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المجلة العراقية لبحوث السوق
وحماية المستهلك

USING MATLAB TO SIMULATION THE CUTTING UNIT OF A POTATO DIGGER

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ABSTRACT

Potatoes are essential crop and providing them in significant quantities requires highly efficient machinery. Since the regulation and standardization process is not fixed, it was necessary to conduct tests to choose the best combination. Therefore, an experiment was conducted to choose the best calibration to obtain the best results. The field experiment was conducted in one of the agricultural fields in the Yusufiyah area of the Mahmoudiya district, which is located about 25 km south of the capital, Baghdad. The experiment was conducted for the purpose of studying the effect of the speed and cutting angle of the potato digger on some performance indicators. A simulation experiment was also conducted by using MATLAB, Solid Works, and 3D MAX for the purpose of comparing the simulation experiment with the field experiment and finding out the extent of agreement between the two experiments. In the two experiments, two factors were used, the first being forward speed, at three levels (1.95, 3, 4.74) km. h^{-1} . The second factor is the cutting angle of the potato digger, with three levels (12, 17, and 20) degrees. The characteristics to be measured are productivity (kg. h^{-1}), Minor losses (%), major losses (%), fuel consumption (l. ha^{-1}) This research used a completely randomized design with three replications. The results were analyzed statistically and the averages were tested at the least significant difference of 0.05. The results showed that there were significant effects of forward speed and cutting angle on all the studied characteristics. Increasing the speed from 1.95 to 4.74 km. h^{-1} led to an increase in productivity, fuel consumption and costs. The percentage of minor losses decreased from 6.1 to 3.3% when the speed increased from 1.95 to 3.00 km. h^{-1}, and when the speed increased to 4.47 km. h^{-1}, the percentage of minor losses increased by 4.6%, as well as in the simulation case.

When the cutting angle increases from 12 to 17 and then to 20 degrees. Productivity (kg.h-1), minor losses (%), and significant losses (%) all decreased. At the same time, both fuel consumption and costs increased.

Keywords: potato digger, MATLAB, solid works, fuel consumption, simulation.

***This article is taken from the first researcher's master's thesis.**

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استخدام الماتلاب لمحاكاة وحدة القطع في قالعة البطاطا

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الخلاصة

تعد البطاطا محصولًا مهمًا، وتوفيرها بكميات كبيرة يتطلب آلات عالية الكفاءة. وبما أن عملية التنظيم والتعيير ليست ثابتة، كان من الضروري إجراء اختبارات لاختيار التوليفة الأفضل. لذلك تم إجراء تجربة لاختيار المعايرة الأفضل للحصول على أفضل النتائج. أجريت التجربة الحقلية في أحد الحقول الزراعية في منطقة اليوسفية التابعة لقضاء المحمودية والتي تقع على بعد حوالي 25 كم جنوب العاصمة بغداد. أجريت التجربة لغرض دراسة تأثير سرعة وزاوية القطع لحفار البطاطس على بعض مؤشرات الأداء. وتم إجراء تجربة محاكاة باستخدام برنامج MATLAB و Solid Works وMAX 3D لغرض مقارنة تجربة المحاكاة مع التجربة الميدانية ومعرفة مدى التوافق بين التجربتين. تم في التجربتين استخدام عاملين الأول هو السرعة الأمامية عند ثلاثة مستويات (1.95، 3، 4.74) كم. ساعة$^{-1}$. العامل الثاني هو زاوية قطع حفار البطاطس بثلاثة مستويات (12، 17، 20) درجة. الصفات التي تم قياسها هي الإنتاجية (كغم. ساعة$^{-1}$)، الخسائر البسيطة (٪)، الخسائر الكبيرة (٪)، استهلاك الوقود (لتر. هكتار$^{-1}$) استخدم في هذا البحث تصميمًا عشوائيًا كامل وبثلاث مكررات. تم تحليل النتائج إحصائيا واختبار المتوسطات عند أقل فرق معنوي قدره 0.05. أظهرت النتائج وجود تأثير معنوي للسرعة الأمامية وزاوية القطع في جميع الصفات المدروسة. زيادة السرعة من 1.95 إلى 4.74 كم. ساعة$^{-1}$، أدى ذلك إلى زيادة الإنتاجية واستهلاك الوقود والتكاليف. كما انخفضت نسبة الخسائر البسيطة من 6.1 إلى 3.3% عند زيادة السرعة من 1.95 إلى 3.00 كم. ساعة $^{-1}$، وعندما ارتفعت السرعة إلى 4.47 كم. ساعة$^{-1}$، ارتفعت نسبة الخسائر البسيطة بنسبة 4.6%، وكذلك في حالة المحاكاة.

وعند زيادة زاوية القطع من 12 إلى 17 ثم إلى 20 درجة، انخفضت الإنتاجية (كغم. ساعة$^{-1}$) والخسائر الطفيفة (%) والخسائر الكبيرة (%)، بينما زاد استهلاك الوقود والتكاليف.

