Potato harvester performance on tubers damage at the eastern of Saudi Arabia

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Abstract: In this study, a potato harvesting machine performance by studying the effect of the potato harvester operating variables on tuber damage was investigated. All field experiments were conducted at the premises of the National Agricultural Development Company (NADEC) located east of the city of Riyadh, in sandy loam soil by using long oval tubers in shape specifications (Hermes), along with one type of potato harvester (i.e., two-row potato harvester with two riddle chains). Therefore, three operating variables pertaining to the potato harvester were utilized: potato harvester forward speed (chain speed) at 1.5 km/h (with the primary chain speed of 2.8 and the secondary chain speed of 1.8 km/h), 1.7 km/h (primary and secondary chain speed of 3.4 and 2.2 km/h), and 2 km/h (with 4 and 2.5 km/h as primary and secondary riddle chain speed); digging depth of 12, 17, and 22 cm; and the primary riddle chain oscillation amplitude of 17 and 25 mm. The optimum operating variables pertaining to the potato harvester, which achieved the highest lifted tuber percentage (97.02%), the lowest damaged tuber percentage (0.04%), and the lowest damaged potato index (0.04), was obtained by utilizing the forward speed (chain speed) of 2 km/h (primary riddle chain speed of 4 and the secondary riddle chain speed of 2.5 km/h), the best digging depth of 22, and 25 mm as the optimum primary riddle chain amplitude.

Keywords: Hermes potatoes, mechanical harvesting, tuber damage, lifted tubers, potato damage index

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1 Introduction

Globally, potato is one of the most important vegetable crops in the world. In the Kingdom of Saudi Arabia, in the 1982 season, the production of approximately 3,653 tons of potato (from 344.4 hectare) was reported, increasing to 404,679 tons (from 16,296 hectare) in the 2011 season (Ministry of Agriculture, 2001 and 2012). Increased mechanization was one of the most influential factors in the ability to expand the potato production and minimize the production cost, thus increasing the net income for potato producers. In practice, in mechanical harvesting, potato tubers are primarily affected by the apparent damage caused in potato roots and unlifted crops. In order to mitigate these issues, potato harvesters have been modified to prevent damage to potato crops (by, for example, altering the chain speed, riddle chain amplitude, or blade tilt angle and digging depth). Thus, in order to assess the extent and type of potato tuber damage during the mechanical harvesting process, performance of a two-row potato digger with two riddle chains potato harvester type was examined. Empirical evidence indicates that numerous studies have evaluated the developments in the potato harvesting mechanization. In addition, potato harvester performance was assessed with an emphasis on minimizing potato tuber damage. However, there is evident paucity of research on the variables affecting harvester performance that are examined in present study.

Kang et al. (1989) designed and constructed an oscillating potato digger using power tillers to evaluate the effects of vibration on the potato digging process. By changing the amplitude, frequency, and travel speed,

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effects of various combinations of these parameters were tested on the digger performance in the potato field. Harvesting loss and damage, as well as storing loss of the mechanically harvested potatoes, were the measured variables. The authors observed that amplitude of 12 mm, the frequency of 9.67 Hz, and the travel speed of 0.87 km/h resulted in adequate digger blade operation. Under these conditions, the total harvesting loss and damage were 3.18% and 0.67%, respectively, indicating a significant improvement relative to 6.83% and 9.83% achieved by traditional harvesting methods.

Abdel–Aal et al. (2002) modified a potato harvester to be suited for Egyptian farms. The modified harvester was a PTO-operated one-row harvester, trailing behind the tractor, to be fitted on the tractor's two-hitch system. The machine consisted of a digging blade, a frame, a gearbox, a hitching system, and a riddle system. The optimum engineering parameters for the modified harvester, which achieved the highest undamaged rate, the lowest damaged potato rate and minimal losses, were forward speed of 2.3 km/h, digger tilt angle of 14°, distance between the blade and elevator chain of 5 cm, chain speed of 2.41 m/s, riddle voltage of 4.63 V and riddle inclination of 7°.

Abdel–Maksoud et al. (2004) developed a potato digger to be used for harvesting, and separating potatoes from soil and transporting tubers on a trailer outside the harvested area. The potato harvesting machine performance before and after implementing the design improvements was investigated in terms of field capacity and efficiency, potato losses, harvesting and cleaning efficiency, power and energy utilization and cost as a function of changes in digger forward speed and penetration angle. The experimental results revealed that the performance of the potato digger developed as a part of the study was superior to that without any improvements, in terms of both of harvesting and cleaning efficiencies, as well as losses and cost. These results were obtained when the digger was operated at forward speed of 2.4 km/h and penetration angle of 14°, along with the adjusted separating sieve at a slope of 8° and an operational speed of 12 m/s.

