



EFFECTS OF FORWARD SPEEDS AND BLADE ANGLES OF POTATO DIGGER ON FUEL CONSUMPTION AND TUBER MECHANICAL DAMAGES

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ABSTRACT

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This experiment was conducted in Shamamik- Erbil state in Iraq-Kurdistan Region during the middle of summer of 2021 in order to determine the effects of different blade angles and forward speeds of potato digger in the fuel consumption and mechanical damages. Split plot arrangement under Randomized Completely Block Design was replications. Two blade angles (18⁰) and (22⁰) were located as main plot, while three forward speeds 2.6, 3.51 and 4.36 Km.h⁻¹ were located as sub plots. The results were as following: the blade angle of (22⁰) recorded the lowest percentage values for all studied traits, namely, undamaged tubers, severe damage, slight damage, lifted tubers and damage index except in digging depth and fuel consumption which gave higher values than those obtained from the blade angle of (22⁰). By increasing the forward speed, weight of (undamaged tubers 69.11%, lifted tubers 79.27% and digging depth 26.16cm) were decreased, while the rest of the traits increased. At any blade angle (18⁰, 22⁰), as the forward speed increased, the values of (severe damage 1.84%, 2.87%, slight damage 17.50%, 12.48, fuel consumption 44, 43 liter.ha⁻¹ and damage index 142, 104) were increased, while the other attributes decreased.

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INTRODUCTION

The obtained results revealed that the proper operating conditions for the prototype potato digger in small holdings are forward speed of 2.30 km.h⁻¹, rake angle of 14°, and digging depth of 30 cm to achieve actual field capacity of 0.23 fed.h⁻¹ and the lowest percentage of total losses, including 2.90% for damaged tubers and 1.20% for un-harvested tubers, as well as high harvesting efficiency (Tawfik & Abdallah, 2012). The percentage of exposed potatoes, undug potatoes, and sliced potatoes dropped when the blade angle of the root crop digger was increased (Rani, Mukesh, Kumar, & Sharma, 2019), They also discovered that a blade angle of 25°, a stroke length of 30 mm, and a speed of 450 strokes per minute were the best parameters for feeding and separation of the material in their research on an oscillating blade for potato harvesting. In an experiment (Hammad, Ibahim, & Amin, 1991) indicated that increasing blade tilt of 8⁰, 12⁰, 16⁰ and 20⁰, the surface tubers were increased of 10.32, 20.27, 52.06 and 78.36%, and the bruised tubers decreased

of 86.77, 73.57, 40.36 and 11.415, respectively, they also found that increasing the undamaged tubers were 86.91, 89.43 and 95.26% and the damage tubers decreased of 13.09, 10.57 and 4.74%, at forward speed of 1.03, 2.1 and 3.05 km.h⁻¹, respectively. (Abdel et al. 2002 cited by Morad et al. 2015) mentioned that the forward speed of the machine is 1.5, 2.3, and 3.1 km. h⁻¹, the blade angle is 14.8 and 20 degrees, and the forward speed of the machine is 1.5, 2.3, and 3.1 km.h⁻¹. The capacity of the machine and the expenses of harvesting were also estimated and compared to manual harvesting. According to the best engineering factors for the operation of the potato harvested machine, which achieved the highest percentage of tubers and the lowest percentage of lost and lost tubers, are the machine's forward speed of 2.3 km.h¹, and the blade's angle of 14 degrees.

The forward speed of operation was another consideration in the design of the potato harvester. Over the course of three years of experiments, the different difficulties of potato damage at harvest were investigated by (Peterson, 1975)., and it was discovered that by increasing field speeds during harvesting machine operation, the bruising damage of the potato was reduced. Potato harvesting machines were also advised to travel at a speed of 2.5-6.5 km.h⁻¹, with an average value of 4.0 km.h⁻¹ (Romanelli & Milan, 2010). The percentage of superficially scratched tubers and broken tubers rose when the forward speed of the harvesting equipment was increased, according to the study findings. As a result, overall tuber damage and the potato damage index value both rose. When the harvester forward speed was raised, the percentage of lifting potato tubers fell and the number of potatoes buried in the soil grew, and the harvester forward speed of 2 km.h⁻¹ was the best performance (Al-Dosary, 2016).

The resulting equations and regression lines reveal that increasing the speed of a potato digger by 1 km.h⁻¹ results in a 2.7 pcs/m² rise in losses of potato tubers in the control variant and a 2.0 pcs/m² decrease in losses of potato tubers in the experimental version. Furthermore, an increase in movement speed from 1.8 to 3.4 km/h resulted in a 4.7 pcs/m² increase in potato tuber losses in the control form, whereas losses were 4 pcs/m² in the experimental variant (Baybulatov, Aushevent, Khamkhoev, & Tsechoeva, 2021). Researchers (Abdel-Maksoud, Morad, & Morghany, 2004) found that utilizing a box-picker cut the cost of excavating by 20%. A potato digger was created to gather potatoes. It was suggested that a forward speed of 2.4 km. h⁻¹ and an operating speed of 1.2 m.s⁻¹ would result in the maximum amount of undamaged potato with the least amount of damage and buried potato. The highest percentage of tubers lifting was 92.47% at a forward speed of 4.5 km.h⁻¹; additionally, as the forward speed increased from 2.5 to 6.5 km. h⁻¹, the scuffed potatoes increased from 1.70 % to 2.48 %, while the highest percentage of total damage tubers was 4.07% at a forward speed of 6.5 km.h⁻¹. The treatment of a 4.5 km.h⁻¹ forward speed (Issa, Zhang, El-Kolaly, Yang, & Wang, 2020). The forward speed of the machine and the speed of the moving elements should be set so that enough soil remains on the machine until the potatoes have completed their journey through it. Potatoes may be damaged during transit, loading and unloading, grading, and other processes, in addition to during harvesting (Hessen & Kroesbergen, 1960). The harvester forward speed of 3.1 km.h⁻¹ the least tuber damage. The percentage of unlifted roots, bruised roots, and cut roots decreased as digging depth and forward speed decreased, but the