الكلمات المفتاحية: حفار البطاطا، ماتلاب، solid works، استهلاك الوقود، المحاكاة.

INTRODUCTION

The potato crop is the major crop in terms of human consumption after wheat and rice, and it is considered the best crop for cultivation because it has high flexibility in adapting to many environments **(Campos & Ortiz, 2019)**. Among the countries that produce the most potatoes are China and India, which produce approximately one-third of the world's potato production **(Rajiv , 2020)**. The Food and Agriculture Organization confirmed in 2021 that global production is estimated at 376 million tons of potatoes worldwide, China produces 94 million tons and India 54 million tons, the major potato-producing countries in 2021. The Food and Agriculture Organization indicated that the total area harvested for the year 2021 globally is 18,132,694 hectares and that the average production per hectare is 21 tons **(FAO, 2023)**. As for the amount of potato crop produced In Iraq, according to the statistics of the Ministry of Planning for the year 2022, it is (271) thousand tons, and the average production per dunum is 5349.8 kg. dunum-1 **(Statistics, 2024)**.

Potatoes are a rich source of vitamins C, B1, B2, B6 and B9, antioxidants and a number of trace elements. It is a necessary part of the diet and plays a functional role in maintaining the human body. Both antioxidants and phenolic compounds have the ability to

suppress cancer cells and improve heart health by reducing the risk of high blood pressure **(Khalid *et al*., 2020)**.

Potatoes are grown in Iraq in three seasons. The spring crop is planted in mid-January in warm regions, the summer crop is planted in mid-March to mid-April, which is in cold regions, and the autumn crop is planted in July to mid-August in the interior regions. The crop maturity period is 3-4 months. The potato crop needs temperatures ranging between 15-20 degrees Celsius, and the soil must be light clay with good water drainage, and the PH rate is between 5.5-7.5 **(Arim *et al*., 2019)**.

(Wasukira *et al*., 2017) stated that potatoes are mature when 75% of the leaves dry or turn yellow. At this point, areola removal surgery should be performed. The tubers are mature if they are larger than 60 mm or of a marketable size, and the skin does not peel off easily. The market value is greatly affected during the harvesting process, due to the damage that occurs during the extraction of potatoes from the ground, so great care is required in order to reduce these damages ***(*Mhaibis, *2019*)**and (**(Baritelle *et al*., 2000)**.

One of the most essential benefits of mechanical harvesting of potato crops is that it saves about 65% of harvest time compared to manual harvesting process **(Siddiq & Saad, 2012)**. Mechanical harvesting also saves 45% of crop costs **(Yasin *et al*., 2003)**

Due to the significant expansion of agricultural areas and the increase in population numbers, the development and evaluation of agricultural machines has become a problem that must be focused on. It is known that these machines are the main source of increasing agricultural production, and in most cases the machines that have been tested in certain countries do not give the same results in other countries because Different circumstances. In addition, the harvesting process requires that there be a good calibration of the machine to ensure obtaining high productivity and quality, and this procedure will require a lot of time and money in addition to the damage resulting from the process of repeating the work for the purpose of calibration, and all of this will affect the expected profits from the project. Therefore, in this research, the MATLAB program will be used to simulate the work of a potato harvester. **(Ingalls, 2008)** indicated that simulation is a process through which a model is designed that simulates the real system and experiments are conducted on it in order to understand a specific behavior or strategy for operating the system.

From the point of view of **(Kelton *et al*., 2015)**, simulation is a significant group of applications and methods used to imitate the operation of real systems. This simulation is usually performed on a computer equipped with special programs. Rossetti *et al*., 2014 indicated that simulation She is experimenting with the model. The behavior of the model simulates some salient aspect of the behavior of the system under study and the user performs experiments with the model to infer this behavior. This general framework has proven to be a powerful aid to learning, problem solving, and design. It is defined by **(Mason *et al*., 2008)** as "the process of designing a model of a real system and conducting experiments on this model for the purpose of either understanding the behavior of the system or evaluating different strategies (within the limits imposed by a standard or set of standards) for operating the system." According to this definition, it can The simulation must be a simulation of a discrete event. The MATLAB program was used for the simulation experiment and was used to design the potato digger to be tested in one of the engineering programs. The solid works program was

used in this research to design all the parts for the cutting unit and the conveyor chain. In the simulation program, the virtual assembly related to the research of the machine, soil and potatoes is designed and analyzed to extract results related to the characteristics. Thoughtful. In order to verify the validity of the simulation process and use it in subsequent tests, field tests must be conducted for the designed machine and the results obtained from the field tests must be compared with the simulation program. By taking into account all of the above-mentioned criteria, this study aims to:

- Verification of the simulation program for the cutting unit in the Potato Digger.
- Design the machine using SOLID WORKS software.
- Identify the best combination of the machine through which the best results can be obtained.
- Comparing the work of the field potato digger with the simulation program.