Younis et al. (2006) developed and tested a two-row potato digger with vibrating digging blade that was mounted on a tractor (110 hp, three-point hitch) by using a variety of potato Sponta at different levels of travel speed (e.g., 0.9, 1.5, 1.9, and 3.2 km/h), oscillation amplitude (e.g., 3, 5, 6, and 10 mm), and oscillation frequency (e.g., 400, 600, 800, 1000, and 1200 rpm). Losses, such as percentage of bruised potatoes, drawbar pull of the vibrating digging blade, and the field capacity were measured as outcomes. It was stated that at the conventional digging blade oscillation frequency of 1200 rpm and amplitude of 10 mm, the drawbar pull of the vibrating digging blade decreased by 25.17, 25.91, 28.43, and 30.47% at travel speed of 0.9, 1.5, 1.9, and 3.2 km/h, respectively. The field capacity was increased by the vibrating digging blade to 8.3%. In addition, with the proper vibrating digging blade oscillation frequency of 800 rpm and amplitude of 6 mm, drawbar pull and the percentage of bruised tubers were decreased. Accordingly, this study confirms that the use of vibrating blade for harvesting potatoes caused a reduction in the power requirement to pull the harvester, as well as decreased potato damage and losses, while improving the separation efficiency of potatoes from the soil, which was studied by Al-Jubouri and McNulty (1984).

In the study conducted by Khater (2009), the effects of working speeds of mechanical harvesting on potato damage at South Eastern Qantara in Egypt was investigated. Harvester forward speeds of 3.1, 5.8, 7.4, and 8.6 km/h, and the chain speeds of 90, 120, and 150 rpm, with the blade angle of 15° were applied to one type of potato harvester (i.e., one-row potato digger with one chain and the width of 1.2 m). The results revealed that the lowest tuber damage was attained with the harvester forward speed of 3.1 km/h and the chain speed of 90 rpm. In addition, the highest energy was obtained at the highest forward speed (8.6 km/h) and the chain speed of 150 rpm, while lowest forward speed (3.1 km/h) and the chain speed of 90 rpm resulted in the lowest energy consumption.

Subba et al. (2012) operated an experimental potato digger mounted on a tractor (18 hp). The machine was tested at three digging depths by adjusting the top link lever of the tractor 3 point hitches (60, 63, and 65 of the top lever lengths). By increasing the top lever length, the digging blades penetration would be decreased. The results indicated that, with the moisture of the field soil 42.90% and constant tractor forward speed (1-2 speed gears) used in this function, 1.69, 7.14, and 4.71% of the potato damage occurred by the 60, 63, and 65 cm length of the top link lever, respectively. In addition, tractor fuel consumption was decreased by increasing the length of the top link lever. Fuel consumption decreased from 2.06 to 1.47 l/h by increasing the length of the tractor top lever from 60 to 65 cm.

Azizi et al. (2014) designed and constructed an oscillating single-row potato digging blade that using 5.5 hp from a tractor power take-off (PTO) to evaluate the effects of vibration on the potato digging blade. By changing the angle and rotary speed of the digging blade and travel speed, effects of various combinations of these parameters were tested on the digger performance in the potato field. Damage of the mechanically harvested potatoes, was the measured variable. The authors observed that travel speed of 1.5-3 km/h, rotary speed of 20-25 rpm, and the digging blade angle of 10-15^o resulted in an adequate digger blade operation. Under these conditions, the mechanical harvesting damage is indicating a significant improvement relative to 4% of the potato total damage.

The main objectives of this study were: to evaluate the performance of a potato harvester with two lines on the Hermes potato crop type, to estimate the effect of some operating variables (e. g., riddle chain amplitude, harvester blades digging depth, and harvester forward speed) pertaining to the potato harvesting machine which equipped with two riddle chains on class Hermes tuber damage, and to exhibiting a maximum productivity in the potato field with getting a lowest damage on potato tubers.

2 Materials and methods

At first, to evaluate the performance of a potato harvester with two lines on the Hermes potato crop type (long oval tubers in shape specifications), which was planted on a sandy loam soil in one of the NADEC fields located east of the city of Riyadh, an Italian two-row potato digging blade with two riddle chains (primary chain in length of 3.95 m and secondary chain in length of 2 m), type Carlotti G & C and model SP160 with harvesting width up to 160 cm, was used to harvest the potato tubers as shown in Figure 1 and 2.