percentage of lifted roots and undamaged roots rose at a digging depth of 40 cm and a forward speed of 1.5 km.h⁻¹, the lowest values of unlifted roots were 3.0%, bruised roots were 5.1%, cut roots were 4.0%, and the greatest values of lifted roots were 97%, undamaged roots were 90.9%, and the digging cost was 44.65(L.E. ton⁻¹), he also discovered that digging depths of 25 and 40 cm and forward speeds of 3.6 and 1.5 km.h⁻¹ yielded the greatest and lowest cost values of 245.28 and 44.65L.E.ton⁻¹, respectively by (Ali, 2013).The objective of the experiment was to test the best blade angle and practical speed in harvesting potatoes using a tuber digger with the least mechanical damage, while calculating the amount of fuel consumed for each treatment.

MATERIALS AND METHODS

Location of the experiment

A piece of trial land was provided and prepared from an experienced volunteer farmer who is growing potatoes for decades. The land was located in Shamamik location at Erbil state, Iraq- Kurdistan Region. The soil type was silt clay. The area of land allocated for conducting the experiment was about 2000 m², of which 1008 m² was an actual area for cultivation, and the rest was allocated for the spaces between the experimental plots, replications and headlands for tractor rotations. On March 3, 2021, we started primary tillage the land with moldboard tillage with the depth of 25-30 cm. After three days, we started the secondary tillage by using disc harrow in order to soften and prepare the land for planting. On March 8, 2021, potato planter was used for planting the potatoes; the equipment was set up to planted the potatoes by 30 cm at each line with a 70 cm separation between the lines. The potatoes were planted at depth of 15 cm. after planting the potatoes. All service operations were carried out for the growing crop and according to the recommendations of adding fertilizer, weed control and irrigation until the crop reached the harvest stage. Two days before picking day, few samples from the potatoes were taken to check for weight and size of the product, and depth of the furrows. Using a couple piece of wood (1.40 m by 1.00 m), the cross-sectional area of the plating line furrows was determined. On August 13,2021 digger potato was used by the different factor of the machine.

Experimental Design

A split plot design was used, two lift angles factor in main plots arranged in the CRBD with three replications, and the tractor forwarding speeds arranged randomly in sub-plots within each main plots. The main block was divided into three blocks, each block was two main plots for blade angles (18⁰) as **A1** and (22⁰) as **A2**, each main plot was divided into three sub-plots; each sub-plot was 1.40 m by 40.00 m. In each sub- plot, the tractor was driven at three various forward speeds (2.6 Km.h⁻¹) as **S1**, (3.51 Km.h⁻¹) as **S2**, and (4.36 Km.h⁻¹) as **S3**. Therefore, the sum of the experimental plots for this study was 18. Three samples were randomly taken from each plot at patches of 1.40 m by 1.00 m. Show the figure number (1). Later on, the results were compared with Duncan's Multiple Range Test at portability level of 5% with different lettering, A and B.

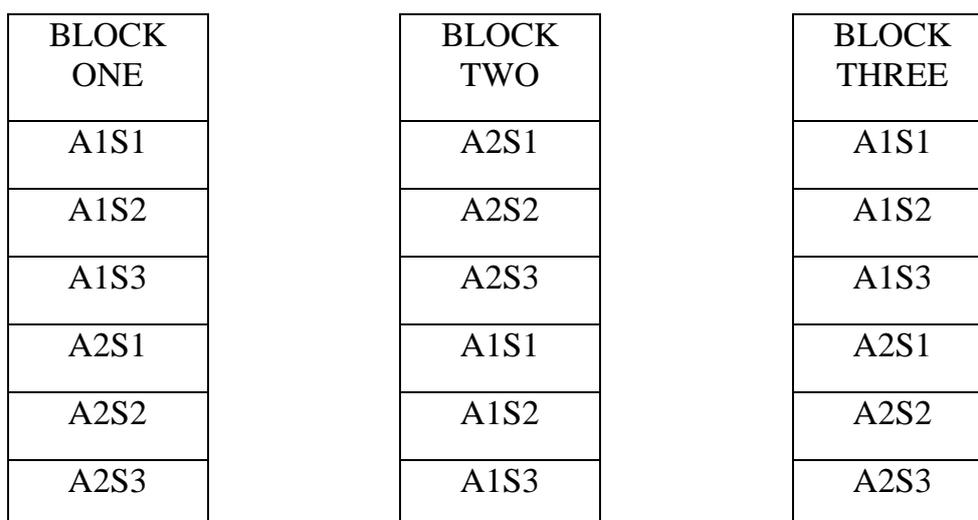


Figure (1): diagram of experiment design

Methodology Outline

1. Each sample was randomly taken from area of 1.40m by 1.00m. three times for each sub-plot
2. Weighing and counting potatoes for each character. Weight and count of the undamaged potatoes and quantitative loss.
3. Counting the damaged potatoes; severe damage and slight damage potatoes.
4. Counting the picked potatoes which are the summation of the damaged and undamaged potatoes.
5. Measuring the amount of fuel used for each factor in each sub-plot, length of 40m.
6. Measuring the depth of picking for each sub-plot at each spot, three times, depth was measured to know the amount of the soil dug/picked with the potatoes.