MATERIALS AND METHODS

Experiment Site

The field experiment was conducted in one of the agricultural fields in the Yusufiya district of the Mahmoudiya district, located south of the capital, Baghdad, about 25 km. The experiment was carried out on 2/28/2024. The experiment was conducted to study the effect of speed and cutting angle of the potato cutter on some performance indicators and compare it with the results obtained by using the MATLAB program to simulate the cutter work. Two factors were used in the research. The first is forward speed and at three levels (1.95, 3, 4.74) km. h^{-1}. The second factor is the cutting angle, at three levels (12, 17, 20) degrees. The characteristics that are intended to be measured are productivity (kg. h^{-1}), Minor losses %, major losses %, fuel consumption liters. hectare-1, total costs. This research used a completely randomized design with three replications. The results were analyzed statistically and the means were tested with the least significant difference of 0.05.

Experiment Design

A completely randomized block design was used, and the experimental units used were 27 experimental units consisting of the speed factor and the cutting angle, with three levels for each, and the number of replicates used was three replicates. The distance used for each experimental unit was 16 meters per experimental unit. The rest period distance before each operation is 5 meters. Thus, the total area becomes 771.12 square meters. The comparison of averages was made using the least significant difference (LSD) and under the probability level of 0.05.

Agricultural tractor

A 2011 New Holland TD80 tractor was used in this experiment

Table (1): showing the specifications of the TD80 tractor **(NEW HOLLAND, 2024).**

Engine	TD80
Engine	New Holland 5800
No. of cylinders	4
Capacity (cm^3)	3908
Bore x stroke (mm)	104 x 115
Rated engine power (hp)	80
Rate engine speed(rpm)	2500
Max . torque at 1500 rpm (Nm)	298
Torque rise(%)	25
Fuel tank capacity (l)	77

Potato Digger

An Iranian-made potato harvester (SABZ DASHT) was used to harvest two rows of potato crops. It is semi-autonomous and carried behind the tractor. The chain derives its movement from the PTO, and through gears it reaches the chain.

Figure (1): shows a front section of a potato digger

Table (2): shows the technological data of the digger. **(Dasht, 2017).**

Title	
Number of rows	2
Working width (cm)	150
Tractor power min(hp)	60
Linkage	Mounted 3 point
Seed hopper capacity (kg)	540
Dimensions (cm)	120*183*254
Weight approx. (kg)	697

Equations And Tools Used To Calculate Characteristics

Productivity (kg.h^{-1})

It is calculated using the following equation used by **(Alsharifi *et al*., 2019)**.

$$P = \frac{W_{UD+SD+SL+QL}}{T} \quad \ldots\ldots\ldots\ldots\ldots(1)$$

whereas :

P = Productivity (kg.h-1)

W = Weight (kg)

UD = weight of undamaged tubers (kg) .

SD = Weight of major damaged tubers (kg).SL = weight of Minor damaged tubers (kg).

QL = quantitative loss (kg).

T = time (hour).

Loss ratio (%)

The following equations were used to calculate total, minor, and major losses, as confirmed by **(Mohamed Issa *et al*., 2020)**:

$$D\ \% = \frac{W_4}{W_3+W_4} * 100\% \quad \ldots\ldots\ldots\ldots\ldots (2)$$

D % = percentage of total losses

W_4 = Minor and major damaged tubers (kg)

W_3 = undamaged tubers (kg)

$$\text{Minor potato } \% = \frac{W_5}{W_3+W_4} * 100\% \quad \ldots\ldots\ldots\ldots\ldots\ldots(3)$$

W_5 = Minor damaged tubers (kg)

$$\text{Major losses } \% = \frac{W_6}{W_3+W_4} * 100\% \quad \ldots\ldots\ldots\ldots\ldots\ldots(4)$$

W_6 = major damaged tubers (kg)

Fuel Consumption (l.ha-1)

The amount of fuel was calculated by using a graduated beaker to measure the amount of fuel for the length of the transaction. This is done by filling the fuel tank completely before each transaction. After completing the transaction, the tank is filled from the graduated beaker and the quantity that was placed for your treatment is determined, as shown below is a picture of the beaker.

Then use the following equation to determine the amount of fuel (litres. hectare^{-1}), which everyone used **(Alsharif & Ameen , 2018)**, as shown below.

$$Q_F = \frac{Q_P * 10000}{W_P * D * 1000} \qquad \text{..... ..... (5)}$$

QF = Fuel consumption (l.ha^{-1}).
QP = Quantity of fuel per treatment length (liters).
WP = working width of the machine (meters).
D = Transaction length (meters).
Software used in simulation

Solid Works

The SOLID WORKS program is used to draw the potato digger in 3D to be used in the simulation process.