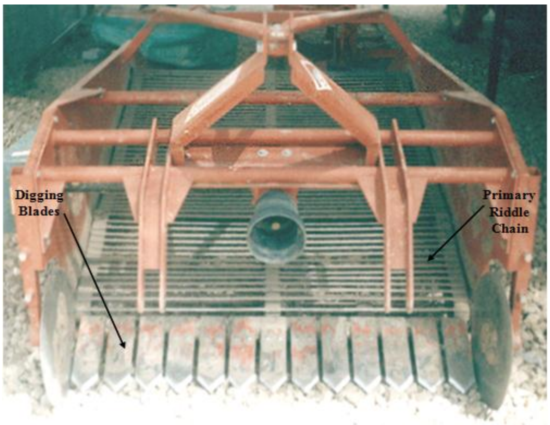

Figure 1 Potato harvesting machine with two-row digging blades and two riddle chains (front view)

Figure 2 Harvesting machine at the potato field (rear view)

Initially, two amplitudes of the primary chain oscillation (17 and 25 mm) were applied to the primary riddle chain and were adjusted by using the sieve amplitude control. As a part of the study, due to the speed of the NADEC's potato machine to harvest tubers was working up to a forward speed of almost 2 km/h, three potato harvester forward speeds (1.5, 1.7, and 2 km/h) were investigated, along with three digging depths (12, 17, and 22 cm) depending on the propagation of potato tubers in the planting lines. A fully randomized design (CRD) was utilized in order to facilitate statistical analysis. Accordingly, after potato harvesting, the tubers were placed on the ground, and the settled tubers that remained under each double row were collected manually (i.e., extracted by hand, using a digging tool) along the 10 m length of each plot. The main dimensions of the potato tubers length, width, and thickness were measured on the average amounts of 70.71, 48.97, and 60.47 mm, respectively. As well as, it was measured the longitudinal spread of the tubers along the potato cultivation line, spreading tubers on the line width, and the distance between the top of the potato cultivation line and the lowest tuber that was set deeply; consequently found that the spreading of potato tubers were on the average amounts of 25.4, 15.1, and 16.4 cm, respectively. Based on the field experiments results, the average Hermes potato productivity in the field was 40.74 ton/ha. Further analysis revealed that the potato field soil was of a sandy loam type, with 10% moisture content. Moreover, the proportion of gravel was estimated at 24.55%, with remaining 75.45% comprised of soft soil. Therefore, the lifted tuber percentage (L_t) (i.e., those that were extracted from the field soil) and the tuber total damage percentage (D_t) were estimated using the following equations (Ibrahim et al., 2008).

$$L_t (\%) = (m_1 / (m_1 + m_2)) \times 100 \quad (1)$$

$$Dt (\%) = (m_3 / (m_4 + m_3)) \times 100 \quad (2)$$

Where:

m_1: mass of the lifted potato tubers (kg/plot)

m_2: mass of the unlifted potato tubers (kg/plot)

m_3: mass of the damaged potato tubers (kg/plot)

m_4: mass of the undamaged potato tubers (kg/plot)

In addition, based on the tuber damage index (d.i), the amount of tubers collected and the amount of tubers damaged by the harvesting machine, tubers were classified into three categories: scratched surface (x_1) (only tuber crust is affected and there is no damage to the tissues), superficial cuts with no the tuber internal damage (x_2) (i.e., tissue damage takes the form of cuts or shatter), and deeply damaged tubers (x_3) (i.e., internal tissue is damaged or cut off, turning black or blue after several days). In the next phase, all items were weighed separately, in order to estimate the percentage of superficially scratched tubers (x_1), broken tubers with no internal damage (x_2), and deeply damaged tubers (x_3). Consequently, the tuber damage index (d.i) could be calculated by using the following equation (McGechan, 1977, and Abo-Habaga and Al-Yahya, 1999):

$$d.i = 1 \times x_1 + 3 \times x_2 + 7 \times x_3 \quad (3)$$

3 Results and discussion

This study was conducted to estimate the effect of some operating variables pertaining to the potato harvesting machine with two riddle chains (e.g., three harvester forward speeds, three digging depths, and two primary riddle chain oscillation amplitudes) on class Hermes tuber damage. The data obtained were analyzed statistically and the results are discussed in the subsequent sections.

3.1 Effects of the potato harvesting machine forward speed on tuber damage

As shown in Table 1 and Figure 3, the harvester forward speed of 1.70 km/h yielded the highest percentage of lifted tubers (88.57%), while the lowest lifted tuber percentage (85.56%) was obtained by the highest forward speed (2 km/h). In addition, from the field observations, the average amount of unlifted tubers ranged from 3.95 ton/ha, achieved with the lowest speed, to 5.05 ton/ha, resulting from the highest speed. In other words, it increased with the increase in the harvester forward speed. However, the statistical analysis revealed no significant differences between the effects of the potato harvester speeds on the percentage of the lifted tubers, at 10% level of significance. When the total damage percentage was examined, the results revealed that, by increasing the harvester forward speed, it increased from 2.88% to 4.63%. Likewise, the tuber damage index increased from 14.28 to 22.78. However, these values are considered to be within the acceptable limits of the potato damage index. Statistically, there was a significant difference between the effects of the potato harvester forward speeds on the total damage percentage, while the effects of the potato harvester forward speeds on the tuber damage index were not statistically significant.

