INVESTIGATE A SIMPLE DESIGN FOR SWEET POTATO HARVESTING

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ABSTRACT

The digging harvesting machine was modified and tested to perform the effect of harvesting speeds on harvesting qualities such as sweet potato lifting, un-lifting, damaged, un-damaged, soil adhesion on tuber surface and machine productivity. These indicators were evaluated under condition of medium at El Dakahlia Governorate (Belqas), Egyptian. A lot of experimental field were conducted on sweet potato harvesting under three different levels of separator length (450, 700 and 1200mm); reciprocated cam with link length of 180, 210 and 240 mm and three forward speeds (3.6;, 5.1 and 7.2km/h) under digging Nose share.. The obtained results concluded that the maximum value of sweet potato lifting efficiency was 97.14% recorded at 3.6 km/h harvesting speed and reciprocated cam with link length of 180mm. At reciprocated cam with link length of 180mm, increasing forward speed from 3.6 to 7.2 km/h increased the un-lifted of 2.74; 1.26 and 1.19 times at separator length of 450, 700 and 1200mm respectively. Generally, increasing harvesting speed increased sweet potato damage and decreased un-damage percentage. For example, at reciprocated cam with link length of 180mm, increasing forward speed from 3.6 to 7.2 km/h increased mechanical damage from 2.80 to 3.85% and decreased un-damage from 97.12 to 96.15% at separator length of 450mm. The harvesting forward speed strongly affected soil adhesion on sweet potato surface. By increasing forward speed from 3.6 to 7.2 km/h decreased soil adhesion on sweet potato surface under all treatments except at reciprocated cam with link length of 180mm.

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INTRODUCTION

Harvesting is one of most important issues and therefore it will be necessary to have the equipment that facilitate the operations in short time and less damage quantity as production increases. The only alternative is to replace labor with machines since agricultural sector is managed by old aged farmers and limited manpower. Farmers have to make the most of available resources. Ramirez (1991) and Ismail et al. (2007) indicated that the sweet potato harvesting can be carried out in three ways, manual, semi-manual and mechanical. The **manual method** is the simplest. It is usually used by the scale producers and involves the use of a digging stick to lever the tuber out of the ground. **Semi- manual** is the most frequently used method in Egypt and involves the removal of the vines with the help of a harrow which clears the vines from the area to facilitate the final harvesting. The elimination of vines must be carried out 24 hours before harvesting. After the vines is removed a double mold plows passed down the center of the hill leaving a ridge in between the original two and ensuring that the soil does not cover part of the adjacent ridges. The tuber exposed after the first pass are picked up by hand and removed prior to making a second pass. Tubers are then again collected by hand. **Mechanical** is not ideally suited to conditions of Egypt. Where this system can be applied satisfactory results can be achieved with a potato harvester. Which this equipment the tubers can be collected in bulk in the field or on a trailer running alongside the harvester. The presence of vines or inadequate soil preparation can make this type of harvesting more difficult. On the others side, Kim et al. (2011) indicated that the experimental field were conducted, from 2005 to 2006 in Mokpo Experiment Station of the National Institute on root crop production, in order to determine the efficiency of mechanical harvesting and compare different harvesting methods. Mechanical harvesting method was done as follows: cutting of vines by machine, removal of plastic film mulching, and harvesting by two-row and one-row harvesting system. The result showed harvesting labor was decreased by 66.6% in two-row harvesting. The ratio of damaged sweet potato by mechanical harvesting decreased by 49.4% in two-row and 38.4% in one-row harvesting compared to conventional method (manual). The total labor cost was saved by 48.2 - 70.4% using mechanical method. In addition, the total income also increased by capacity 62.9 - 81.2%. Thus, it was concluded that mechanical harvesting is more efficient and economical method than conventional one. Furthermore, in the combine harvester an image acquisition system was constructed by Wooten et al. (2000) for mounting on a sweet potato harvester (machine vision). Images were captured with a standard digital camera.

The digging shovel, clamping conveyor and power transmission mechanism were designed and the key parameters were determined. The key parameters of the bar-type shovel are shovel's plane angle of on more 20°, the shovel's length of is 550 mm and shovel's width is 1000 mm. The total transmission ratio is 2.29 and gearbox's transmission ratio is 2. The gearbox output shaft speed is 500rpm. The chain transmission ratio is 1.15, and output speed is 435rpm and it may be used with medium-sized tractor (Liao Yulan et al. – 2012).

