Effect of Operation Variables of Potato Digger with Double Chain Conveyors on Crop Handling and Machine Performance

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***Abstract*—** *The experiments were conducted at Al- Gimma Agricultural Scheme in the Tragma area- Shendi locality, River Nile State during April – 2017, to study the effect of some operational factors related to harvesting machine such as tractor forward speed (4.4, 5.6 and 6.7km/hr, harvesting depth (16, 18 and 21cm) and the conveyer inclination (15° and 20°) on some of potato crop handling such as lifting potatoes, cut of potatoes, Bruised and Total bruised (Damage) index potato and some of machine performance such as travel reduction (wheel slippage), effective field capacity and fuel consumption. The results showed that, there were significant influences of forward speed, harvesting depth and conveyer inclination on tubers lifting, cut of potatoes while the effect of different forward speed showed no significant effect on potatoes damage, further no significant on the percentage of scuffed damage tubers, peeler damage tubers, severe damage tubers, total damage index as effecting by conveyer inclination. As the digging depth of digger increased from 16 to 18, the lifting potatoes increased from* 93.42 *to* 94.42%*, while decreased from* 94.42% *to 87.72% when the digging depth decreased from 21cm to 18cm. Significant and consistent increase in tubers lifting percentage was recorded due to increase in conveyer inclination. Less percentage of scuffed, peeler, severe damage tubers and total damage index of 0.2%, 0.0%, 1.6% and 21.9, respectively were recorded at speed of 6.7km/hr, while the highest percentage of scuffed, peeler and severe damage tubers of 2.1%, 0.3% and 2.7% respectively were recorded at Speed of 4.3km/hr.*

Statistical analysis (P<0.05) showed that increasing the forward speed, increased effective field capacity and fuel consumption significantly while there was no significance effect on wheel slippage. Furthermore, increasing the digging depth increased the wheel slippage and fuel consumption significantly where the effective field capacity significantly decreased. The conveyer inclination showed no significant effect on machine performance.

***Keywords*— potato digger machine, lifting potatoes, cut of potatoes, bruised potato, and Total Damage index and machine performance.**

I. INTRODUCTION

The tropical root and tuber crops are comprised of crops covering several genera. They are staple foods in many parts of the tropics, being the source of most of the daily carbohydrate intake for large populations. These carbohydrates are mostly starches found in storage organs, which may be enlarged roots, corms, rhizomes, or tubers. Many root and tuber crops are grown as traditional foods or are adapted to unique ecosystems and are of little importance to world food production. Others such as cassava (ManihotesculentaCrantz) and white-fleshed sweet potato (Ipomoea batatas L.) are known worldwide. [1].

The potato (Solanum tuberosum L.), Solanaceae, is the most important oleracea culture around the world. It is considered the fourth largest source of human food, standing after rice, wheat and corn. The global annual production of potato is around 321 million tons, being cultivated in about 125 countries. More than a billion people eat potatoes every day around the world [2]; [3].

Potato is one of the main human alimentary resources. It was the sixth alimentary product in the world after sugar cane, maze, rice and paddy, wheat and milk [4]. Among the processes that make up the production system of potato cultivation, harvesting is presented as a crucial step, and one of the most expensive in the production process [5]. In Sudan There are problems regarding potato cultivation and storage. The collection of these problems cause the cut of product yield and rise of wastage value as the mean of potato production is 24 tons/ha but this number amounts to 50 tons/ha at developed countries [6].

Potato wastage values during the investigation were 48% from harvest stage to consumption and wastages of harvest implements were declared 1.72% [7]. Mechanical harvest of potato relative to manual harvest causes 65% frugality at harvest time and 45% at harvest costs [8].

These statistics show importance of activities in the field of potato diggers. [9] Made a potato digger and evaluated it. Mean of hurt potato tubers by set was stated 3.2%. [10] Designed a one row mounted potato digger that the hurts of harvested potatoes were reported 4% and up to skin. [11] Studied a potato digger with oscillating blade. Generated clods with lower mean of geometric diameter were reported and volumetric density was decreased.

