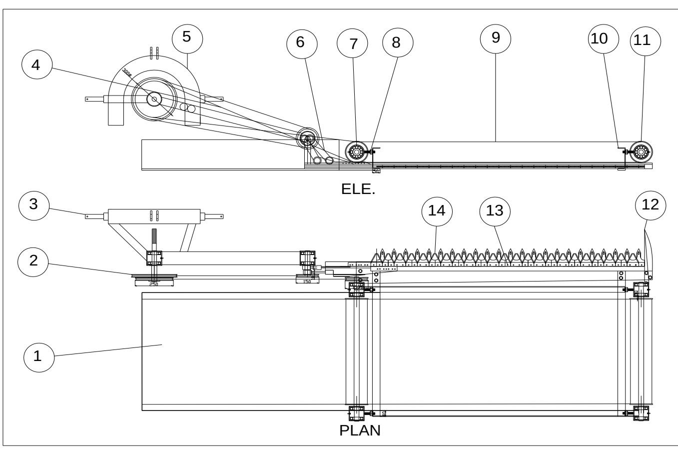


Fig (3): A schematic of transmission system after development

(A)Double drive pulley (B) Belt (C) Cutter bar pulley (D) Reversible belt (E) Driven pulley (F) Drive drum (G) Harvesting conveyer (H) Driven drum

The overall features of the developed mower are shows in Figure (4).



14	Blade
13	Cutter bar
12	External shoe
11	Conveyer driven drum
10	Transferring system frame
9	Harvesting convayer
8	Harvesting conveyer tension
7	Conveyer drive drum
6	Reciprocating arm
5	Main frame
4	Reversible belt
3	Three point hitch
2	Main Transmission
1	Storage Pan
No.	Main Parts

Fig (4): The mower after development

Tractors:

A Kubota tractor model M 9000, 90 hp engine at 540 r.p.m., was used to operate the modified machine with 150 kg front weight. The tractor was equipped with narrow tires. Four forward speeds were selected during the experiments. The speed was adjusted and stabilized with assistance of fuel hand control lever.

Design methodology:

1. Evaluate the performance of the machine to be developed to determine the developed elements.
2. The development of the machine functional and its components manufactured and tested.
3. Evaluation of the model developer technically and economically.
4. Testing the developed machine of some leafy crops,

2-5: Measurements and calculation:

The design of the component-units of the machine was carried out putting into consideration, the specific functions of each component units. The main units are: the conveyor, power requirement and the operating capacity.

- Machine flied capacity (Fc)

Actual field capacity was calculated as follows:-

$$Fc = A/t$$

Where:

Fc= Felid capacity, feddan/h;

A=Harvested area, feddan;

t = Machine operating time, h.

- The pulley diameter

$$D = \frac{ds}{V}$$

Where:

D = Diameter of driven pulley, mm.

d = Diameter of driving pulley, mm.

V= Speed transmitted to driven pulley, mm/sec.

s = Speed if driving pulley, mm/sec.

- <u>Conveyer speed:-</u>

The conveyer speed was calculated by using the following formula:

$$\frac{N_1}{N_2} = \frac{D_2}{D_1}$$

Where,

N_1= First pulley speed, rpm;

N_2= Second pulley speed, rpm;

D_1=First pulley diameter, mm;

D_2=Second pulley diameter, mm.

Table (1): The drive and driven pulley diameter

Diameter (A) (mm) 540 rpm	Diameter (E) (mm)	Drive drum (rotary speed) rpm	Conveyer linear speed m/s
250	150	900	3.53
250	180	750	2.94
150	180	450	1.76
150	250	324	1.27

- Cutting efficiency:

Cutting efficiency was calculated by using the following formula according to Hanna and Suliman (1986) as follow:

$$E_c = \frac{H_a - H_b}{H_a} * 100$$

E_c= Cutting efficiency, %;

H_a= Height of plant stands above the soil before cutting, cm;

H_b = Height of stubble after cutting (height of cut), cm.

- Power requirement

The following formula was used to estimate the engine power according to Embaby (1985)

$$E.P = Fc\left(\frac{1}{60*60}\right) P.F * LCV * 427 * \eta_{th} * \eta_m * \frac{1}{75} * \frac{1}{1.63}, kW$$

Where:

Fc = The fuel consumption, L/h.

P.F = The density of fuel, kg/L (for solar = 0.85).

L.C.V =The lower calorific value of fuel (k.cal/kg) average L.C.V of solar is 10000 k.cal/kg).