Studied factors

In this experiment, two factors were studied:

Two blade angle degree were selected for the digging potatoes, were degrees of (18°) and (22°) and three different forward speeds (2.6,3.51, 4.36) km.h⁻¹

Ratio of the characters in each sub-unit is in kilogram for each hectare

Weight of the undamaged and damaged potatoes for each sub-unit is in kilogram for each hectare.

Ratio of (UD, SD, SL, QL) in the one sample (ton.ha⁻¹) =

$$\frac{\text{weight in sample } \frac{\text{kg}}{1000}}{\text{area of sample } \frac{100 \text{ cm} \times 140 \text{ cm}}{10000}} \times 10000$$

Where:

$$\text{Change kilogram to Ton} = \frac{\text{kilogram (kg)}}{1000}$$

$$\text{Change unit area (cm}^2\text{) to (m}^2\text{) divided into (10000)} = \frac{100 \text{ cm} \times 140 \text{ cm}}{10000}$$

Change unit area (m²) to (hectare) divided into (10000) = $\frac{100 \text{ cm} \times 140 \text{ cm}}{10000} = \frac{14000}{10000}$

UD = undamaged tuber

SL = slight damage

SD = severe damage

QL = quantitative loss

Amount of Digging Potatoes

Amount of the potatoes is calculated for weight, number, or price of the undamaged and damaged potatoes.

$$LT = UD + SL + SD$$

Where:

LT = Lifted tubers of the potatoes (ton.ha⁻¹)

Summation of the Damaged Potatoes for Each Sample

Amount of the damaged potatoes is calculated for weight, number, of the potatoes.

$$TD = SD + SL$$

Where:

TD is Amount of the damaged potatoes in (ton.ha⁻¹)

Product of One Sample

Production yield was taken for each sample in weight or number of the damaged and undamaged tubers potato.

$$YI = UD + SD + SL + QL$$

Where:

YI is Production of yield of the potatoes (ton.ha⁻¹)

Based on the damage factors, the damage rate can be described according to the description in (McGechan, 1977). As it shows in the Table (1)

Table (1): the number of potato damage plants and the description of the rates of damage to tubers.

Description	Tuber damage index
The rate of damage is high and don't acceptable, the harvesting must be stopped immediately.	More than 300
The rate of damage is high with caution in the process of harvesting	200 to 300
middle damage rate	150 to 200
Damage rate acceptable	100 to 150
Damage rate allowed	Less than 100

RESULT AND DISCUSSION

Effect of lift angle of potato digger in studied characteristics:

It is clear from the table of variance analysis Table 2. That there are significant differences in the all studied characters due to the influence of a digger's angle factor, as follows:

Undamaged tubers

The data in Table 2 indicate that the first angle (18°) had better significant results for this trait compared to the second angle (22°), which recorded the highest percentage of undamaged tubers 72.48% weight of potatoes (ton) per area (hectare) which is the symbol of (ton. ha⁻¹) and the number of tubers potato 72.76% number of tubers per aera (hectare) which is the symbol of (tubers.ha⁻¹), While the second angle (22°) gave the lowest percentage of undamaged tubers by (71.84% ton.ha⁻¹) and number of tubers of (71.89% tubers.h⁻¹). A weight difference between the highest rate and the lowest rate was (1.36% ton. ha⁻¹) and number of tubers difference was (0.87% tubers.ha⁻¹). Increasing the blade angle of the tubers from 18° to 22° leads to an increase in the depth of the soil and thus raises a larger amount of soil that acts as a protective cushion for the tubers from collisions with each other and reduces the mechanical impact of the machine parts on the tubers, this is what by (EI-Khateeb, Marey, & Sayed-Ahmed, 2006).

Sever damage tubers

It is evident from Table 2 that the second angle (22°) achieved significantly the best results for these characteristic compared to the first angle (18°), as the lowest percentage of scratched tubers was recorded at the second angle (22°), reached 0.96% (ton. ha⁻¹) and number of tubers 1.71% tubers/ hectare. While the first angle (18°) recorded the highest percentage of severe damaged tubers a weight of 1.66% (ton. ha⁻¹), number of tubers 2.95% (tuber.ha⁻¹) a difference in weight less by 0.70% (ton. ha⁻¹), number of tubers 1.24 % (tubers.ha⁻¹). when using angle (18°) to the machine. It decreases digging depth and decrease soil lifting, here-upon tubers contact with part of the machine increases and severe damage increases. These result consistent with result from (Itodo & Daudu, 2013).

Slight damage tubers

The influence of blade angle on the slight damage tubers was shown in the Table 2, that the second angle (22°) achieved significantly the best results for these characteristic compared to the first angle (18°), as the lowest percentage of slight damage tubers was recorded at the second angle (22°), reached (9.15% ton.ha⁻¹) and number of tubers (6.68% tubers.ha⁻¹). So the first angle (18°) recorded the highest percentage of slight damage tubers, the weight of (15.98% ton. ha⁻¹), number of tubers potato (tubers.ha⁻¹), a difference in weight less by (6.83 % ton.ha⁻¹), number of tubers (2.73 % tubers.ha⁻¹). when using angle (22°) to the machine. It increases digging depth and increase soil lifting, her-upon tubers reduced contact with part of the machine (share, conveyer chain) and slight damage decreases. These results are in agreement with (Itodo & Daudu, 2013).