[12] Designed and tested a two row mounted potato digger and reported that potato bruises were increased with addition of frequency and amplitude of vibration but it had not much effect on the remained potatoes in soil. In addition, amplitude had not much effect on traction but with increase of frequency traction was diminished

In Sudan, harvesting is usually performed manually or semi-mechanized, and share responsibility for the high cost of production. In the semi-mechanized harvesting, diggers are used, coupled to a tractor, which degrade the furrows and expose the tubers. Later, the collection is done manually by men or young women who also carry out a preliminary field selection. However, self-propelled harvesters have been used in advanced countries for potato culture. The trend toward mechanization of the total harvest is related to the availability and cost of manpower. These harvesters chop the ridges apart and collect the potatoes, in two or more rows, directing them to the carrier trucks. They are larger machines, which require elongated rows to avoid maneuvers and frequent loss of time [13], which reduce the operational capability of the machine.

According to [14], the process of mechanized harvesting of potatoes can represent a great advance for the producing regions, mainly to optimize the production process, with increased production area, faster removal of tubers from the ground when free risk of attack from pests and diseases, and stronger compliance with delivery dates of production. However, the decision to invest invariably involves risks, which must be provided when one decide to invest in certain equipment. The acquisition of harvesters involves high investment, and is only justified if there is a significant effect on the profitability of the activity [15]. The selection of an agricultural machine can become a daunting task, because there are many variables to consider, and choose the most appropriate equipment to a farm is one of the most important stages of the production process [16].

Cultivation in a large area will involve labour intensive work especially during the harvesting operation. Currently, sweet potato is mostly harvested manually. The manual labour cost for a harvesting operation constitutes about 30 - 40% of the total operational cost [17]. In manual harvesting of sweet potato tubers, the farmers have to cut and pull out the vines and lay them along the furrow. The tubers will then be dug by using a hand tool such as a hoe and fork, followed by manual collection. The tubers are transported in a basket or gunny sack. The most strenuous and back-breaking task is digging the tubers. The harvesting operation of sweet potato requires about 150 man-hours per hectare [18]; [17].

The potato harvesters specialized in supplying the potato industry began a movement for the acquisition and exchange of experiences with imported potato harvesters, and this created, consequently, a demand for information relating to real opportunities for the improvement that the harvest mechanization has facilitated [14]. With the advent of new technologies, studies are needed to quantify the real operational capability and costs of these new harvesters, as well as any loss of tubers during harvest, given the low availability of such data and the recent entry of self-propelled harvesters.

Keeping in view all the above salient criteria, the main objective of the present research work is to study the effect of some operational factors related to harvesting machine such as tractor forward speed, harvesting depth and the conveyer inclination on some of potato crop handling such as lifting, cut of potatoes, Bruised and Total bruised (Damage) index potato and some of machine performance such as travel reduction (wheel slippage), effective field capacity and fuel consumption.

II. MATERIAL AND METHODS

2.1 Experimental site

The experiments were conducted during April - 2017 in a commercial potato crop grown in the area under the center pivot system, in Al- Gimma Agricultural Scheme owned by GIAD Industrial Group, in the Tragma area- Shendi locality, River Nile State (North of Sudan). The variety that grown was Belini, spaced 18 cm between plants and distance between rows was 90 cm depth of 7 cm. The crop was planted on 24-29/12/2016 and the harvesting began on 10/4/2017. The Engineering characteristics of the examined soil are given in Table 1; the predominant soil type is sandy clay loam soil.

2.2 Experimental design and treatments applications:

In this study, a factorial experiment was (arranged in a split – split plot design with three replicate for each, the three lifting depths (16, 18, 21cm) were assigned to the main plots while the three forward speeds (4.4, 5.6 and 6.7 km/hr) and two conveyer inclination degree (15° and 15°) were distributed to the sub-plot and sub-sub-plots respectively, giving a total of 54 plots. The treatments were randomly distributed in the main; sub plot and sub-sub plot, the sub–sub plot area was 90m2 (50m × 1.8m) were separated by a distance of 2m between each sub-sub plots and by distance of 10m at the end of sub-sub plot. Amounted digger Fig. 1 was used for all the tests, the specifications of the potato crop digger was illustrated in Table 2.

Potato harvesting machine used in this research had two chain conveyors Fig.1. These types of machines are used in different areas of Sudan, especially in areas with light soils. This machine is suitable for use in above condition, but when the soil is moist and sticky, not used. The major advantage of potato harvesting machine with chain conveyor is delivering potatoes on a row in the field that will facilitate the gathering potatoes by hand, although it will not be caused a significant reduction in the number of workers needed to collect the potatoes. Compared with other types of harvesting machines, components of this type of machine have higher erosion. Dimensions properties and the specifications of machine used in this study are summarized in Table 2.