η_{th} = The thermal efficiency of the engine, consider to be about 40 percentage for diesel engine).

427 = Thermo-mechanical equivalent, kg.m/kcal.

η_m = The mechanical efficiency of the engine, consider to be 80 percentage for diesel engine).

Power requirement = 3.16 Fc, kW/h.

So, the energy requirement in (kW.h/fed.), was calculated as follows

$$Engerey\ requirment = \frac{the\ required\ power\,(kw)}{actual\ fild\ capacity\ (\frac{feddan}{h})},\ \text{kW.h/feddan}$$

- Economical evaluation:

The economical evaluation of the developed mower was based on a group of parameters. These parameters were tractor and harvesting operating costs, Internal Rate of Return *(IRR)*, Net Present Value *(NPV)* and Pay Back Period *(PBP)* were used to evaluate the benefit of the developed mower

<u>Operation costs:</u>

The tractor and mower operating costs were calculated from following equation according to Oida 1997. These costs include depreciation *(D)*, annual capital interest (*I*) taxes, housing and insurance (*THI*), repair and maintenance *(R)*, fuel cost (*F*), oil cost *(O)* and labor cost *(L)*

$$Tc = \frac{\left\{\left[\left(\frac{Pc - Sv}{Y}\right) + \left(\frac{Pc + Sv}{2} * \frac{i}{100}\right) + 0.02\,Pc\right] + \left[\left(\frac{Pc * r_c}{Y}\right) + (0.25\,Pt * fc) + (Oc * c * n) + (N * L * n)\right]\right\}}{n}$$

Tc	= Total cost	, LE/h;
P_c	= Purchase price	, LE;
Sv	= Salvage value	, LE;
	$= 0.56\,(0.885)^{Y} * P_c$ for machine.	
	$= 0.68\,(0.920)^{Y} * P_c$ *for* tractor.	
i	= Interest rate	, %;
r_c	= Coefficient of repair and maintenance = 0.80	, decimal;

Y	= Anticipated length of time owned = 5	, year;
Pt	= Tractor power	, HP;
fc	= Fuel price	, LE/lit;
Oc	= Oil consumption = $0.00059 * Pt + 0.02169$	, lit/h;
C	= Oil price	, LE/lit;
N	= Number of labors = 1	;
L_c	= Labor cost	, LE/h;
n	= yearly working hours = 500	, h/year.

RESULTS AND DISCUSSION

1. Dimensional characteristics of Parsley:

The results showed that the maximum frequency of the crop height was 310 mm and the minimum frequency was 110 mm and the majority has a height in rang 230- 270 mm, Figure (5) showed frequency of the taken measurements of the crop height.

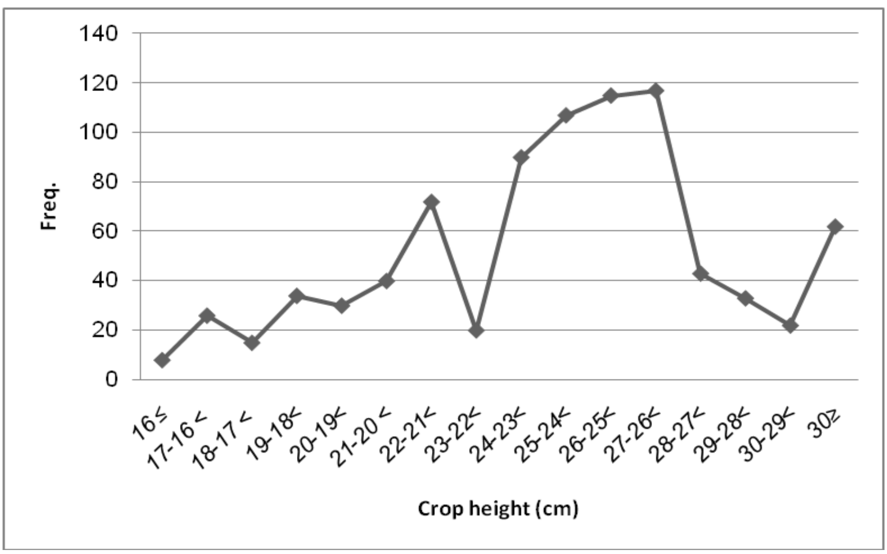


Fig (5) show frequency of the taken measurements of the crop height

Also, the results show that the maximum frequency of the crop stems cross section was≥ 0.5mm and the minimum frequency was ≤0.1mm and the majority have a stem in the rang 0.2- 0.3mm, Figure (6) show frequency of the taken measurements of the stem diameter.