Kowalczuk (2001) mentioned that, an increases in the speed of the harvester within the studied range (0.26 - 0.64m/s) had a significant effect on greater losses caused by the fact that the roots were not removed from the soil and they were damaged and on reduced inorganic contamination in the collected material. No significant effect was observed of the working speed of the harvester on the losses caused by the root loss and on the quality of root heading. With the lowest speed of the harvester (0.26 m/s), all the carrot roots were removed from the soil and no broken roots were found in the collected material. Losses caused by root loss were 6.8%, while damage of the roots caused by their breaking was 2.6%. Leuschner and Herold (1988) conducted the experiments on impacted force during harvesting. A computer based method of evaluating impact forces on the harvested crop was developed. Impact points on the machinery which might cause damage were identified and impact forces were measured and compared with permissible crop deformation levels (sweet potato). Reasons for excessive impact forces were analyzed and modifications proposed. An example using a root harvester is presented. Finally, the soil adhesion on sweet potato surface was recorded by many researchers (Ruysschaert et al. -2007; Lilanga -2013 and Charles et al. -2012). There indicated that quantify soil and nutrient loss due to the harvesting of carrots, onion and round potatoes, determine the contribution of the named crops to soil and nutrient losses during harvesting, and develop guidance to management decision on proper harvesting techniques. Soil sticking to crop roots was washed out and the soil oven dried to estimate the amount of soil lost after harvesting. The soil samples from the crop roots were dried passed through a 2 mm sieve to obtain a fine earth for laboratory analysis. Soil loss due to crop harvesting (SLCH) leads to the reduction of substrate fertile layer.

To overcome the above problems facing sweet potato harvesting a simple machine was investigated. The aim of this study is to ameliorate the sweet potato lifting efficiency, reducing each of losses, damage and soil adhesion on tuber surface.

MATERIALS AND METHODS

This study was conducted in two stages; first one is that the new design of harvester parts was manufactured and adjusted at workshop of Agri. Engineering Dep., Mansoura University. While, the primary testes identified at Mechanical ZEI Lab. Second step is that, conducted experimental field to evaluate harvesting machine at El Dakahlia Governorate (Belqas) in season of 2012-2013. The soil specification was tabulated in table (1).

Table (1): Soil specification and moisture content

Soil components				Mc % "wb"	Soil structure
Clay %	Silt %	Coarse sand %	Fine sand%		
41	34	6	19	13.2	Clay loam

The designed unit operation

The ordinary potato harvester face many disadvantage during sweet potato harvesting then some considerations take in our mined such as:-

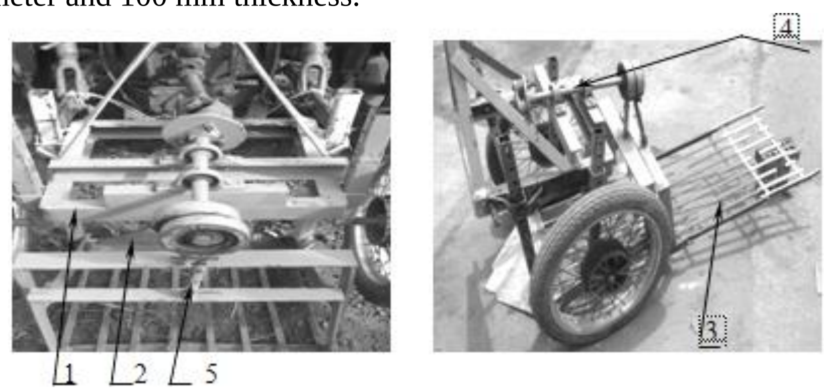
1- The design should lead to develop a digger that realizes minimum damage, maximum lifting and productivity.
2- The digger should improve harvesting efficiency with adequate safety and reduce drudgery in harvesting.

3- The root crops digger should be able to operate down depth of 280 mm for sweet potato.
4- The new prototype should be able to dig out, clean under the lowest injuring of root crops with operating width of 500 mm.