Lifted tubers

It is clear from Table 2 that the first angle (18°) achieved significantly the best results for these characteristic compared to the second angle (22°), as the highest percentage of lifted tubers was recorded by using the first angle (18°) by (90.13% ton. ha⁻¹) and number of tubers (85.13% tubers.ha⁻¹). The angle (22°) recorded the lowest percentage of lifted tubers of potato the weight of potatoes (81.96% ton. ha⁻¹) number of tubers potato (80.29% tuber. ha⁻¹), a difference in weight of potato less by (8.17% ton.ha⁻¹), number of tubers potato (4.84 % tubers.ha⁻¹). Increasing the angle of raising the tubers accompanied by lifting a greater amount of soil may sometimes lead to the displacement of some tubers without raising them (Hyde, Thornton, & Woodruff, 1983).

Digging depth

The data in Table 2 indicate that applying the second blade angle (22°) achieved better morale the results for this character compared to the first blade angle (18°) by recording the highest percentage of digging depth of soil by 30.44cm. When using angle (18°) in the share of potato digger equipment the lowest deep digging rate was created, which was 28.55cm. A difference between the highest deep digging rate and the lowest deep digging rate which was 1.89cm. Because the slope penetration share of equipment at angle (22°) is higher than the angle (18°), here-upon digger depth of angle (22°) is better than angle (18°). These result consistent with result of (Ibrahim, Amin, & Farag, 2008).

Fuel consumption

Table 2 shows that when the first blade angle (18°) was used, the lowest percentage of fuel consumption was recorded by 38.33 litter per aera (hectare) which is the symbol of (L. ha⁻¹) compared to applying the blade angle (22° which in turn gave the highest percentage of fuel consumption by 39 (L. ha⁻¹). The difference between the highest rate and the lowest rate of fuel consumed is 0.67 (L. ha⁻¹). When the increases angle from (18°) to (22°) at the time increases the deep digging from (28.55 cm) to (30.44cm), here-upon the soil resistance increases and it needed more power because the rate of fuel consumption changes. These results are in agreement with (Alsharifi, Aljibouri, & Taher, 2019).

Damage index

It is clear from Table 2 that the second angle (22°) achieved the best results for this characteristic compared to the angle (18°), the highest value of the tuber damage index was recorded at the first angle (18°), and it amounted to 124.52%. While the second angle (22°) recorded the lowest value of the tuber damage index, which amounted 79.22. It is inferred from Table 1 that the damage rate of the tubers at the first angle (18°) was within the limits of the acceptable damage rate (100-150), while the damage rate of the tubers at the second angle (22°) was within the limits of the permissible damage rate (less than 100). The reason for the decrease of this characteristic at the second corner and its height at the first corner may be due to the vocabulary constituting this trait and the reasons that the sound tubers were exposed to, severely damaged tubers, slight damage and severely scratched tubers, which combined affected the yield (McGechan, 1977).

The effect of the Tractor Forwarding speed on the studied characters:

It is clear from the table of variance analysis Table 3. That there are significant differences in the all studied characters due to the influence of a speed factor, as follows:

Undamaged tubers

As illustrated in Table 3 that the first speed 2.6 K. h⁻¹ achieved better morale the results for this trait compared to the highest forward speed 4.36 Km.h⁻¹, as they scored the highest percentage of un-damaged tubers with amount of (73.79% ton. ha⁻¹) and number of tubers 74.83%tuber. Hectare⁻¹ Although it did not significantly outperform the results of the second speed which achieved 73.09% and 74.16% for the percentage of undamaged tubers and the number of tubers, respectively, which in turn also significantly superior the results of the third speed 4.36 Km. h⁻¹ by 69.60% ton/ hectare for the lowest percentage of undamaged tubers and (67.97% tubers. ha⁻¹) for number of tubers. The percentage of weight difference between the first and third speed was (4.19% ton. ha⁻¹)and (6.86% tubers.ha⁻¹) for number of tubers. The percentage of undamaged tubers increases with the increases of speeds (2.6,3.51 and 4.36 Km.hr⁻¹), as the speed of the sifting chains increases, and thus the speed of the passage of tubers and soil increases with the increase in the flow of tubers and soil on the transmitting chain thus reducing the period of contact of tubers with sifting chain, which may help protect tubers from damage (Abdel et al. 2002 cited by Morad et al. 2015).

Table (2): Effect lift angle of potato digger in studied characteristics.

Digger's angle	Studied characteristics							
	Character's unit %	Undamaged tubers UD%	Severe Damage SD%*	slight Damage SL%*	Lifted Tubers (L.T%	digging depth (cm)	Fuel consumption L.ha ⁻¹ *	damage index d.i %*
18	Weight (Ton.ha ⁻¹)	72.48 a	1.66 a	15.98 a	90.13 a	28.55 b	38.33 b	124.52a
	No of tubers.ha ⁻¹	72.76 a	2.956 a	9.41 a	85.13 a			
22	Weight (Ton.ha ⁻¹)	71.84 a	0.96 a	9.15 b	81.96 b	30.44 a	39.00 a	79.22b
	No of tubers.ha ⁻¹	71.89 a	1.71 b	6.68 b	80.29 b			

* Least is the best

-Different letters on the means, there are a significantly difference between them. By using Duncan's test to the level (0.05)

Severe damaged tubers

It is clear from Table 3 that the first speed 2.6 Km.hr⁻¹ achieved significantly the best results for this characteristic compared to other speeds, as the third speed 4.36 Km. h⁻¹ recorded the highest percentage of scratched tubers reached (2.36% ton. ha⁻¹) and number of tubers (2.93% tubers.ha⁻¹) While the first speed 2.6 Km.h⁻¹

recorded the lowest percentage of severe damaged tubers, a weight of potatoes ($0.29\% \text{ ton. ha}^{-1}$), and a number of tubers potato ($0.45\% \text{ tuber.ha}^{-1}$). The difference between the highest rate and the lowest rate of achievement is weight of potatoes was ($2.07\% \text{ ton. ha}^{-1}$) and number of tubers of ($2.48\% \text{ tubers.ha}^{-1}$) The reason for this differences between the mean of results for the characteristic is that the proportional relationship between the percentage of the severe damage tubers and the forward speed of the tractor is significantly, as the increase in forward speed reduces the depth of digging and the shearing process at cutting depths more than required due to increased soil resistance, thus effecting on cutting, scratching and shearing the tuber, which man increasing the percentage of scratched tubers significantly, and this is consistent with (Arafa, 2019).