Table 1 Results of the effect of the harvester forward speed on the potato harvesting

Harvester forward speed (km/h)	The percentage of potato tubers (%)						Damage index
	Lifted tubers	Un-lifted tubers	Superficially scratched tubers	Broken tubers (no internal damage)	Deeply broken tubers	Total damage	
1.50	88.34[a]	11.66[a]	0.27[a]	1.06[a]	1.55[a]	2.88[b]	14.28[a]
1.70	88.57[a]	11.43[a]	0.28[a]	1.17[a]	2.12[a]	3.57[ab]	18.63[a]
2	85.56[a]	14.44[a]	0.83[a]	1.16[a]	2.64[a]	4.63[a]	22.78[a]

Note: Values denoted by the same letter in the same column are not statistically significantly different.

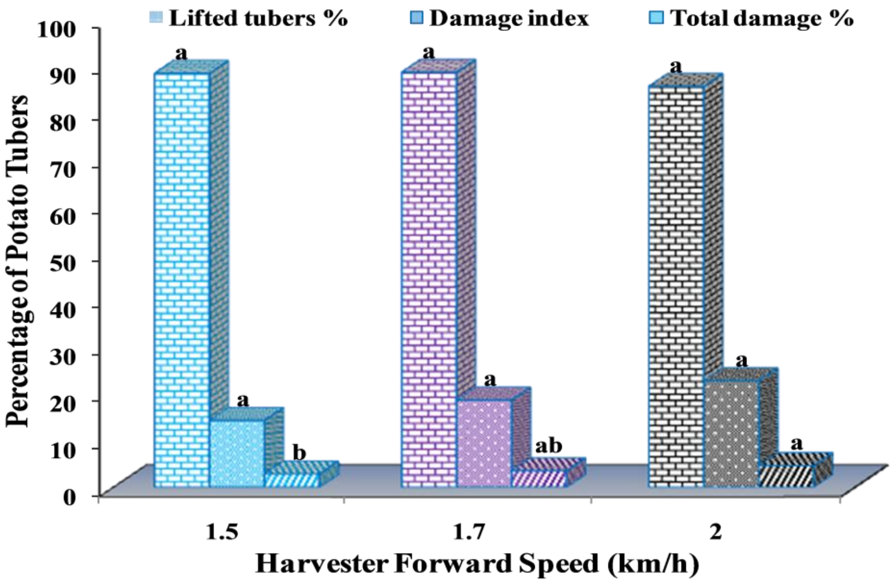

Figure 3 Effects of the changing in the harvester forward speed on the potato harvesting

3.2 Effects of the potato harvesting machine digging depth on tuber damage

Clearly, digging depth of the potato harvester blades affects the percentage of the lifted tubers, tuber total damage, and the tuber damage index, as shown in Table 2 and Figure 4. Statistically, at the 10% level of significance, there was a significant difference between the effects of the potato harvester digging depth on the percentage of lifted tubers, the total damage percentage, and the tuber damage index. More specifically, the findings revealed that increasing the harvester digging depth from 12 to 22 cm increased the percentage of lifted tubers from 70.92% to 97.25%, while the tuber total damage decreased from 8.36% to 0.49%, and the potato damage index declined from 43.75 to 2.21. Moreover, from the field observations, the average amount of unlifted tubers ranged between 10.22 ton/ha, achieved by the lowest digging depth of 12 cm, and 1.01 ton/ha, resulting from the highest digging depth of 22 cm. In general, it can be concluded that increasing the blade digging depth resulted in a much greater percentage of extracted potato tubers that were in the tuber distribution area in the potato line. It was also effective in reaching the tubers located at the lowest point under the soil. In addition, by increasing the digging depth, the amount of soil on the riddle chains increased, acting as padding between the chains and the potato tubers. This had a positive effect on the extraction efficiency, as it reduced the impact of the chains, resulting in less damage to the potatoes.