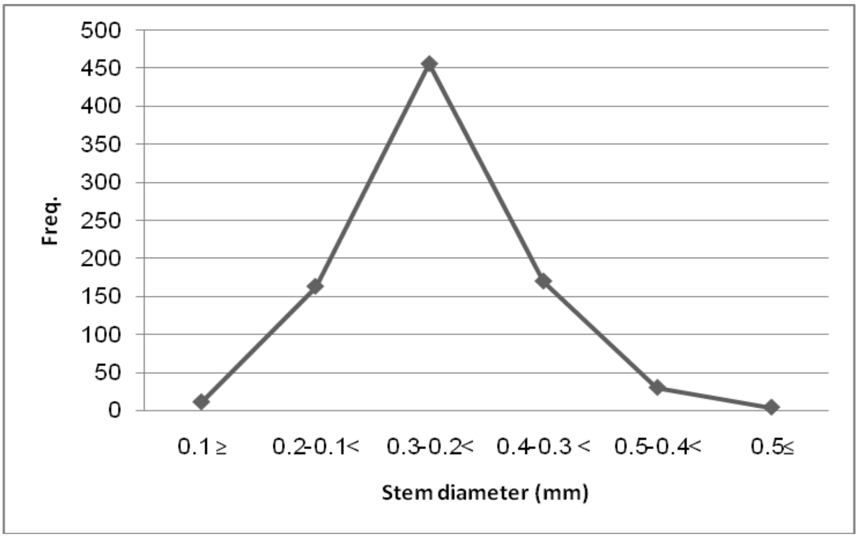


Fig (6) show frequency of the taken measurements of the stem diameter.

The maximum value of the leaves surface area was ≥ 23 mm^2. While the minimum value of the leaves surface area was ≤10mm^2 and the majority of leaves have surface area 10-14mm^2, Figure (7) show Frequency of the taken measurements of the leaf surface area.

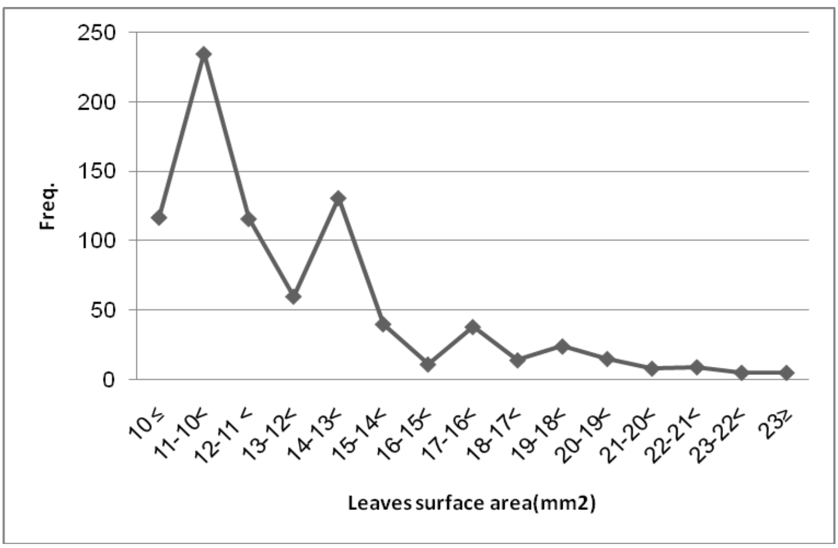


Fig (7): Frequency of the taken measurements of the leaf surface area.

It was realized in the field that the plant dimension was differ from place to other in the same field and other fields according to the agricultural practices.

2. Performance of the developed mower:

The procedure of testing the modified mower was as the following steps:-

1.Testing the developed mower at the same forward speeds that compared with the original machine by changing the tractor selected gearbox lever.

2.Each conveyer speed was tested at four forward speed by changing the speed ratio by changing the conveyer's drive and driven pulleys.

3.Determine the field capacity at the same conditions.

1- Field capacity:

The developed mower was used to harvest parsley at four different conveyer speeds and four forward speeds Figure (8) showed the relation between Forward speed and field capacity in different conveyer linear speed.

The results showed that there is no relationship between the conveyor speed and the average field capacity. The field capacity of the original machine was near to the field capacity of the modified machine at the same selected gear.