Slight damaged tubers

As illustrated in Table 3 that the first speed (2.60 Km. h^{-1}) achieved significantly the best results for this characteristic by recording the lowest percentage of the slight damage tubers weight ($10.34\% \text{ ton. ha}^{-1}$), number of tuber ($6.25\% \text{ tubers. ha}^{-1}$) compared to the third speed (4.36 Km. h^{-1}) with a difference in weight of ($4.65\% \text{ ton. ha}^{-1}$) and number of tubers ($4.20\% \text{ tubers. ha}^{-1}$). As it is noted from the same table, that the results of the first speed (2.60 Km. h^{-1}) did not reach the level of significance with what was obtained from the second speed (3.51 Km. h^{-1}), which in turn differed significantly with the results of the third speed in this characteristic. While the highest percentage of the slight damage tubers was recorded at the third speed 4.36 , which reached a weight of potatoes ($14.99\% \text{ ton. ha}^{-1}$) and number of tubers potato ($10.45\% \text{ tubers.ha}^{-1}$) The reason for the decrease in the percentage of this characteristic with the increases of forward speed may be is due to the proportional relationship between the percentages of the slight damage tubers with the front speed of the tractor. As the high forward speed of the tractor decreases the digging depth, thus the soil rising to the chain carrier will be little and the earthen cushion that protects the tubers from scratching during the transmission of tubers on the surface of the chain are few. Also, the forward speed increase it will lead to an increase in the speed of the chain conveyor and an increase in the speed of the vertical vibrations of the chain, which helps to shake off soil over the chain carrier in a shorter time, and these results agree with the results obtained by (Arafa, 2019).

Lifting tubers

As illustrated in Table 3 the third speed 4.36 significantly achieved the best results for this characteristic compared to in the other speeds, the highest percentage of lifting tubers was recorded at the third speed, (4.36 Km. h^{-1}) and reached a weight of potatoes ($86.96\% \text{ ton. ha}^{-1}$), and number of tubers ($82.36\% \text{ tubers. ha}^{-1}$). while the first forward speed (2.6 Km. h^{-1}) results the lowest percentage of lifting tubers reached a weight of ($84.42\% \text{ ton. ha}^{-1}$) and number of tubers ($81.54\% \text{ tubers. ha}^{-1}$). The weight difference was ($2.54\% \text{ ton. ha}^{-1}$) and number of tubers was ($0.82\% \text{ tuber. ha}^{-1}$). The explanation of the decrease in the lifting tubers ratio was at the first speed (2.6 Km. h^{-1}) and then its gradual increase to the second speed (3.51 Km. h^{-1}) and then the third speed (4.36 Km. h^{-1}) is due to the fact that the relationship is direct between the lifting of tubers and the ground speed of the tractor. Increasing the ground speed of the digging process will increase the resistance of the soil to the uprooting during

operation, which will affect it and lead to its entry into the tuber spreading area, which increases the lifting of the tuber, These results are in agreement with.(Kalinin et al., 2021).

Digging depth

The data in Table 3 Show that using the first speed (2.6 Km. h⁻¹) achieved the better results for this character compared to other speeds, as they scored the highest percentage of digging depth soil 33.58cm. While when the third speed (4.36 Km. h⁻¹) applying, the lowest percentage of digging depth was resulted by 25.25cm. A difference of digging depth between the deepest and the least depth of achievement is 8.33 cm. This may be due to a high percentage of digging depth at the first speed 2.6 and a decrease at the second speed 3.51, then the third speed 4.36 until the inverse relationship between the ground speed and digging depth. These results are in agreement with (Issa et al., 2020).

Fuel consumption

Based on the averages obtained from ANOVA analysis which shown in Table 3, the first speed (2.6 Km.hr⁻¹) significantly achieved the best results for this characteristic compared to in the other speeds, the lowest percentage of fuel consumption was resulted from using the first speed (2.6 Km.h⁻¹) reached to 33 litter per hectare which is the shortened (L.ha⁻¹). while by applying the third speed 4.36 Km. h⁻¹, the highest percentage of fuel was spent by (43.50 L. ha⁻¹). The fuel consumption difference was (10.50 L. ha⁻¹). The explanation of the increase in the fuel consumption ratio at the first speed 2.6 and then its gradual increase to the second speed 3.51 and then the third speed 4.36 is due to the fact that with an increase in the forward speed of the machine, the amount of resistance of the soil facing it increases, and therefore more fuel is spent to overcome that resistance. This is consistent with what was stated (Alsharifi et al., 2019) that by increasing the forward speed of the tuber extraction process, the fuel consumption increased.