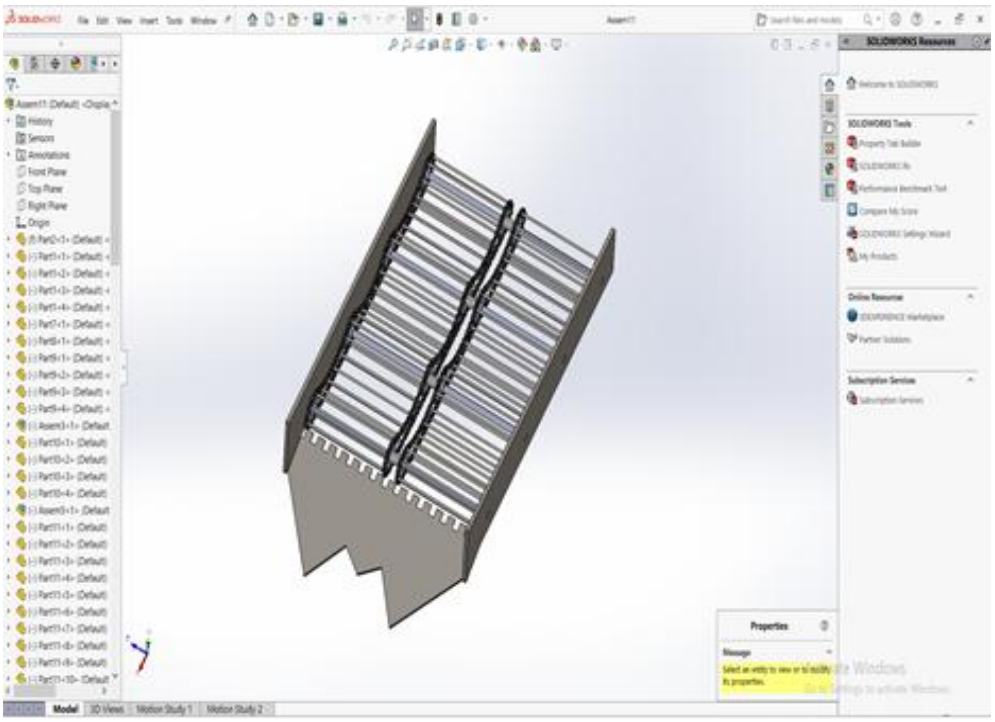

Figure (2): shows an top section of a potato digger.

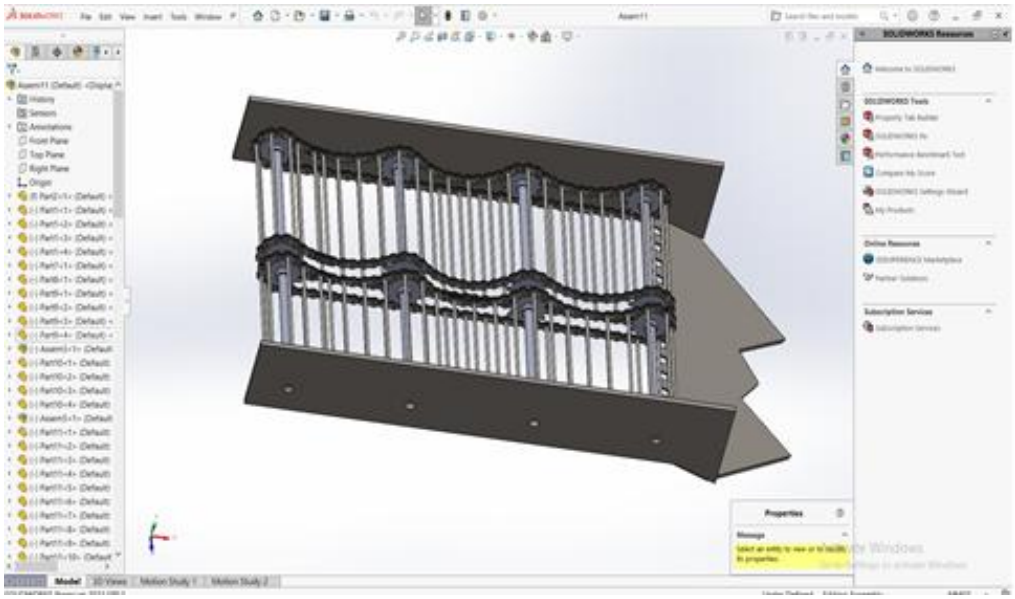

Figure (3): shows a side section of a potato digger.