3.3 Effects of the oscillation amplitude of the harvester primary riddle chain on tuber damage

Obviously, Table 3 and Figure 5 present the results pertaining to the potato harvester primary riddle chain oscillation on the potato harvester performance, whereby two amplitudes are tested. From the field observations, the average amount of unlifted tubers ranged from 3.77 ton/ha, achieved by the highest chain amplitude (25 mm), to 5.13 ton/ha, obtained by the lowest chain amplitude (17 mm). In addition, the data indicates that, when the oscillation amplitude was increased from 17 to 25 mm, the percentage of lifted tubers increased from 85.34% to 89.65%, while the potato total damage increased from 3.24 to 4.14%, which was unexpected. In addition, by increasing the primary riddle chain amplitude, the tuber damage index also increased from 15.89 to 21.24. However, these damage index values are considered to be within the acceptable limits. After conducting an appropriate statistical analysis, none of the aforementioned differences were found to be statistically significant at 90% level of confidence on the potato harvesting machine performance.

3.4 Effects of the interaction of the potato harvester operating variables

In terms of the potato harvester operation, Table 4

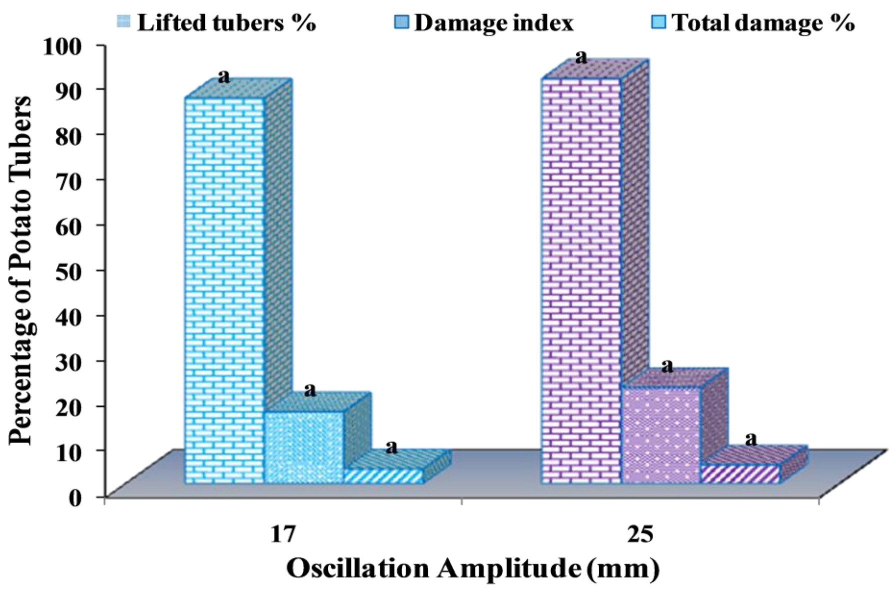

Figure 5 Effects of the changing in the harvester primary riddle chain oscillation on the potato harvesting

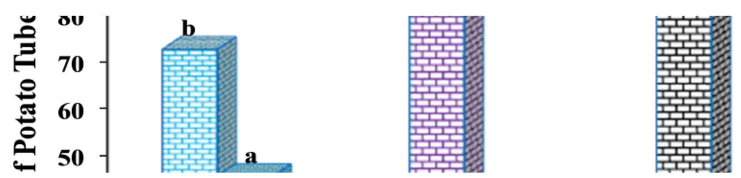

Table 3 Results of effect of the harvester primary riddle chain oscillation on the potato harvesting

Oscillation amplitude (mm)	The percentage of potato tubers (%)						Damage index
	Lifted tubers	Un-lifted tubers	Superficially scratched tubers	Broken tubers (no internal damage)	Deeply broken tubers	Total damage	
17	85.34[a]	14.66[a]	0.34[a]	1.19[a]	1.71[a]	3.24[a]	15.89[a]
25	89.65[a]	10.35[a]	0.58[a]	1.07[a]	2.49[a]	4.14[a]	21.24[a]

Note: Values denoted by the same letter in the same column are not statistically significantly different

Figure 4 Effects of the changing in the harvester blade digging depth on the potato harvesting and Figure 6 are demonstrating that the highest percentage of lifted potato tubers was 99.10%, which obtained by examining 39.36 ton/ha of tubers extracted onto the soil surface, and was achieved using the forward speed of 1.50 km/h, the primary riddle chain oscillation amplitude of 25 mm, and the harvester blade digging depth of 22 cm. On the other hand, the lowest percentage of the lifted tubers was 51.25%, obtained using the highest forward speed of 2 km/h, the lowest primary riddle chain oscillation amplitude of 17 mm, and the lowest harvester blade digging depth of 12 cm. The subsequent statistical analysis indicated that, at 10% significance level, the effect of oscillation amplitudes and the harvester forward speeds on the percentage of the lifted potato tubers was not significant. Similarly, no statistically significant differences between the effects of the harvester digging depths of 17 and 22 cm on the lifted potato tubers percentage were noted. On the other hand, the effects of the digging depth of 12 cm were statistically significantly different from those obtained with 17 and 22 cm depths.