FIG. 1: Potato harvesting machine used in this research

TABLE 1
SOME OF SOIL PROPERTIES OF THE EXPERIMENTAL SITE BEFORE TEST

Depth (cm)	Bulk density (gm/cm3)	pH	Moisture content (%)	infiltration rate	Soil texture
0-25cm	1.72	7.3	7.6	6.8 cm/hr	sandy clay loam

2.3 Measurement

The following performance parameters were determined to evaluate the root drop digger

2.3.1 Crop parameters

Number of tubers per meter row length

The numbers of tubers were counted in one meter row length. The counting was done before harvesting of crop. The data was recorded at ten places selected randomly.

TABLE 2
TECHNICAL SPECIFICATIONS AND CHARACTERISTICS OF THE TRACTOR AND POTATO DIGGER

Characteristics	Description
Tractor	
Brand	Massey Ferguson
Model	480 Xtra
Engine Power	96.9 kW (130 hp)
Potato digger	
Brand	Grimme
Model	WH200
Number of rows	2
Number of conveyor	2
Working Width	1.8 m
Share shape	Trapezium
Share width	56 cm
Hitching	Three point linkage

2.3.2 Depth of crop

The data was recorded at ten random places. The depth was measured by a measuring scale after removing the soil from side of the bed.

2.3.3 Tubers lifting

The lift potato was calculated to know how much of the potato remained un-dug. It was defined as follows

$$\text{Lift potato \%} = \frac{c}{d} \times 100$$

Where,

c is the total number of digged potato.

d is the total number of potato (digged and un-dug both).

2.3.4 Cut potato

Cut potato was calculated to know the percentage of potato which was cut by the digging blade. It was defined as follows

$$\text{Cutpotato \%} = \frac{f}{d} \times 100$$

Where,

f is the total number of cut potato by the digging blade

2.3.5 Bruised and bruised index potato

Bruised potato required to know the percentage of bruised potato (skin comes cut) either by striking with soil clods or due to rubbing action while being conveyed on the oscillating conveyor. It was defined as follows

$$\text{Bruised potato\%} = \frac{e}{d} \times 100$$

Where,

e is the total number of potato which are bruised

To calculate the bruised index random samples of tubers were collected from each treatment and classified as follows:

Undamaged: tubers have no bruise and cut, Scuffed: only skin broken, no flesh damage,

Peel damage: This can be removed by a stroke 3 mm deep of hand potato peeler.

Severe damage: This cannot remove by a 3 mm deep stroke of a hand peeler.

The total damage index (TDI) was calculated as indicated by [19].

$$\text{TDI} = \text{Scuffed x } 1 + \text{Peeler x } 3 + \text{Severe x } 7$$

2.3.6 Rear wheel slippage (%)

The tractor rear wheel slippage (S) was calculated as a percentage of loss of forward speed as in the following equation

$$S\,(\%) = \left(1 - \frac{V_a}{V_t}\right) \times 100$$

The actual travel speed (Va) for tillage was measured using stopwatch to record the time taken by the tractor to travel specific distance (100 m). Theoretical travel speed (Vt) of the tractor was measured by the same way mentioned above with the implements raised up and the tractor traveled the same distance (100 m).

2.3.7 Effective field capacity (EFC)

The actual operating time along with time lost for turning of machine were recorded in the field test area. The effective field capacity of the machine was calculated as follows

$$\text{EFC} = \frac{A}{T_p + T_1}$$

Where,

EFC = Effective field capacity, ha h-1

A = Area covered, ha

TP = Productive time, h

T1 = Non-productive time, h

(Time lost for turning, excluding refueling and machine trouble).

2.3.8 Fuel consumption

For measuring the fuel consumption of tractor, the fuel tank was filled up to neck of the fuel tank before and after the digging operation. The amount of refilling measured after the test was the fuel consumption for digging operation and it was expressed as liter per hour.

2.4 Statistical Analysis of the data

The quantitive data were quantified according to standards laid down and tabulated to draw meaningful inferences. In order to see the significance of results for un-dug, bruised, cut and digging efficiency, the data were subjected to the statistical analysis by the analysis of variance technique programme given by O.P. Sheoran (www.hauernet.in). Critical differences were also calculated at 5 per cent and 1 per cent level of significance.