Damage index

It is clear from Table 3 that applying the first forward speed 2.60 Km. h⁻¹ achieved the best results for this characteristic compared to other forward speeds, the highest value of the tuber damage index was resulted from using the third forward speed which amounted 123.31. When the first forward speed (2.60 Km. h⁻¹) was applied, the lowest value of the tuber damage index scored 82.17. It is inferred from Table 1 that the damage rate of the tubers at the third speed was within the limits of the acceptable damage rate (150-100), in material method, while the damage rate of the tubers at the first and second speed was within the limits of the permissible damage rate (less than 100). The reason for the decrease in this characteristic at the first speed and its rise at the second speed and then the third speed may be due to the components of this trait in terms of undamaged tubers, slightly scratched tubers and those that are severely damaged and all influences related to lifting conditions. This is consistent with findings(McGechan, 1977).

Effect of interaction between digging angle and forward speed:

It is clear from the analysis of variance Table 4 that there are significant differences for some of the studied characters when this interference affects them, as follows:

Undamaged tubers

Table 4 shows influence of digging angle and tractor forward speed interaction on the undamaged tubers percentage. The highest percentage of undamaged tubers was resulted from applying the treatment of the first blade angle (18°) and the first speed (2.6 Km. h⁻¹) which reached a weight of potatoes (74.53% ton. ha⁻¹), and number of tubers potato (75.91% tubers. ha⁻¹). While the lowest percentage of undamaged tubers was recorded from using the second blade angle (22°) with third speed (4.36 Km. h⁻¹), which reached a weight of (69.11%ton. ha⁻¹) and number of tubers by (65.97% tubers.ha⁻¹).

The difference in weight and number of tubers potato were (5.44 % ton. ha⁻¹) and (9.94 % tubers. ha⁻¹). The data in Table 4 indicate that the first blade angle (18°) with the three studied speeds (2.6, 3.51 and 4.36 Km.h⁻¹) recorded the best results for the undamaged tubers by (70.10 %, 73.80% and 74,53 % ton. ha⁻¹), and number of tubers of (69.97 %, 75.91 % and 76.38% tubers. ha⁻¹). While the second angle (22°) with the three speeds (2.6, 3.51 and 4.36 Km.h⁻¹) gave undamaged tubers (69.11%, 72.37% and 73.05 % ton. ha⁻¹), and number of tubers was (69.97 %, 71.94% and 73.76 % tubers. ha⁻¹). The using angle of (22°) in this machine lead to work deeper

Table (3): Effect of forward speed in studied characteristics.

Forward Speed	Studied characteristics							
	Characters unit %	Undamaged tubers UD%	Severe Damage SD%*	slight Damage SL%*	Lifted Tubers L.T%	digging depth (cm)	Fuel consump. L/ha*	damage index d.i %*
2.6	Weight (Ton.ha ⁻¹)	73.79 a	0.29 c	10.34 b	84.42 b	33.58 a	3300 c	82.17 b
	No of tubers.ha ⁻¹	74.83 a	0.45 b	6.25 b	81.54 a			
3.51	Weight (Ton.ha ⁻¹)	73.09 a	1.29 b	12.36 b	86.75 a	29.66 b	39.50 b	100.13 b
	No of tubers.ha ⁻¹	74.16 a	2.61 a	7.43 ab	84.21 a			
4.36	Weight (Ton.ha ⁻¹)	69.60 b	2.36 a	14.99 a	86.96 a	25.25 c	43.50 a	123.31 a
	No of tubers.ha ⁻¹	67.97 b	3.93 a	10.45 a	82.36 a			

*Least is the best

-Different letters on the means, there are a significantly difference between them. By using Duncan's test to the level(0.05)

in the soil and extracting a lot of soil which will protect the tubers from damages and cause increasing the value of undamaged qualitative loss, so decreases

undamaged tubers. In general, it can be observed that the percentage of undamaged tubers increases when the forward speed of the tractor decreases for both of blade angles (Rani *et al.*, 2019).

Severe damaged tubers

It is clear from the averages in Table 4 that there are significant differences for the interaction of the blade angle with the forward speed in the characteristic of severe damaged tubers. The highest percentage of severe damaged tubers was resulted from applying the first angle (18°) at the third forward speed (4.36 K.h^{-1}) which reached a weight was ($2.87\% \text{ ton. ha}^{-1}$) and number of tubers ($4.93\% \text{ tubers. ha}^{-1}$). While the lowest percentage of severe damaged tubers was recorded in the second angle (22°) with first speed (2.6 Km. h^{-1}) that is equal to zero. The difference between the highest rate and lowest rate in weight of potatoes and number of tubers potatoes were ($2.87\% \text{ ton. ha}^{-1}$ and $4.93\% \text{ tubers. ha}^{-1}$). As shown in Table 4, the second angle (22°) with the three studied speeds ($2.6, 3.51$ and 4.36 Km.h^{-1}) recorded the best results for the severe damaged tubers when it gave (0.00% , 1.03% and $1.84\% \text{ ton. ha}^{-1}$) and number of tubers of (0.00% , 2.19% and $2.94\% \text{ tubers. ha}^{-1}$) While the first angle (18°) with the three forward speeds ($2.6, 3.51$ and 4.36 Km.h^{-1}) recorded severe damaged tubers of (0.58% , 1.55% and $2.87\% \text{ ton. ha}^{-1}$) and number of tubers (0.90% , 3.03% and $4.93\% \text{ tubers. ha}^{-1}$) Using blade angle (22°) increases digging depth and soil lifting, which lead to reduce the contact percentage with the parts of the potato digger, thus, severe damage will decrease. In general, it can be observed that the percentage of severe damaged tubers increases when the forward speed of the tractor increases for both of blade angles (Sharma & Verma, 1986).