In addition, the effects of the interaction between the harvesting digging depth, oscillation amplitude of the primary riddle chain, and the forward speed of the potato harvester on the percentage of total damage of tubers and the amount of potato tubers were examined and the results are shown in Table 4, 5, and Figure 7. As can be seen from the results, the lowest percentage of total tuber damage was 0.04%, obtained by examining 40.04 ton/ha of tubers extracted onto the soil surface. This percentage was achieved using the digging depth of 22 cm, the oscillation amplitude of 25 mm, and the highest harvester forward speed of 2 km/h. The highest amount of lifted potato tubers 42.27 ton/ha was recorded by examining of the interaction between the digging depth of 17 cm, the oscillation amplitude of 25 mm, and the harvester forward speed of 1.70 km/h. Also, the highest percentage of potato total damage (12.01%) was recorded by examining 28.65 ton/ha of potato tubers lifted on top of the soil surface. It was a result of the interaction between the digging depth of 12 cm, the oscillation amplitude of 25 mm, and the highest harvester forward speed of 2 km/h. The highest percentage of potato total damage was obtained using the lowest digging depth of 12 cm, which resulted in a greater amount of tubers broken by the harvester blades and less soil. As soil acts as a cushion between the rods of the riddle chains and tubers, could protect the tubers when the harvester riddle chains are in operation. Thus, having greater amount of extracted soil is beneficial.

Generally, at the significance level of 10%, statistical analysis revealed no significant differences in the effect of the primary chain oscillation amplitude on the total potato damage percentage. On the other hand, the effects of digging depths on the total potato damage percentage were statistically significant. In addition, while the effects of the first and second forward speed, the second and third forward speed, on the percentage of the potato total damage were not statistically significant, there was a significant difference between the effect of the first and the third forward speed.

The effects of the interaction of the three operating variables on potato tuber damage index are presented in Table 6 and Figure 8. As can be seen, the highest value of the damage index was 58.42, and was a result of the interaction between the third forward speed, the primary chain oscillation amplitude of 25 mm, and the digging depth of 12 cm. This lowest digging depth of 12 cm, which resulted in more broken tubers, was the main contributor to this high value of damage index. On the other hand, the lowest tuber damage index was 0.04, and was achieved at the forward speed of 2 km/h, the oscillation amplitude of 25 mm, and the harvester digging depth of 22 cm. Obviously, an increase of the harvester digging depth, irrespective of the harvester forward speed or the primary chain oscillation amplitude, decreased the potato tuber damage index. The statistical analysis findings indicated that the effect of the primary chain oscillation amplitude and harvester forward speed on the potato tuber damage index was not statistically significant. Moreover, no statistically significant differences between the effects of the digging depth of 17 and 22 cm on the potato tuber damage index could be noted. However, there was a significant difference between the effect of the digging depth of 12 cm on one side and the depths of 17 and 22 cm on the other, at the significance level of 10%. Finally, as can be been observed from the results reported in Table 6, pertaining to the potato tuber damage index values achieved at different harvester digging depths, primary riddle chain oscillation amplitudes, and harvester forward speeds, all values are considered to be within the acceptable range. More specifically, all potato damage index values are below 100, set as the lower limit of the potato damage index that described by Bishop and Maunder (1980).

Table 4 Proportion of lifted tubers and total potato damage at the operating variables

Oscillation Amplitude (mm)	Harvester Forward Speed (km/h)	Percentage of Lifted Potato Tubers (%)			Percentage of Tuber Total Damage (%)		
		Digging Depth (cm)			Digging Depth (cm)		
		12	17	22	12	17	22
17	1.50	72.82	83.96	97.75	3.36	2.81	0.58
	1.70	74.88	96.11	95.89	5.66	2.73	0.86
	2	51.25	98.02	97.36	10.96	1.47	0.76
25	1.50	79.89	96.54	99.10	8.65	1.26	0.60
	1.70	73.88	94.23	96.42	9.50	2.54	0.10
	2	72.80	96.93	97.02	12.01	2.53	0.04

Table 5 Amount of lifted, un-lifted, and potato tuber damage at the operating variables

Oscillation Amplitude (mm)	Harvester Forward Speed (km/h)	Lifted Potato Tuber (ton/ha)			Un-lifted Potato Tuber (ton/ha)			Potato Tuber Damage (ton/ha)		
		Digging Depth (cm)			Digging Depth (cm)			Digging Depth (cm)		
		12	17	22	12	17	22	12	17	22
17	1.50	23.07	24.72	35.90	8.57	5.31	0.75	0.76	0.71	0.19
	1.70	28.82	39.97	35.25	9.66	1.74	1.49	1.62	1.12	0.30
	2	18.73	37.07	30.75	17.13	0.72	0.84	1.77	0.55	0.23
25	1.50	29.80	32.67	39.36	7.56	1.18	0.35	2.42	0.42	0.23
	1.70	26.64	42.27	38.24	9.32	2.47	1.43	2.18	1.10	0.036
	2	28.65	41.75	40.04	9.08	1.30	1.22	2.67	1.05	0.02