III. RESULTS AND DISCUSSION

Table 3 shows the analysis of variance results related to the effects of forward speed, harvesting depth and conveyer inclination on the Tubers lifting, cut of potatoes, total damage index, wheel slippage, fuel consumption and effective field capacity of Potato Digger with Double Chain Conveyors.

3.1 Effect of operating variables of Potato Digger with Double Chain Conveyors on Tubers lifting

Table (3) indicates that, the influence of forward speed and harvesting depth on tubers lifting was highly significant at 5 percent level of confidence, where there was a significant difference when it was influenced by conveyer speed (P>0.05) (Table 3).

TABLE 3
ANOVA DESCRIPTION FOR ALL OBSERVED PARAMETERS AT DIFFERENT FORWARDS SPEED, HARVESTING DEPTH AND CONVEYER INCLINATION AND THEIR INTERACTIONS.

Observed parameters	Lifting		Damage		Scuffed		Peeler		Severe		Damage Index		Wheel slippage		EFC		Fuel consumption	
Source	P	SS	P	SS	P	SS	P	SS	P	SS	P	SS	P	SS	P	SS	P	SS
Speed	0.00	123.1	0.98	0.49	0.06	33.9	0.51	0.78	0.39	13.89	0.40	1015.5	0.47	33.81	0.00	1.89	0.00	166.01
Depth	0.00	470.3	0.00	330.1	0.00	43.8	0.12	2.21	0.00	249.9	0.00	12777.5	0.06	113.3	0.07	0.05	0.00	385.9
inclination	0.02	144.1	0.97	0.735	0.26	6.10	0.61	0.003	0.46	5.447	0.12	706.0	0.45	11.27	0.05	0.03	0.00	33.23
Speed × depth	0.00	998.9	0.71	3.93	0.01	39.7	0.92	1.21	0.42	38.47	0.60	1215.5	0.28	92.33	0.24	0.05	0.00	222.7
Speed × inclination	0.54	28.30	0.27	15.7	0.71	3.19	0.08	2.34	0.66	8.340	0.37	572.5	0.94	2.18	0.26	0.02	0.00	55.36
Depth × inclination	0.00	533.9	0.61	5.58	0.54	5.89	0.91	0.07	0.06	8.34	0.12	1293.0	0.18	72.44	0.60	0.01	0.00	39.79
Speed×Depth× inclination	0.01	409.60	0.3	28.95	0.57	13.8	0.13	3.34	0.93	7.74	0.81	420.2	0.05	225.1	0.78	0.009	0.00	67.743

EFC = Effective field capacity, P = probability SS = sum. of Square

There was a consistent decrease in the tubers lifting with increase in forward speed from Sp1 to Sp2 and Sp3. Pooled data of tubers lifting showed that forward speed Sp2 of (5.6km/hr) was having the highest tubers lifting percentage of 93% which was nearly 0.2% and 3.5% more than that at (Sp1 of 4.4km/hr) and (Sp3 of 6.7km/hr), respectively Fig. 2. Our findings with regarding to tubers lifting are in conformity with those of [20]and [21]who found that, the forward speed of digger increased resulted to the un-dug potatoes increased. The best result of lifting potatoes was found when the machine was working in Sp2.

With increase in harvesting (digging) depth, the tubers' lifting goes on increasing. Highest percentage of tubers lifting was recorded due to harvesting depth at deepest harvesting of 21cm as compared to other two depths of 18 cm and 16cm. it can be seen that as the digging depth of digger increased from 16 to 18, the lifting potatoes increased from 93.42 to 94.42%, while decreased from 94.42% to 87.72% when the digging depth decreased from 21cm to 18cm as showed in Fig. 2.

Significant and consistent increase in tubers lifting percentage was recorded due to change in conveyer inclination from inclination 1 to inclination 2 (table3). Tubers lifting percentage at inclination 2 were slightly superior to inclination by 3.49%. (Fig. 2).