Matlab

The Matlab program was used for the purpose of simulation, where the following equations were used to calculate the studied characteristics.

```
    if V==1.95
p(a) = 0.0038*a^5 - 0.2*a^4 + 3*a^3 + 6.1e-12;
p1(a) = 0.017*a^4 - 0.6*a^3 + 5.9*a^2 + 5.6e-13;
p2(a) = 0.00056*a^5 - 0.02*a^4 + 0.2*a^3 + 4.8e-13;
p3(a)= - 4.2e-08*a^6 - 2.5e-06*a^5 + 0.00012*a^4 + 0.5  ;
   elseif V==3
p(a) = - 7e-05*a^6 - 0.0039*a^5 + 0.14*a^4 + 2.6e-12;
p1(a) = 0.0072*a^4 - 0.24*a^3 + 2.3*a^2 + 2.3e-13;
p2(a)= 0.00019*a^5 - 0.0066*a^4 + 0.064*a^3 + 1.5e-13;
p3(a) = - 1.6e-07*a^6 - 7.2e-07*a^5 + 0.00013*a^4 + 0.5;
   elseif V==4.74
p(a) =  7.4e-05*a^6 - 0.0086*a^5 + 0.17*a^4 + 3.6e-13;
p1(a) = 0.00065*a^5 - 0.022*a^4 + 0.2*a^3 + 5e-13;
p2(a) = 0.00015*a^5 - 0.0054*a^4 + 0.051*a^3 + 1.2e-13;
p3(a)= - 1.1e-07*a^6 - 2.2e-06*a^5 + 0.00015*a^4 + 0.5;
    if A==12
p(s)= - 1.1e+02*s^3 + 7.1e+02*s^2 + 62*s + 3.1e-12;
p1(s) = 0.00065*s^5 - 0.022*s^4 + 0.2*s^3 + 5e-13 ;
p2(s) = 3.1*s^3 - 23*s^2 + 65*s - 4.6e-14;
p3(s)=  - 0.0011*s^6 - 0.0023*s^5 + 0.24*s^3 + 0.5;
    elseif A==17
```

p(s)= 2.3*s^6 - 22*s^5 + 2.9e+02*s^3 + 3.7e-12;
p1(s)= 1.7*s^3 - 11*s^2 + 51*s - 7.6e-15;
p2(s)= 0.8*s^3 - 5.3*s^2 + 17*s - 8.7e-15 ;
p3(s)= - 0.00065*s^6 - 0.0073*s^5 + 0.32*s^3 + 0.5;
elseif A==20
p(s) = - 55*s^4 + 3e+02*s^3 + 1.2e+02*s + 3.3e-12;
p1(s) = 0.97*s^4 - 5.1*s^3 + 38*s - 4.1e-14;
p2(s)= 0.58*s^3 - 3.4*s^2 + 12*s - 4.9e-15;
p3(s)= - 0.00043*s^6 - 0.0087*s^5 + 0.33*s^3 + 0.5;
v = speed
a = angle
p = Productivity (kg.h-1)
p1= Minor potato (%)
p2= major potato(%)
p3= Fuel consumption ($l.ha^{-1}$)

3ds Max

The 3ds Max program was used to produce the simulation process, as the MATLAB program was linked to the 3ds Max program, as shown in the images below.

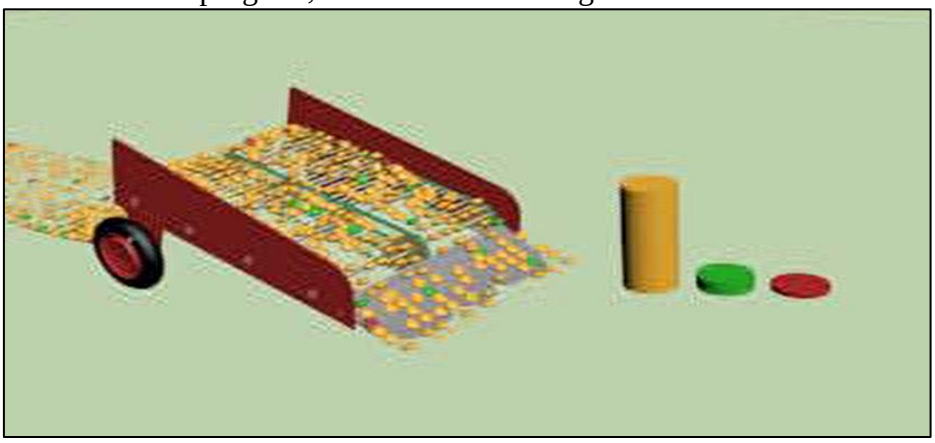

Figure (4): shows the simulation process.

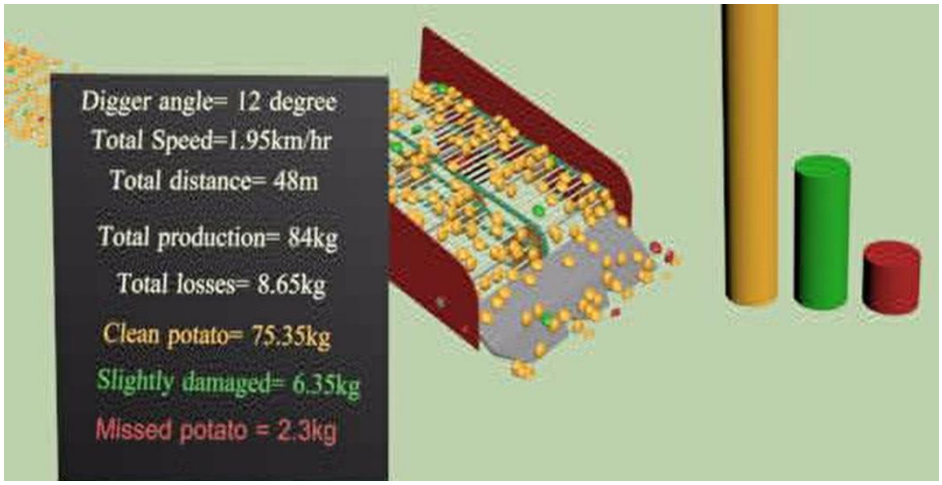

Figure (5): shows the production quantity in the simulation.