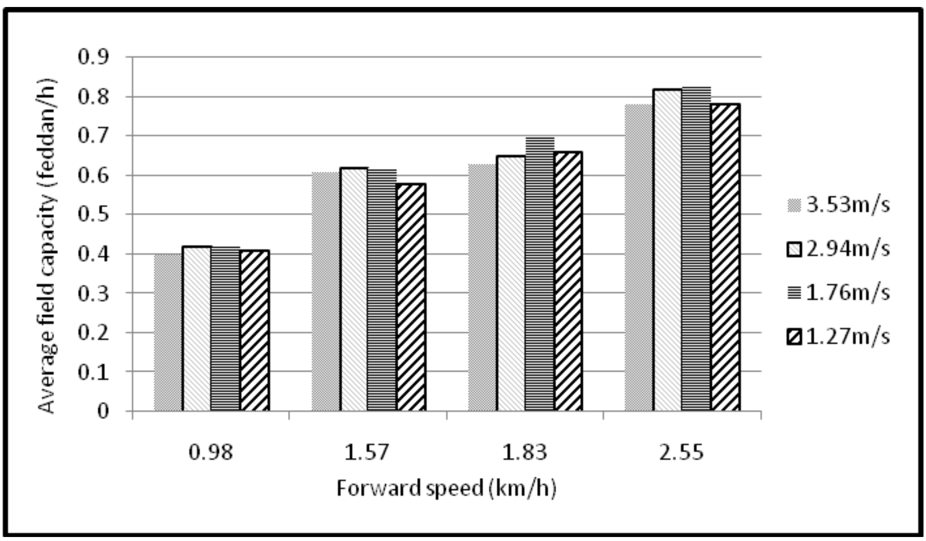


Fig (8): The relation between Forward speed and field capacity in different conveyer linear speed.

The results showed that the mower forward speed directly proportional to the field capacity.

At conveyor linear speed 3.53 m/s and forward speed 1.38km/h and 2.55 km/h, high losses of the crops behind the conveyor, at the conveyor linear speed 2.94m/s and forward speed 2.55 km/h, high losses of the crops behind the conveyor, were noticed to justify refusing this working speed were recorded, recommending to perform cutting operation at the forward speed.

It was also realized when using a conveyor speed at 1.27m/s the harvested leafs began to contend and cause clogging on the conveyor.

On the other hand, at the conveyor linear speed 1.76 m/s and forward speed 1.83km/h and 2.55km/h recorded the best results to perform the cutting operation.

2- Cutting efficiency:-

The harvest stem were checked after harvesting with the modified mower to determine the cutting efficiency. Figure (9) showed the relation between cutting efficiency and forward speed for the modified mower

The results showed that there was no relationship between the conveyor speed and the average cutting efficiency. The cutting efficiency of the original machine was near to the cutting efficiency of the modified machine at the same selected gear.

The results showed that the mower forward speed directly proportional to the cutting efficiency Also, at conveyor linear speed (3.53 m/s, 2.94m/s, 1.76m/s and 1..27m/s) and forward speed 2.55 km/h, high losses of the crops by cutting, were recorded, recommending to perform cutting operation at high forward speed.

On the other hand at the conveyor linear speed (3.53m/s, 2.94m/s, 1.76m/s and 1.27m/s) and forward speed (0.98km/h, 1.57km/h and 1.83km/h) recorded the best result to the cutting operation.

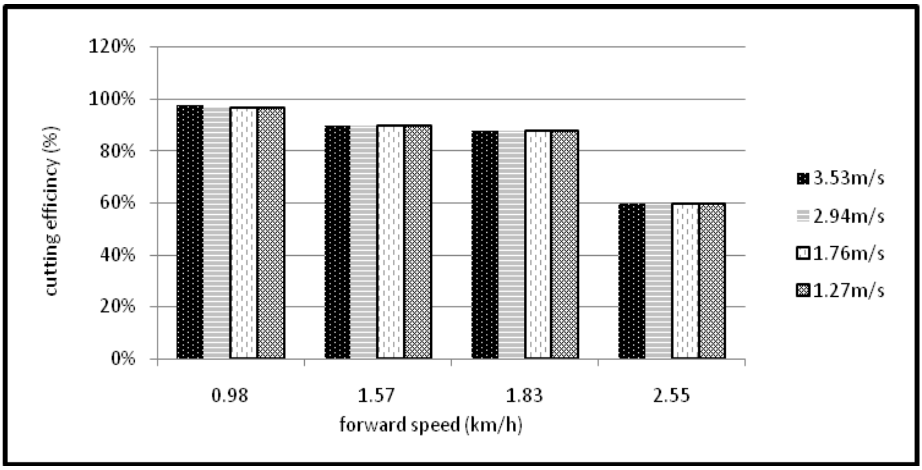


Fig. (9): The relation between cutting efficiency and forward speed for the modified mower

3. Operation cost

The calculation of the operating costs included fixed and variable costs were made for tractor and the machine. Applying the input data in Table (2) to Microsoft office software (Excel 2003), the total operating costs for a 50 hp tractor and original mower were 38.9 LE/h On the other hand, the total operating costs for A 90 hp tractor and developed mower were 45.4LE/h.