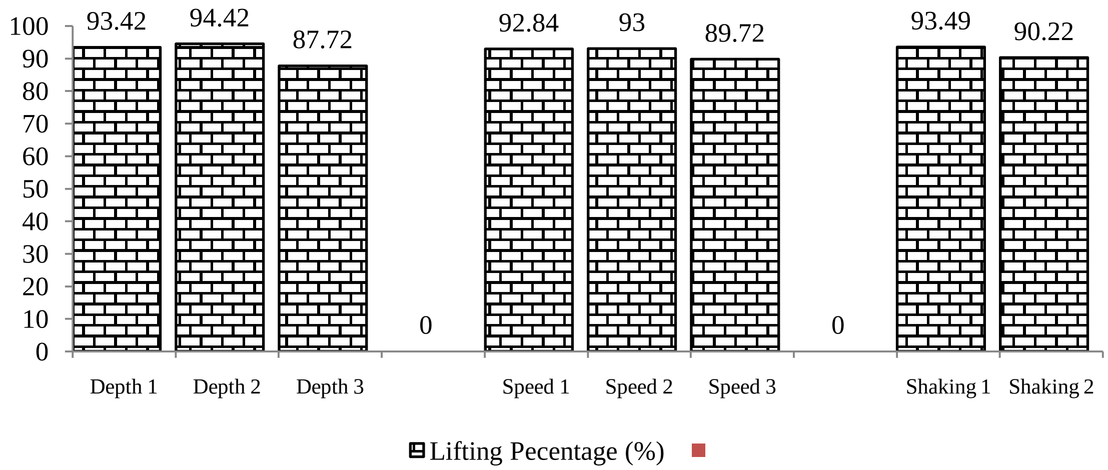

FIG. 2: Effect of operating variables on Tubers lifting percentage (%)

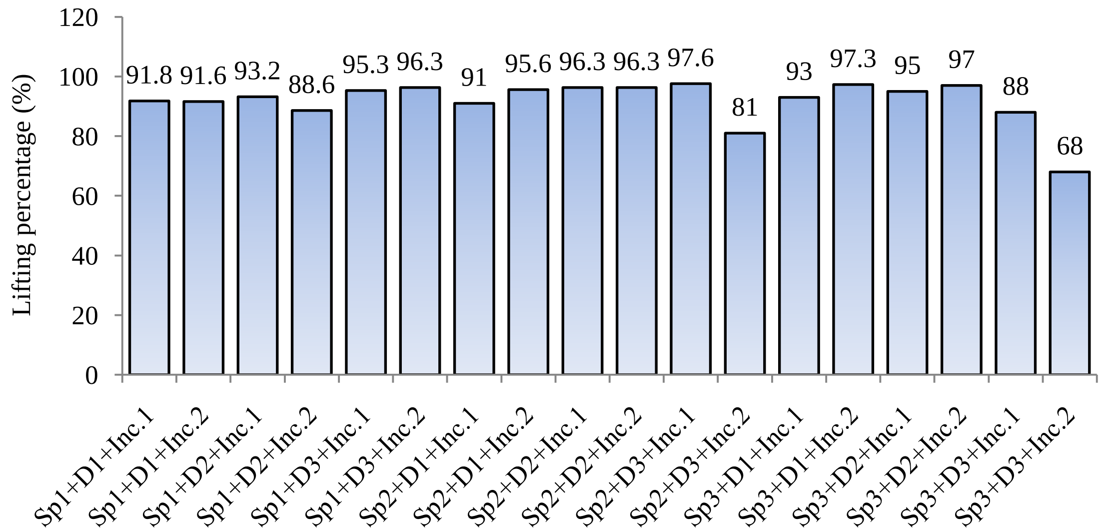

FIG. 3: Effect of interaction of operating variables on Tubers lifting percentage (%)

3.2 Effect of operating variables of Potato Digger with Double Chain Conveyors Cut potatoes

The statistical analysis of data on the influence of study variables on the cut potatoes indicated that the cut potatoes were highly influenced by forward speed at 5% level of significance and harvesting depth at 5% level of significance as indicated in Table (3), where there was no significant difference when it was influenced by conveyer inclination ($P>0.05$). The interaction of forward speed and harvesting depth and the interaction of harvesting depth and inclination of conveyers were not- significant (P>0.05) as shown in Table (3).