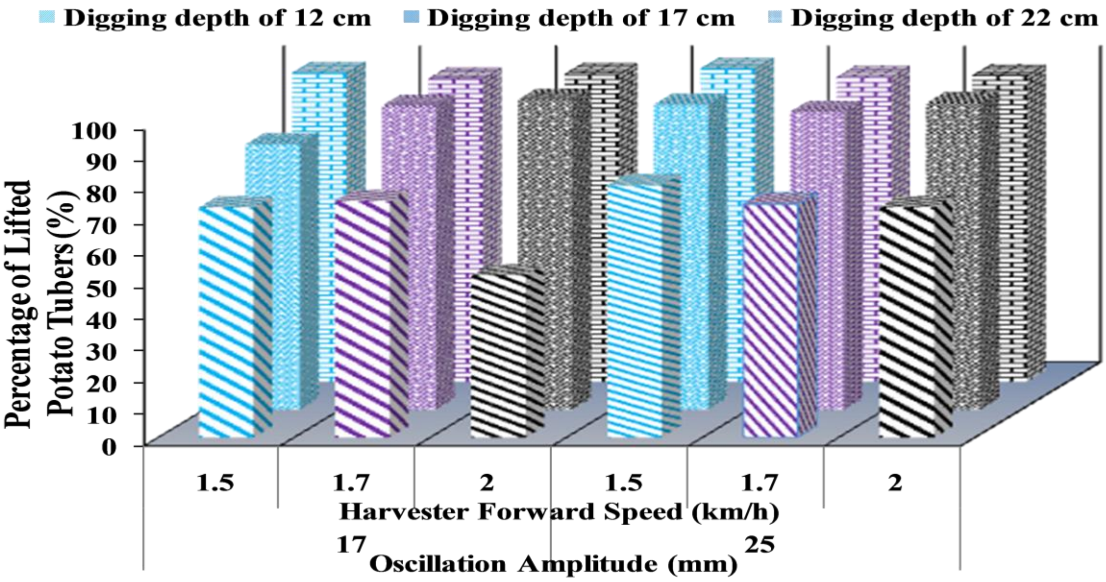

Figure 6 Effects of the interaction of the operating variables on the lifted potato tubers

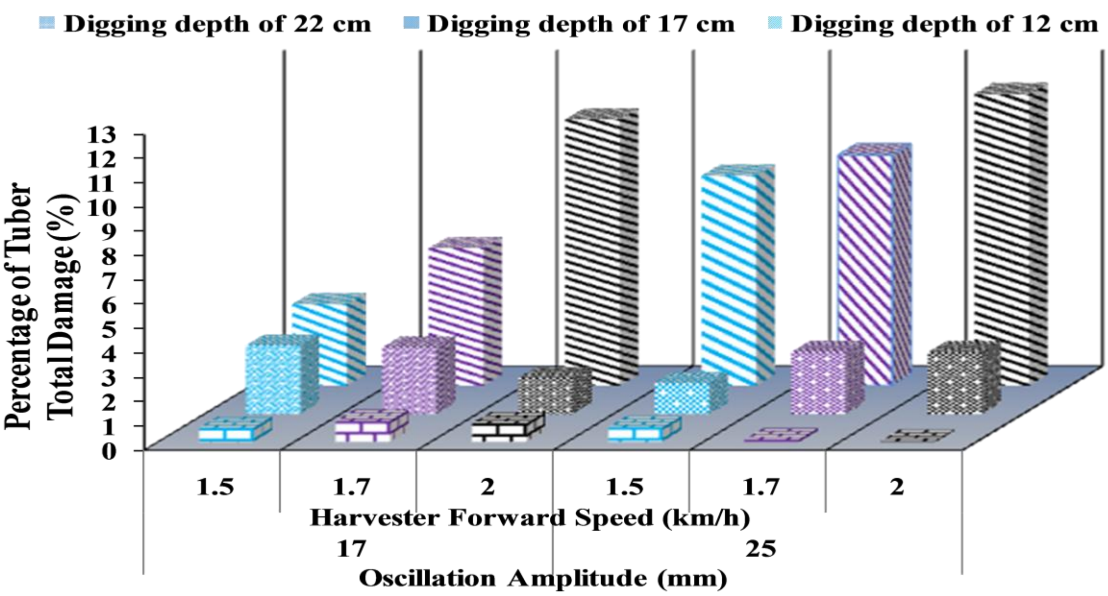

Figure 7 Effects of the interaction of the operating variables on the tuber total damage