Slight damaged tubers

The influence of blade angle with speed of tractor on the slight damaged tubers shows in Table 4. The highest percentage of slight damaged tubers was recorded at the first angle (18°) of the third forward speed (4.36 Km. h^{-1}) reached a weight of potatoes ($17.50\% \text{ ton. ha}^{-1}$) and number of tubers ($12.96\% \text{ tubers. ha}^{-1}$). While the lowest percentage of slight damaged tubers was recorded in the second angle (22°) at the first speed (2.6 Km. h^{-1}) which reached of ($6.22\% \text{ ton. ha}^{-1}$) and number of tubers by ($5.64\% \text{ tubers. ha}^{-1}$). The difference in weight and tuber number was ($11.28\% \text{ ton. ha}^{-1}$ and $4.54\% \text{ tubers. ha}^{-1}$). Also, Table 4. refers to the best results for slight damaged is obtained from using the second angle (22°) at any of the three forward speeds ($2.6, 3.51$ and 4.36 Km.h^{-1}) were (6.22% , 8.76% and $12.48\% \text{ ton. ha}^{-1}$). So number of tubers potato (5.64% , 6.46% and $7.95\% \text{ tubers. ha}^{-1}$) The first blade angle (18°) with the three forward speeds ($2.6, 3.51$ and 4.36 Km.h^{-1}) gave weight of slight damaged of tubers potato (14.46% , 15.97% and $17.50\% \text{ ton. ha}^{-1}$) and number of tubers of (6.86% , 8.40% and $12.96\% \text{ tubers. ha}^{-1}$). As it observed from Table (4), the percentage of severe damaged of tubers increases when the forward speed of the tractor increases with both of blade angle. thus, with the increasing of forward speeds the soil lifting and digging dept reduced, at the time that rotating conveyer chain increases mean increase the contact of tubers with each other and the equipment parts (Ibrahim *et al.*, 2008).

Lifted tubers

The effect of blade angles and forward speed of tractor on the lifted tubers is shown in Table 4. The highest percentage of lifted tubers was recorded at the first angle (18°) that used with the second forward speed (3.51 km.h⁻¹) reached a weight of (91.33% ton. ha⁻¹) and number tubers (87.83% tubers. ha⁻¹). While the lowest percentage of lifted tubers was recorded in the second angle (22°) which applied with first forward speed (2.6 km. h⁻¹) reached a weight of (79.27 % ton. ha⁻¹) and number of tubers (79.40% tubers. ha⁻¹). The difference between the highest rate and the lowest rate for weight of potatoes and number of tubers potato were (22.6 % ton. ha⁻¹) and (8.43 % tubers. ha⁻¹). As indicated in Table 4 the first blade angle (18°) recorded the best results for the lifted tubers were (91.33 %, 89.57% and 90.48 % ton. ha⁻¹) and number of tubers of (87.83 %, 83.68% and 87.87 % tubers. ha⁻¹) at forward speeds (2.6, 3.51 and 4.36 Km.h⁻¹). The second lift angle (22°) gave lifted tubers of (79.27%, 82.17% and 83.44% ton. ha⁻¹) and number of tubers of 79.40%, 80.60% and 76.86 % tubers. ha⁻¹) at forward speeds (2.6, 3.51 and 4.36 Km.h⁻¹). It can be observed that the percentage of lifted tubers increases when the forward speed of the tractor decreases for both of blade angles (Issa et al., 2020).

Digging depth

Table 4 shows the effect of blade angle of equipment and speed of tractor on the inter soil percentage. The highest percentage of digging depth was recorded at the second angle (22°) of the first speed (2.6 km. h⁻¹) reached a depth of 35 cm. While the lowest percentage of digging depth was recorded in the first angle (18°) with the third forward speed (4.51 km. h⁻¹) reached a depth of 24.33 cm. The difference of deep digging rate between the highest rate and the lowest rate was 10.67 cm. The data in Table 4 indicate that the second angle (22°) with the three forward speeds (2.6, 3.51 and 4.36 Km.h⁻¹) recorded the best results for the digging depth (26 ,30 and 35 cm), While the first blade angle (18°) with the three forward speeds (2.6, 3.51 and 4.36 Km.h⁻¹) gave digging depth of (24.33, 29.16 and 32.16cm). It can be observed that the percentage of digging depth decreases, when forward speed increase. The increase of forward speed results in increasing the soil resistance toward the equipment operation. Thus, digging depth reduced with increase forward speed. These result consistent by result of (Issa et al., 2020).

Fuel consumption

The influence of the interaction between the blade angle and tractor forward speed in the characteristic of fuel consumption as shown in Table 4. The highest percentage of fuel consumption was recorded at the second angle (22°) at the third forward speed (4.31 km. h⁻¹) reached (44 L. ha⁻¹). While the lowest amount of fuel was spent in the first angles (18°) at the first speed (2.6 km. h⁻¹) that reached (33 L. ha⁻¹). The averages in Table 4 show that the first angle (18°) with three studied speeds (2.6, 3.51 and 4.36 Km.hr⁻¹) recorded the best results for the fuel consumption were (43, 39 and 33 L. ha⁻¹) respectively. The third forward speed (2.6 km. h⁻¹) recorded the best result for the fuel consumption, while fuel consumption in the second speed (3.51 km. h⁻¹) gave less fuel than the first speed (4.36 k. h⁻¹) for both blade angles. Since the tractor's forward speed and cutting depth are opposite with soil resistance,

Table (4): Effect of interaction between digging angle and forward speed.