General description of novelty sweet potato harvester

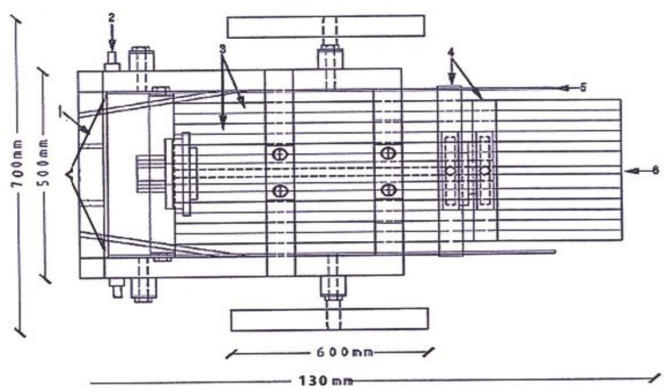
The proposed harvesting unit was developed on the basis of one row digging harvester with the main parts as shown in figures (1and 2).

Frame: it is made of squared steel with dimensions of 50 × 50 × 7mm. It takes a rectangular shape (650 × 550mm) and it includes elements to convey rotary movement from tractor PTO to a cam. The hitching system was connecting with the front frame and it was supplying with digger and elevators. The digger frame is holding with two tire wheels of 600 mm diameter and 100 mm thickness.



1- Frame 2- Digging blade 3- Separating 4- Transmission unit 5- Reciprocating link

Figure (1): Digging harvesting components



1- Share 2- Hatching points 3- Strips 4- Two longitudinal frames
5- Share frame 6- Separating unit

Figure (2): Plane view of digging harvesting

Digging blade: The digging forming shape was investigated as shown in figure (3). There are made from steel sheet with constant till angels of (26°) and operating width of 500m.

Separating unit: It consists of a frame with three different splits 450, 700 and 1200mm longs with constant width of 500mm, 8 mm thickness. It contains 7 stripes each with 25 mm and the distance between strips 10 mm. This frame is connected to the vibrating blade with fixable joint.

Figure (3): Nose furrow

Transmission system: It having main shaft transmit rotational cam motion to generate a vibrating motion. The arm of four bar linkage was adjusted with three different link length (180, 210 and 240mm) to get three different of reciprocating motions. The developed digger connected with a three points hitch of a 48.51 kW (65 hp) tractor.

Experiments and Measurements

A lot of experimental field were conducted on sweet potato harvesting further down three different levels of separator length (450, 700 and 1200mm); reciprocated cam with link length of 180, 210 and 240mm and three forward speeds of 3.6, 5.1 and 7.2km/h under digging Nose share.

Lifted and un-lifted efficiency (Li): there were recorded after harvesting operation done per every variable for the experimental groups. Sweet potato tuber lifted (m1) and un-lifted (m2) collected and weighted. There were calculated from the following equations:-

$$Li, \% = \frac{m1}{m1 + m2} \times 100$$

Mechanical damage (MD): The percent of mechanical damage may be determined using the following formula:

$$MD, \% = \frac{m3}{m3 + m4} * 100$$

Where: m3: mass of damaged root crops

m4: mass of root crops which have no bruise or cutting

Un- damage: It was calculated using the following equation:

$$UD, \% = [1 - (\frac{m3}{m3 + m4} \times 100)]\ \%$$

Soil adhesion on sweet potato surface (SAdh): the tuber were collected and weighted immediately after harvesting (m5) and then washing and left to dry and then weighing (m6). The soil adhesion was calculated according following equation (Ruysschaert et al. -2006):-

$$SAdh, \% = \frac{(m5 - m6)}{N}, \qquad g.\ tuber^{-1}$$

Machine productivity: the tubers per unit harvesting area were collected, weighted and then the ratio between the unite area and field was determined hence, the machine productivity was calculated.

RUSULTS AND DISCUSSION

Sweet Potato Lifted and Un-Lifted Efficiency

The relationship between harvesting forward speed and both of lifted and un-lifted of sweet potato tuber are illustrated in figure (4) under three levels of separator length (450, 700 and 1200mm) and reciprocated cam with link length of 180, 210 and 240mm. Generally, by increasing the forward speed decreased the lifted percentage of sweet potato and vice versa for un-lifted. For example, at reciprocated cam with link length of 180mm, by increasing forward speed from 3.6 to 7.2 km/h decreased lifted efficiency from 97.14 to 92.15% at separator length of 450mm. Also, the same trend of results were found at increasing the forward speed from 3.6 to 7.2 km/h, for separating length of 700 and 1200mm, the lifted of sweet potato in percentage decreased from 94.29 to 92.77% and from 94.28 to 93.15% respectively (Ismail et al. -2009).

Also, at reciprocated cam with link length of 180mm, increasing forward speed from 3.6 to 7.2 km/h increased the un-lifted 2.74 time at separator length of 450mm. Nonetheless, by increasing the forward speed from 3.6 to 7.2 km/h, for separating length of 700 and 1200mm, the un-lifted in percentage increased 1.26 and 1.19 times respectively.