RESULTS AND DISCUSSION

The Effect of Forward Speed And Cutting Angle Of The Potato Cutter And Their Interaction On Productivity (kg.h-1)

Table (3) shows the effect of the practical speed of the machine unit and the cutting angle of the potato cutter and their interaction on productivity (kg.h-1) for both the field experiment and the simulation experiment. The results of the two experiments showed that there are significant differences between the average speed and practical productivity values at a significant level (0.05). In the field experiment, it turns out that increasing the practical speed from 1.95 to 3.0 and then to 4.74 km.h^{-1} led to a significant increase in practical productivity. The lowest productivity was 1804 kg.h^{-1} at a speed of 1.95 km.h^{-1} and productivity increased to 3782 and then to 4732 kg.h^{-1} when the speed increases to 3.00 and then to 4.74 km.h^{-1}. The reason for this may be attributed to the fact that increasing the speed will lead to an increase in the amount of crop raised during the uprooting process for the same distance traveled. Otherwise, at slow speeds, the amount of raised crop will be less because time is inversely proportional to the speed, and therefore at high speed it requires less time for the uprooting process and vice versa. However, at slow speed, it will take more time. This is consistent with the findings of **(Abdulla *et al.*, 2022)** and **(Alsharifi *et al.*, 2019)**. In the simulation experiment, the results also showed that there were significant differences between the average speed and the practical productivity values kg.h^{-1}. Increasing the practical speed from 1.95 to 3.0 and then to 4.74 km.h^{-1} led to an increase in the practical productivity of the machine unit kg.h^{-1}. The lowest productivity was 1910 kg.h^{-1} at the lowest operating speed 1.95 km.h^{-1}, and productivity increased to 4112 and then to 5090 kg. h^{-1} when the speed increases to 3.00 and then to 4.74 km. h^{-1}. The reason for this may also be that increasing speed may also have affected the amount of crop passing during the same time period for the same specified distance. This indicates that there is agreement in the practical productivity and the productivity in the simulation, and that the difference in the amount of production is due to the germination rate and the conditions that must be available during the growth stage, in addition to the difference in moisture and soil compaction in the same location.

From the same table (3), the results showed that there were no significant differences between the average angles in the practical productivity values at a significance level (0.05) for both the field experiment and the simulation experiment.

The same table (3) also shows the effect of the interaction between both practical speed and extraction angles on practical productivity. The results showed that there were significant differences in productivity values, and that the highest productivity in the field experiment was 4745 kg. h^{-1} at the highest speed of 4.74 km.h^{-1} and the minimum angle of cut is 12 degrees. While the lowest productivity was 1664 kg. h^{-1}at the lowest speed of 1.95 km.h^{-1} and the highest cutting angle of 20 degrees. The reason for this is that the distance traveled is greater at the highest speed and lowest angle, and thus the productivity is higher. In the simulation, the results also showed significant differences in productivity values. The highest productivity was 5162 kg. h^{-1} at the highest speed of 4.74 km.h^{-1} and the highest angle of cut is 20. While the lowest productivity was 1735 kg. h^{-1}at the lowest speed of 1.95 km.h^{-1} and the cutting angle is 17 degrees.

Table (3): The effect of forward speed and cutting angle and their interaction on productivity (kg.h-1).

Speed(field) (km.h-1)	***Angle* (field)**			**Speed average**
	12	17	20	
1.95	2069	1678	**1664**	1804 C
3.00	3572	3904	3868	3782 B
4.74	**4745**	4726	4725	4732 A
Angle average	3462 A	3436 A	3419 A	---
LSD (P≤0.05)	**speed : 110.410 * , angle : 110.410 NS, interference 191.240***			
Speed(simulation) (km.h-1)	Angle (simulation)			Speed average
	12	17	20	
1.95	2240	**1735**	1755	1910 C
3.00	3878	4294	4163	4112 B
4.74	4999	5111	**5162**	5090 A
Angle average	3706 B	3713 A	3693 C	---
LSD (P≤0.05)	speed : 12.873* , angle : 12.873*, interference 19.055*			

The Effect Of Forward Speed And Cutting Angle Of The Potato Cutter And Their Interaction On The Percentage Of Minor Losses %