Table (2).Items of developed mower costs:

Item	Machine	Tractor
Purchase price (L.E)	17000.00	75000.00
Inflation ratio	1.00	1.00
Hp		90.00
Salvage value (L.E)	30.40	29.54
Life (h)	2500.00	10000.00
Repair percentage %	60.00	100.00
Depreciation (L.E)	4.73	5.28
Interest (L.E)	3.16	2.63
Interest value (%)	14.00	14.00
Other ownership costs (L.E)	0.68	0.75
Fixed costs (L.E)	8.57	8.66
Repair and maintenance costs (L.E)	4.08	7.50
Fuel cost (L.E)		5.72
Lubrication		0.86
Labor cost (L.E)	5.00	5.00
Variable costs (L.E)	9.08	19.08
Total costs /h (L.E)	17.65	27.74

By using formula the total operation cost was:

Total operation cost /h		45.4

SUMMARY AND CONCLUSION

The Development of leafy crops harvester was made through designing and manufacturing a conveyor behind the cutter bar of a common reciprocating side mower to collect the leafs in a box. Those modifications were made to increase performance of the harvesting process of leafy crops rather than manual harvesting; this resulted in an increase in the value of the crop and decreasing the collect time and reducing wastes.

The developed mower was successful to harvest parsley leafs and transfer them to a collected box clean and well controlled. Testing the machine at different forward speeds and different conveyer speeds showed that the optimum conveyer linear speed for transfer parsley is 2.94 - 1.76 m/s.

Based on results of the present study, the developed mower may be used successfully for harvesting other leafy crops.

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الملخص العربى

تطوير أله لحصاد المحاصيل الورقية

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تعتبر المحاصيل الورقيه من اهم المحاصيل التى تعتمد عليها الانسان فى غذاءه حيث انها تمد الجسم بإحتياجاته من البروتين وبعض المواد العلاجيه وتعتبر مصدرا للعديد من الفيتامينات الهامة لصحة الانسان والالياف التى تساعد على عملية الهضم. وفى ظل سياسة الدولة فى التوسع الافقى فى زراعة الاراضى المستصلحة تعتبر المحاصيل الورقية من المحاصيل ذات العائد الاقتصادى المرتفع لذا كانت عمليه حصاد للمحاصيل الورقية من اهم العمليات الزراعية التى يجب إجرائها بوسائل ميكانيكيه لتفادى تلامس العامل لها والحصول على مواصفات تصديريه قياسيه مطابقة. ونظرا لعدم توافر معدات مناسبه للحصاد علاوة على ارتفاع اسعار الالات المستوردة يجعل من الضرورى ايجاد آلات مناسبه للقيام بعمليه الحصاد.

تم تصميم آليه ملحقة بالمحشة الترددية وهى مكونه من سيرناقل لنقل المحصول الى صندوق التخزين الموجودة خلف عجلات الجرار الخلفيه مما يقلل من التالف او الفاقد من المحصول وتقليل العماله القائمة بنقل المحصول وعدم ملامسه العامل لها مع رفع جودة ناتج الحصاد.

وتم تقييم المحشة الترددية المتطورة فى مزرعة بميت خلف على محصول البقدونس حيث اظهرت النتائج مايلى:-

١- بزيادة سرعة التقدم للجرار يزداد معدل الأداء للمحشة زيادة واضحة مقارنة باقل سرعة تقدم.

٢- تزداد كفاءة القطع للبقدونس عندما تقل سرعة التقدم .

٣- تم تحديد مدي سرعات السير الذي يناسب الحصاد بدون فقد في المحصول او زوران وتجمع للاوراق علي السير حيث بلغت سرعه السير الناقل المناسبه ٢.٩٤ الي ١.٧٦ م/ث.

٤- اجمالى تكاليف التشغيل ٤٥.٤ جـ/فدان فى مدى السرعات المناسبه فنيا .

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