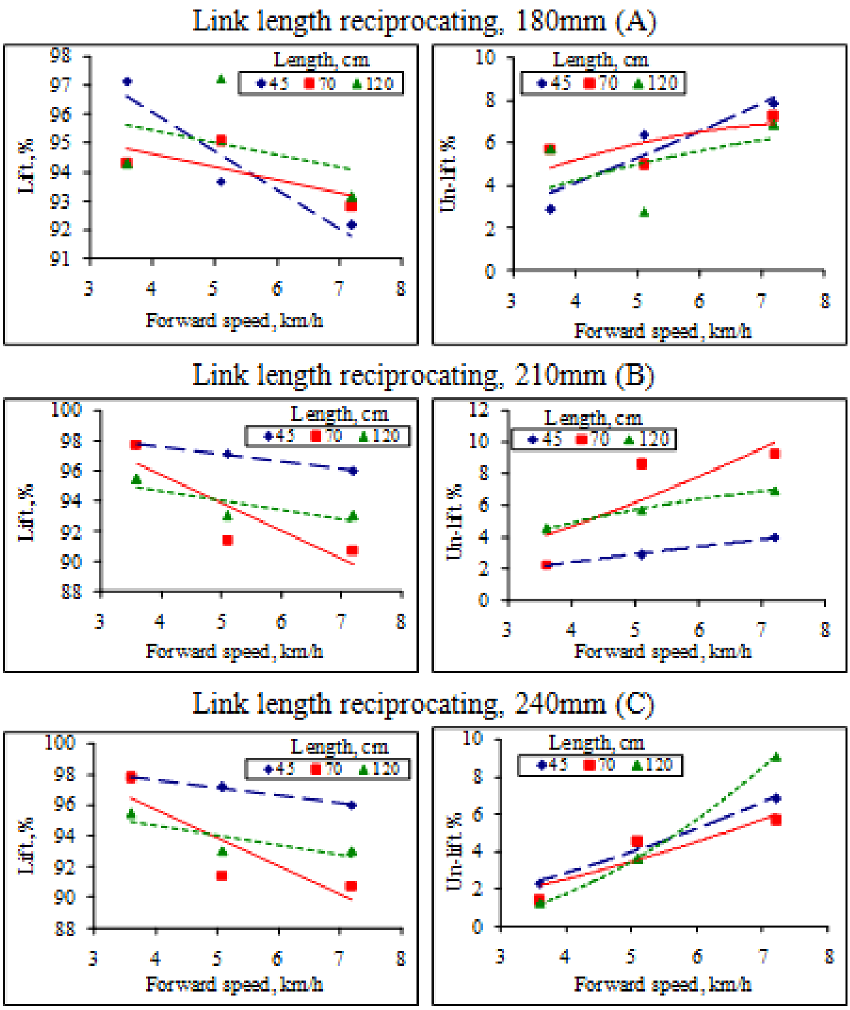


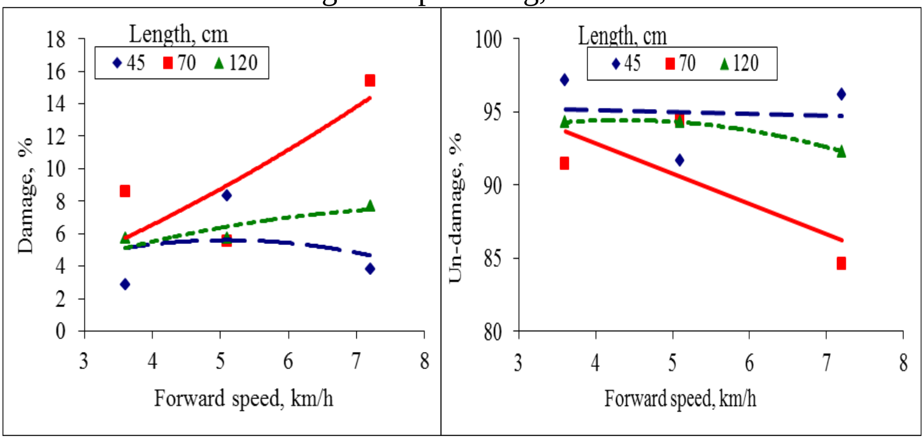
Figure (4): Effect of harvesting forward speed on lifted and un-lifted tuber