Table (4) shows the effect of the practical speed of the machine unit and the cutting angle of the potato cutter and their interaction on Minor losses for both the field experiment and the simulation experiment. The results showed that there are significant differences between the average speed and the values of Minor losses at a significance level (0.05). In the field experiment, it turns out that increasing the practical speed from 1.95 to 3.0 km. h^{-1} led to a Minor decrease in the percentage of losses from 6.1 to 3.3%, and with an increase in speed to 4.74 km. h^{-1} Losses increased to 4.6%. In the simulation experiment, the results also showed that there were significant differences between the average speed and the percentage of Minor losses. The practical speed increases from 1.95 to 3.0 km. h^{-1} led to a Minor decrease in the percentage of losses from 5.1 to 2.9%, and with an increase in speed to 4.74 km. h^{-1} The percentage of Minor losses increased again to 4.1%. The reason for this may be that at high speeds the knife may rise to the top and thus lead to damage to the crop compared to slow speeds, and this was confirmed by **(Ibrahim *et al*., 2008)**, **(Tikuneh *et al*., 2023)**, and **(Alkaabi & Al-Ani , 2023)**. As for the slow speed, dust may fall from between the bars at the 8beginning of the chain, which is why

the dirt cushion is small and thus Minor damage to the crop occurs. This is consistent with what was found by **(Ali, 2013)** and ***(*Kheiry *et al*., 2018)**. From the results, it is clear that there is a great agreement between the results of the small losses in the practical experiment and the small losses in the simulation experiment.

From the same table (4), the results showed that there were significant differences between the average angles in the values of Minor losses at a significance level (0.05) for both the field experiment and the simulation experiment. In the field experiment, it was found that increasing the cutting angle from 12 to 17 and then to 20 degrees decreased the percentage of Minor losses. The highest Minor losses were 7.7% at the angle of 12 degrees, and the Minor losses decreased from 3.6 to 2.6% at the angles of 17 and 20 degrees, respectively. In the simulation, it appears that increasing the cutting angle from 12 to 17 and then to 20 degrees decreased the percentage of Minor losses. The highest Minor losses were 6.6% at the angle of 12 degrees, and the Minor losses decreased from 3.3 to 2.3% at the angles of 17 and 20 degrees, respectively. The reason for this is that when the cutting angle increases, the edge of the knife will move away from the crop, in addition to the fact that the dirt cushion will be major, and therefore the percentage of Minor losses will decrease, and this is consistent with **(Wu *et al*., 2021)**. It turns out that increasing the angle in both experiments led to a decrease in the value of Minor losses.

Table (4) also shows the effect of the interaction between practical speed and extraction angles on the percentage of Minor losses. The results showed that there are significant differences in the values of Minor losses. The highest losses in the field experiment were 10.4% at the second speed of 1.95 km.h-1 and the minimum cutting angle of 12 degrees. While the smallest losses were 1.7% at speed 3.00 and the highest cutting angle was 20 degrees. In the simulation, the results also showed significant differences in the values of Minor losses. The highest losses were 8.2% at a speed of 1.95 km. h^{-1} and the minimum cutting angle is 12. While the smallest losses were 1.3% at a speed of 3.00 km. h^{-1} and the highest cutting angle is 20 degrees. This indicates that there is agreement in field Minor losses and simulation Minor losses.

Table (4): The effect of forward speed and cutting angle and their interaction on the percentage of Minor losses %.

Speed(field) (km.h-1)	**Angle (field)**			**Speed average**
	12	17	20	
1.95	10.4	4.5	3.3	6.1 A
3.00	5.6	2.6	1.7	3.3 C
4.74	7.1	3.8	2.9	4.6 B
Angle average	7.7 A	3.6 B	2.6 C	---
LSD (P≤0.05)	speed : 0.2 * , angle : 0.2 *, interference 1*			
Speed(simulation) (km.h-1)	Angle (simulation)			Speed average
	12	17	20	
1.95	8.2	4.1	2.9	5.1 A
3.00	5.1	2.3	1.3	2.9 C
4.74	6.4	3.4	2.6	4.1 B
Angle average	6.6 A	3.3 B	2.3 C	---
LSD (P≤0.05)	speed : 0.2 * , angle : 0.2 *, interference 0.3*			

The Effect Of Forward Speed And Cutting Angle Of The Potato Cutter And Their Interaction On The Percentage Of Major Losses %

From the same table (5), the results showed that there were significant differences between the average angles in the values of major losses at a significance level (0.05) for both the field experiment and the simulation experiment. In the field experiment, it was found that increasing the cutting angle from 12 to 17 and then to 20 degrees decreased the percentage of major losses. The highest major losses were 3.4% at the angle of 12 degrees, and the major losses decreased from 1.0 to 0.8% at the angles of 17 and 20 degrees, respectively. In the simulation, it appears that increasing the cutting angle from 12 to 17 and then to 20 degrees decreased the percentage of major losses. The highest major losses were 2.3% at the angle of 12 degrees, and minor losses decreased from 0.9 to 0.8% at the angles of 17 and 20 degrees, respectively. Here, there is agreement between practical and simulation.