Blade angle	digger speed Km h ⁻¹	Studied characteristics							
		Characters unit %	Un-damaged tubers UD%	Severe Damag e SD%*	slight Damag ed SL%*	Lifted Tubers L.T%	digging depth cm	Fuel consump. L. ha ⁻¹ *	damage index d.i %*
18	2.6	Weight (Ton.ha ⁻¹)	74.53 a	0.58 bc	14.46 ab	89.57 a	32.16 b	33.00 e	109.67 b
		No of tubers.ha ⁻¹	75.91 a	0.90 cd	6.86 b	83.68 ab			
	3.51	Weight (Ton.ha ⁻¹)	73.80 ab	1.55 ab	15.97 ab	91.33 a	29.16 c	39.00 d	121.69 ab
		No of tubers.ha ⁻¹	76.38 a	3.038 b	8.40 ab	87.83 a			
	4.36	Weight (Ton.ha ⁻¹)	70.10 bc	2.87 a	17.50 a	90.48a	24.33 e	43.00 b	142.22 a
		No of tubers.ha ⁻¹	69.97 a	4.93 a	12.96 a	87.87 ab			
22	2.6	Weight (Ton.ha ⁻¹)	73.05 abc	0.00 c	6.22 b	83.44 b	35.00 a	34.00 e	54.68 d
		No of tubers.ha ⁻¹	73.76 a	0.00 d	5.64 b	76.86 b			
	3.51	Weight (Ton.ha ⁻¹)	72.37 abc	1.03 bc	8.76 b	82.17 c	30.16 c	40.00 d	78.57 cd
		No of tubers.ha ⁻¹	71.94 ab	2.19 bc	6.46 b	80.60 b			
	4.36	Weight (Ton.ha ⁻¹)	69.11c	1.84 ab	12.48 b	79.27d	26.16 d	44.00 b	104.42 bc
		No of tubers.ha ⁻¹	65.97 ab	2.94 b	7.95 ab	79.40 b			

* Least is the best

Different letters on the means, there are a significantly difference between them. By using Duncan's test to the level (0.05)

and in order to overcome increased soil resistance, the tractor needs more fuel to operate at higher cutting speed and depth, and this is the case when the blade angle and forward speed gradually increase. These result such as result of (Embaby, 1985).

Damage index

Table 4 illustrate the effect of the interaction of the blade angles with the forward speed in the characteristic of damage index of tubers. The lowest percentage of damage index of tubers was recorded at the second angle (22°) when the first forward speed was used (2.6 km. h⁻¹) that reached to 54.68%. While the highest percentage of damage index of tubers was recorded when the first angle (18°) and the third forward speed applied (4.36 km. h⁻¹) that reached to 142.22%. It is inferred from Table 1 that the damage rate of the tubers at the second angle (22°) with forward speeds of (2.6 km. h⁻¹) and (3.51 km. h⁻¹) was within the limits of the permissible damage rate (less than 100). While the lift angle (22°) with the speed (4.36 km.hr⁻¹) and the angle (18°) with the three studied speeds was within the limits of the middle damage rate (100-150). These result consistent with result from (McGechan, 1977)

CONCLUSION

1. Increasing the blade angle resulted lowest percentage values for all studied traits, namely, undamaged tubers, severe damage, slight damage, lifted tubers and damage index, while the digging depth and fuel consumption gave higher values
2. By increasing the forward speed, undamaged tubers, lifted tubers and digging depth were decreased, while the rest of the traits increased.
3. At each blade angle, as the forward speed increased, the values of severe damage, slight damage, fuel consumption and damage index increased, while other attributes decreased.
- 4.

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CONFLICT TO INTEREST

Authors declare no conflict of interest regarding the publication of this study.

تأثير زوايا السكين والسرعات الأمامية لقاعة البطاطا الالية على استهلاك الوقود والأضرار الميكانيكية

للدرنات

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الخلاصة

نفذت هذه التجربة في موقع شامامك - أربيل بإقليم كردستان- العراق منتصف صيف 2021 بهدف تحديد تأثير زوايا السكين والسرعات الأمامية المختلفة لقاعة البطاطا الالية في استهلاك الوقود والأضرار الميكانيكية على الدرنات. تم تطبيق تصميم القطاعات العشوائية الكاملة بنظام القطع المنشقة، تم اختيار زاويتين لسكين رفع الدرنات وهما (18⁰) و (22⁰) كألواح رئيسية وثلاث سرعات أمامية 2.6 و 3.51 و 4.36 كم / ساعة كالواح شقية. كانت النتائج كالتالي: سجلت زاوية السكين البالغة (22⁰) اقل قيم للنسب المئوية لجميع الصفات المدروسة وهي الدرنات غير التالفة والضرر الشديد والضرر الطفيف والدرنات المرفوعة ومعامل التلف باستثناء عمق القلع واستهلاك الوقود حيث اعطت قيم اعلى من تلك التي تم الحصول عليها من زاوية السكين البالغة (22⁰). من خلال زيادة السرعة الأمامية، انخفضت الدرنات غير التالفة 69.11%، الدرنات المرفوعة 79.27% وعمق القلع 26.16 سم، بينما زادت قيم بقية الصفات. عند اي قيمة لزاوية الرفع، كلما زادت السرعة الأمامية للآلة، زادت قيم الضرر الجسيم 1.84 %، 2.87 %، والضرر الطفيف 17.55 %، 12.48 %، واستهلاك الوقود 43 ، 44 لتر/هكتار، ومؤشر الضرر 104 ، 142، بينما انخفضت الصفات الأخرى.

الكلمات الدالة: زوايا السكين، السرعات الأمامية، استهلاك الوقود، الأضرار الميكانيكية للدرنات

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