Referring to figure (4-A), the general trend of data curve for lifted rapidly decreased at separator length of 1200mm and slowly decreased at each of 450 and 700 mm separator length. By increasing the reciprocating cam length to 210mm the direction curves of lifted rapidly decreased at separator length of 700mm and slowly decreased at each of 450 and 1200mm separator length as shown in figure (4-B). While, by increasing the reciprocating cam length to 240mm the trend curves of lifted for the separated length (L) of 450 and 1200mm were slowly decreased and vice versa for L = 700mm (figure- 4-C). The vice versa were found with the negative effect for all above treatments at studies the influence of factors affecting un-lifted percentage. Generally, the lowest lifted (Li,%= 90.7%) of sweet potato was found at 7.2 km/h harvesting speed and elevator length of 700mm for reciprocating cam with link length of 210mm. But, at increasing reciprocating link length to 240mm the lowest lifted (Li = 90.9%) was recorded at 7.2 km/h and elevator length of 1200mm. Also, for reciprocating cam with link length of 210mm, the lowest lifted (Li = 92.9%) was recorded at 7.2 km/h harvesting speed and elevator length of 1200mm. of sweet potato was found at 7.2 km/h harvesting speed and elevator length of 700mm for reciprocating cam with link length of 210mm. But, at increasing reciprocating link length to 240mm the lowest lifted (Li = 90.9%) was recorded at 7.2 km/h and elevator length of 1200mm. Also, for reciprocating cam with link length of 210mm, the lowest lifted (Li = 92.9%) was recorded at 7.2 km/h harvesting speed and elevator length of 1200mm.

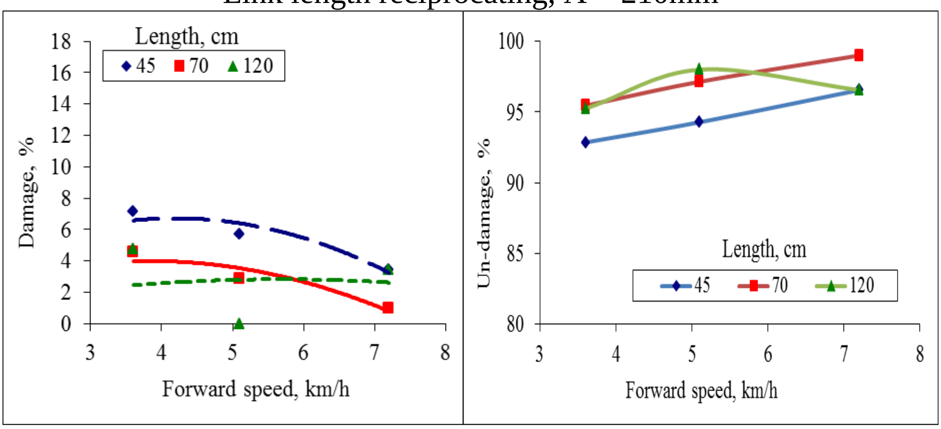
Mechanical Damage and Un-Damage Percentage

The relationship between harvesting forward speed and sweet potato damage and un-damage is illustrated in figure (5) under different three levels of separator length (450, 700 and 1200mm) and reciprocated cam with link length of 180, 210 and 240mm. Generally, increasing harvesting speed increased sweet potato damage and decreased un-damage percentage. For example, at reciprocated cam with link length of 18cm, increasing forward speed from 3.6 to 7.2 km/h increased mechanical damage from 2.8 to 3.85% and decreased un-damage from 97.12 to 96.15% at separator length of 450mm. Also, the same trend of results were found at increasing harvesting forward speed from 3.6 to 7.2 km/h, for reciprocated cam with link length of 700 and 1200mm, the mechanical damage increased from 8.57 to 15.38% and from 5.7 to 7.69% and un-damage decreased from 91.43 to 84.62% and from 94.3 to 92.31% respectively. Referring to figure (5-A), the general trend of data curve for mechanical damage rapidly increased at separator length of 700mm and slowly increased at each of 450 and 1200mm separator length and vice versa for un-damage percentage. By increasing the reciprocating cam length to 210mm the direction curves of mechanical damage for all treatment slowly decreased but the direction of un-damage slowly increased as shown in figure (5-B).