Table (5) also shows the effect of the interaction between practical speed and cutting angles on the percentage of significant losses. The results showed that there are significant differences in the values of major losses. The highest losses in the field experiment were 5.7% at a speed of 4.47 km.h^{-1} and a minimum angle of cut of 12 degrees. While the smallest losses were 0.6% at speed 3.00 and the highest cutting angle was 20 degrees. In the simulation, the results also showed significant differences in the values of major losses. The highest losses were 2.8% at a speed of 1.95 km. h^{-1} and the minimum cutting angle is 12. While the smallest losses were 0.5% at a speed of 3.00 km. h^{-1} and the highest cutting angle is 20 degrees

Table (5): The effect of forward speed, cutting angle, and their interaction on the percentage of major losses %.

Speed(field) (km.h-1)	Angle (field)			Speed average
	12	17	20	
1.95	1.9	1.2	0.9	1.3 B
3.00	2.7	0.8	0.6	1.4 B
4.74	5.7	1.1	1.0	2.6 A
Angle average	3.4 A	1.0 B	0.8 B	---
LSD (P≤0.05)	speed : 0.2 * , angle : 0.2 *, interference 1*			
Speed(simulation) (km.h-1)	Angle (simulation)			Speed average
	12	17	20	
1.95	2.8	1.2	0.9	1.6 A
3.00	1.8	0.6	0.5	1.0 C
4.74	2.4	0.01	0.9	1.4 B
Angle average	2.3 A	0.9 B	0.8 C	---
LSD (P≤0.05)	speed : 0.2 * , angle : 0.2 *, interference 0.5*			

The Effect Of Forward Speed And Cutting Angle Of The Potato Digger And Their Interaction On Fuel Consumption (l. ha^{-1})

From the same table (6), the results showed significant differences between the average angles in fuel consumption values at a significance level (0.05) for both the field and simulation experiments. When the cutting angle increases, fuel consumption increases. The reason for this may be due to the power that the tractor needs in order to overcome the resistance of the soil when the cutting angle is major, as it requires a greater torque force from the engine, and to provide the engine's torque, it

requires saving more fuel. Otherwise, at small angles, this requires a greater amount of fuel, and this is consistent with **(Embaby, 1985)** and **(Tikuneh *et al.*, 2023)**. The table also shows that there is great agreement between the field experiment and simulation.

The same table (6) also shows the effect of the interaction between practical speed and take-off angles on fuel consumption. The results showed that there were significant differences in fuel consumption values, and that the highest fuel consumption for the field experiment was 41,230 L . ha^{-1} at the highest speed of 4.74 km. h^{-1} and the major cutting angle of 20 degrees. While the lowest fuel consumption was 15,190 L . ha^{-1} at the minimum speed of 1.95 and the minimum cutting angle of 12 degrees. In the simulation, the results also showed significant differences in fuel consumption values. The highest fuel consumption was 40,150 L . ha^{-1} at the highest speed is 4.74 km. h^{-1} and the highest cutting angle is 20. While the lowest fuel consumption was 14,760 L . ha^{-1} at the lowest speed of 1.95 km. h^{-1} and angle cut 12 degrees.

Table (6): The effect of forward speed, cutting angle, and their interaction on fuel consumption (L . ha^{-1}).

Speed(field) (km.h-1)	Angle (field)			Speed average
	12	17	20	
1.95	15.190	18.450	19.530	17.723 C
3.00	28.210	34.720	36.890	33.273 B
4.74	32.550	39.060	41.230	37.613 A
Angle average	25.316 C	30.743 B	32.550 A	---
LSD (P≤0.05)	speed : 1.521 * , angle : 1.521 *, interference 2.635*			
Speed(simulation) (km.h-1)	Angle (simulation)			Speed average
	12	17	20	
1.95	14.760	18.010	18.880	17.217 C
3.00	27.560	33.850	36.020	32.477 B
4.74	31.470	37.980	40.150	36.533 A
Angle average	24.597 C	29.947 B	31.683 A	---
LSD (P≤0.05)	speed : 1.085 * , angle : 1.085 *, interference 1.508*			

CONCLUSIONS

- The highest productivity (kg.h^{-1}) was at the third speed, 4.74 km.h^{-1}, and the angle was 12 degrees, and the lowest productivity was at the speed of 1.95 km. $hour^{-1}$ and the angle is 20 degrees.
- There is no significant effect when increasing the cutting angle of the potato digger from 12 to 17 and then 20 degrees on productivity (kg. h^{-1}).
- The lowest percentage of minor losses was at a speed of 3.00 km. h^{-1} and the cutting angle was 20 degrees for both the practical and simulation experiments, which were 1.7% and 1.3%, respectively.
- There is no significant effect between speed 1.95 and 3.00 km. h^{-1} for significant losses, as well as between angles of 17 and 20 degrees

- When the speed increases from 1.95 to 3.00 and then to 4.74 km. Hour-1 The amount of fuel consumption increased for both experiments, when the angle increased from 12 to 17 and then to 20 degrees.

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