Table 6 Values of the potato damage index at the various operating variables

Oscillation Amplitude (mm)	Harvester Forward Speed (km/h)	Potato Tuber Damage Index		
		Digging Depth (cm)		
		12	17	22
17	1.50	14.52	13.63	1.60
	1.70	28.89	12.03	4.87
	2	56.86	7.50	3.13
25	1.50	48.23	4.30	3.40
	1.70	55.60	10.17	0.25
	2	58.42	10.74	0.04

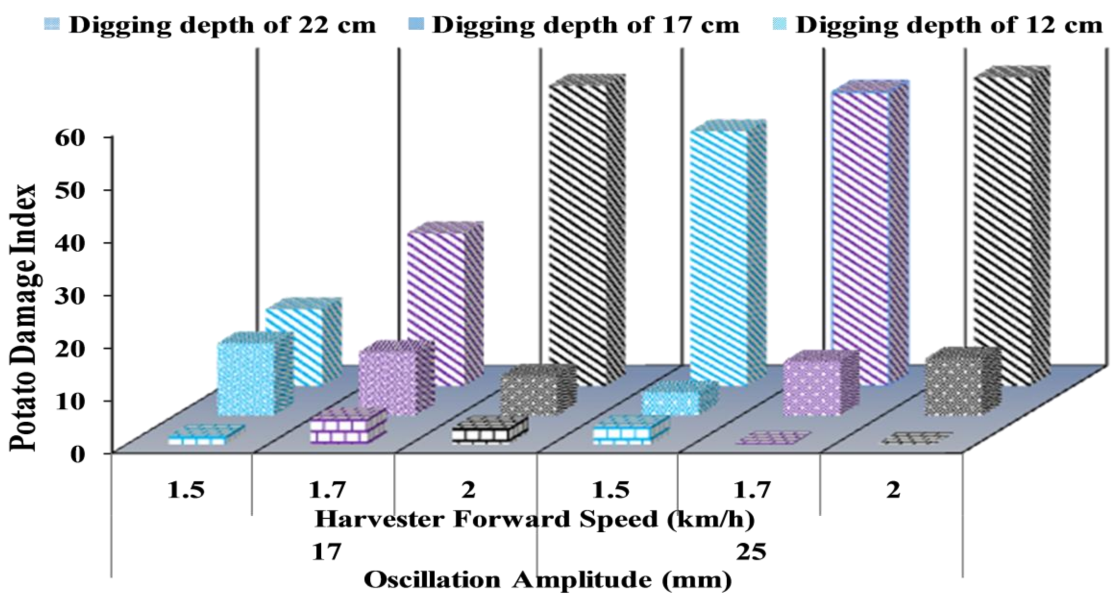

Figure 8 Effects of the interaction of the operating variables on the potato damage index

4 Conclusions

The study findings indicate that, by increasing the forward speed of the harvesting machine, the percentage of superficially scratched tubers and broken tubers increased. Therefore, the total tuber damage and the value of the potato damage index increased. The percentage of lifted potato tubers decreased and the amount of potatoes buried in the soil increased when the harvester forward speed increased. There was a high significant effect of digging depth on lifted, damaged tuber percentage and potato damage index, at 10% significance level. By increasing the digging depth from 12 cm to 22 cm, the lifted tuber percentage increased from 70.92% to 97.25%, and the damaged tuber percentage decreased from 8.36% to 0.49%. In addition, the damaged tuber index decreased from 43.75 to 2.21 due to the adequate increase in the digging depth, as well as at 90% level of confidence, statistical analysis revealed that the primary riddle chain oscillation amplitude had no significant effect on the percentage of lifted tubers, damaged tubers, and potato damage index.

Practically, interaction between the forward speeds, digging depths, and the primary riddle chain oscillation amplitudes of the potato harvester showed that the highest lifted tuber percentage of 97.02%, the lowest percentage of damaged tubers (0.04%), and potato damage index (0.04), which was obtained at the forward speed of 2 km/h, the digging depth of 22 cm, and the primary riddle chain amplitude of 25 mm.

Finally, in light of these findings, it can be concluded that, when operating a potato harvesting machine with two-row digging blades and two riddle chains, the following operating variables would yield the most optimal results: forward speed of 2 km/h, digging depth of 22 cm, and the primary riddle chain oscillation amplitude of 25 mm. These variables achieved the highest percentage of lifted potato tubers 97.02% (40.04 ton/ha), the lowest percentage of tuber total damage 0.04% (0.02 ton/ha), and the lowest potato damage index (0.04).

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