Link length reciprocating, A = 180mm



Link length reciprocating, A = 210mm



Link length reciprocating, C = 240mm

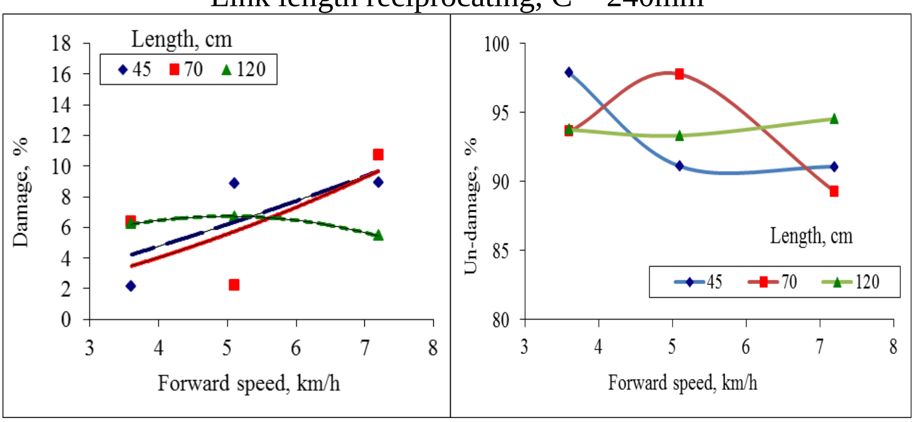


Figure (5): Effect of the harvesting forward speed on sweet potato

While, during increasing the reciprocating cam length to 24cm the trend curves of mechanical damage for the separated length (L) of 450 and 700mm were slowly increased and vice versa for L = 1200mm (figure -5-C). While, under the above condition, the trend curves of un-damage for the separated length (L) of 450 and 1200mm were slowly decreased and vice versa for L = 700mm. Generally, the maximum damage (D = 16.2%) of sweet potato were found at 7.2 km/h harvesting speed and elevator length of 700mm for reciprocating cam with link length of 180mm. But, at increasing reciprocating with link length to 210mm the maximum damage (D = 8.2%) were recorded at 3.6 km/h and elevator length of 450mm. It may be due to, the interaction between sweet tuber and the surface of elevator recorded heights damage because of less soil with sweet tuber.

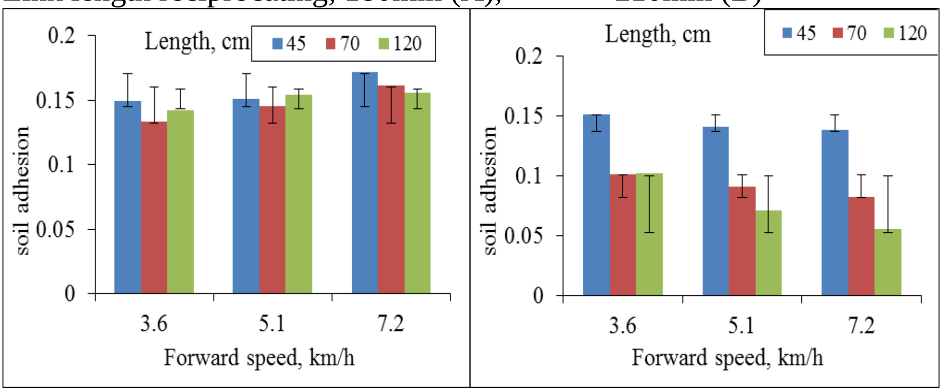
Also, for reciprocating cam with link length of 240mm, the maximum damage (D = 10.2%) were recorded at 7.2 km/h harvesting speed and elevator length of 700mm and vice versa for un-damage.

Soil adhesion on sweet potato surface

Figure (6) indicated the relationship between harvesting forward speed and soil adhesion on sweet potato surface under three levels of separator length (450, 700 and 1200mm) and three levels of reciprocated cam with link length of 180, 210 and 240mm. From figure, the results indicate that increasing forward speed from 3.6 to 7.2 km/h decreased soil adhesion on sweet potato surface under all treatments (figure 6-B and 6-C) except at reciprocated cam with link length of 180mm. It increased with increased harvesting speed (figure 6-A). It may due to, increases harvesting speed, the amount of soil on the surface of the elevator moving over.

Thus, the compatibility between the soil and the amount of movement of the elevator does not allow the removal of soil from the surface of the sweet potato. For example, by increasing forward speed from 3.6 to 5.1 km/h decreased soil adhesion on sweet potato surface by about 8.6 and 3.3% for separator length of 450mm and 700mm respectively at reciprocated cam with link length of 180mm (figure 6-A). Also, the same trend of results at 210mm link length of reciprocated cam were found at increasing harvesting forward speed from 3.6 to 7.2 km/h, for reciprocated cam with link length of 700 and 1200mm, the percentage of soil adhesion on sweet potato surface decreased 12.2 and 18.0% respectively (figure 6-B). Also, at 240mm link length of reciprocated cam, the percentage of soil adhesion on sweet potato surface decreased from 0.120 to 0.109 g.tuber^{-1}, from 1.118 to 0.101 g.tuber^{-1} and from 0.109 to 0.065 g.tuber^{-1} at increasing forward speed from 3.6 to 7.2 km/h and at separator length 0f 450, 700 and 120mm respectively.

Link length reciprocating, 180mm (A), 210mm (B)



Link length reciprocating, 240mm (C)

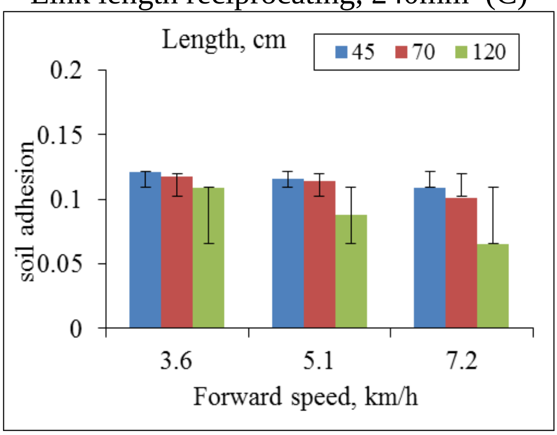


Figure (4-6): Harvesting forward speed via soil adhesion on sweet potato

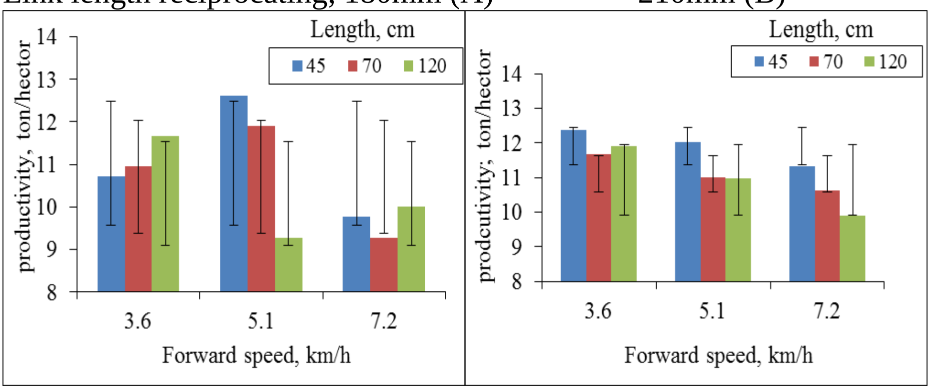
On the other side, by increasing the reciprocating cam length from 180 through 240mm, the percentage of soil adhesion decreased. It may be explain that by lengthening the length of the cam arm leads to increased amplitude, which do to reduce the soil adhesion on the tuber surface. For example, increasing the cam arm from 180mm to 240mm, the amount of soil adhesion reduce from 0.142 to 0.109 g.tuber^{-1} at harvesting speed of 3.6 km/h and 1200mm separator length.

At 210mm separator length recorded the best results of reducing the soil adhesion on sweet potato surface. The data at harvesting speed of 5.1km/h and 700mm of separator length were 0.091 g.tuber^{-1} at 210mm separator length against 0.145 and 0.114g.tuber^{-1} at 180 and 240mm respectively.

Harvesting productivity

Figure (7) indicated the relationship between harvesting forward speed and harvesting productivity (ton/hector) under three levels of separator length (450, 700 and 1200mm) and three levels of reciprocated cam with link length of 210 and 240mm. From figure (7), the results indicate that increasing forward speed from 3.6 to 7.2 km/h decreased harvesting

Link length reciprocating, 180mm (A)   210mm (B)



Link length reciprocating, 240mm (C)

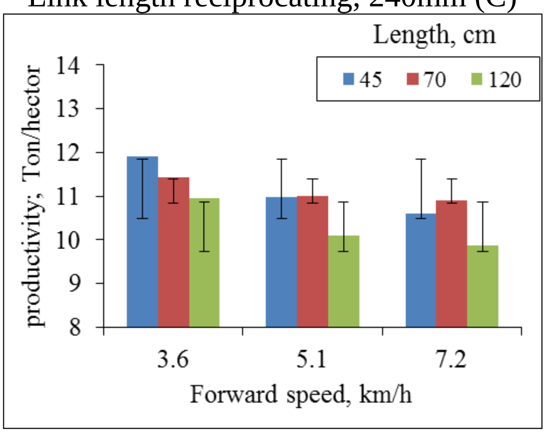


Figure (7): Harvesting forward speed via machine productivity

productivity (figure 7-B and 7-C) except at reciprocated cam with link length of 180mm the productivity increased until harvesting speed of 5.1km/h after then it strangely decreased (figure7-A).

CONCLUSION

The conclusions of this paper are summarized as follow:

1- The maximum value of sweet potato lifting efficiency was 97.14% recorded at 3.6 km/h harvesting speed and reciprocated cam with link length of 180mm.
2- At reciprocated cam with link length of 180mm, increasing forward speed from 3.6 to 7.2 km/h increased the un-lifted 2.74, 1.26 and 1.19 times at separator length of 450, 700 and 1200mm respectively.
3- Generally, increasing harvesting speed increased sweet potato damage and decreased un-damage percentage. For example, at reciprocated cam with link length of 180mm, increasing forward speed from 3.6 to 7.2 km/h increased mechanical damage from 2.80 to 3.85% and decreased un-damage from 97.12 to 96.15% at separator length of 450 mm.
4- The harvesting forward speed strongly affected soil adhesion on sweet potato surface. By increasing forward speed from 3.6 to 7.2 km/h decreased soil adhesion on sweet potato surface under all treatments except at reciprocated cam with link length of 180mm.

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الملخص العربى

إقتراح تصميم بسيط لحصاد البطاطا الحلوة

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طارق حسني الشبراوي** و هشام سامى فالح***

تم تعديل آلة لحصاد واختبار أداء تأثير سرعات الحصاد على جودة الحصاد مثل درنات البطاطا المحصودة وغير المحصودة، والتالفة، وغير التالفة، والتصاق التربة على سطح الدرنة وإنتاجية الآلة. تم تقييم الأداء الآلى تحت ظروف متوسطة في مركز بلقاس بمحافظة الدقهلية، جمهورية مصر العربية. وقد أجريت الكثير من التجارب الحقلية على حصاد البطاطا الحلوة تحت ثلاثة مستويات مختلفة من طول وحدة الفصل (٤٥٠، ٧٠٠، ١٢٠٠مم)، ثلاث أطوال لزراع الكامة (١٨٠، ٢١٠، ٢٤٠مم)، ثلاث سرعات أمامية (٣,٦، ٥,١، ٧,٢كم/ساعة) وشكل سلاح الحصاد (Nose share). وكانت النتائج المتحصل عليها:

١- أقصى قيمة سجلت لكفاءة الحصاد ٩٧,١٤٪ وذلك عند سرعة ٣,٦ كم / ساعة وطول زراع كامة ١٨٠مم. وعند طول زرع كامة ١٨٠ مم وزيادة سرعة القدم من ٣,٦ – ٧,٢ كم/ساعة.

٢- زادت الدرنات الغير محصودة ٢,٧٤، ١,٢٦، ١,١٩ مرة عند أطوال وحدة فصل ٤٥٠، ٧٠٠، ١٢٠٠مم على التوالى.

٣- عامة فإن زيادة سرعة الحصاد تؤدى إلى زيادة زادت زيادة سرعة الضرر فى الدرنات وإنخفاض الالدرنات الغير مصابة. وعلى سبيل المثال، عند طول زراع كامة ١٨٠مم، وزيادة سرعة التقدم من ٣,٦ – ٧,٢ كم/ساعة يزداد الضرر الميكانيكى من ٢,٨٠ – ٣,٨٥ % وتقل الدرنات الغير مصابة من ٩٧,١٢ – ٩٦,١٥ % عند طول وحدة فصل ٤٥٠مم.

٤- نتج من التجارب أن عامل سرعة التقدم يؤثر بدرجة كبيرة على التربة اللاصقة بسطح الدرنات. حيث بزيادة سرعة التقدم من ٣,٦ – ٧,٢ كم/ساعة تنخفض التربة اللاصقة على سطح الدرنات عند كل عوامل الدراسة ما عدا عند طول زراع كامة ١٨٠مم.

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