The mean values of cut potatoes at different forward speed, harvesting depth and conveyer inclination are shown in Fig. 4, Fig. 5 and Fig. 6, respectively. From Fig. 4, Fig. 5 and Fig. 6, it can be seen that as the forward speed increased from Sp1 to Sp3 the cut potatoes increased from 2.3% to 2.5%, while it was decreased from to 5.9% to 1.2% and from 1.2% to 0.2% as the harvesting depth increased from 16cm to 18cm and from 18cm to 21cm, respectively. The increase in the percentage of the cut potatoes with increase in forward speed of the root crop digger may be attributed to the reason that as the speed increased, the fluctuation of digging blade increased and the potatoes which were at varying depth got cut by the digging blade. Similar trends of increase in cut potatoes with increase in forward speed of root crop digger have been reported by [22] and [23]. [24]reported that percentage of tuber damage decreased with the decrease in forward speed. Similarly the cut potatoes decreased from 2.6% to 2.3% as the inclination changed from inclination1 to inclination 2 (Fig. 6).

As shown in Table 3, the interaction between forward speed, harvesting depth and conveyer inclination were significant different (P>0.05).

From the obvious results which was shown in Fig.7, it may be considered that, the lowest cutting percentage of (0%) under the following treatment of Sp1 + harvesting depth3+ conveyer inclination 2, treatment of Sp2 + harvesting depth3 + conveyer inclination 1 and Sp3 + harvesting depth3+ conveyer inclination 1.

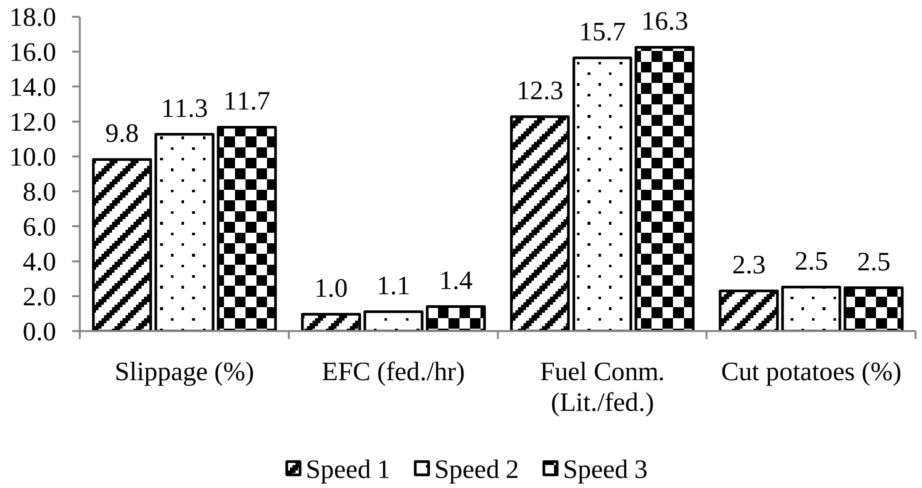

FIG. 4: Effect of different forward speed on machine performance and percentage of cut potatoes

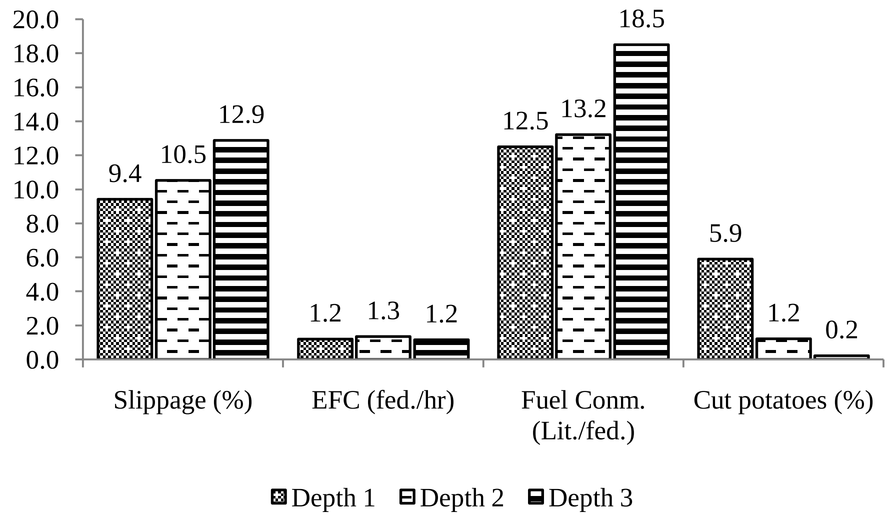

FIG. 5: Effect of different harvesting (digging) depths on machine performance and percentage of cut potatoes

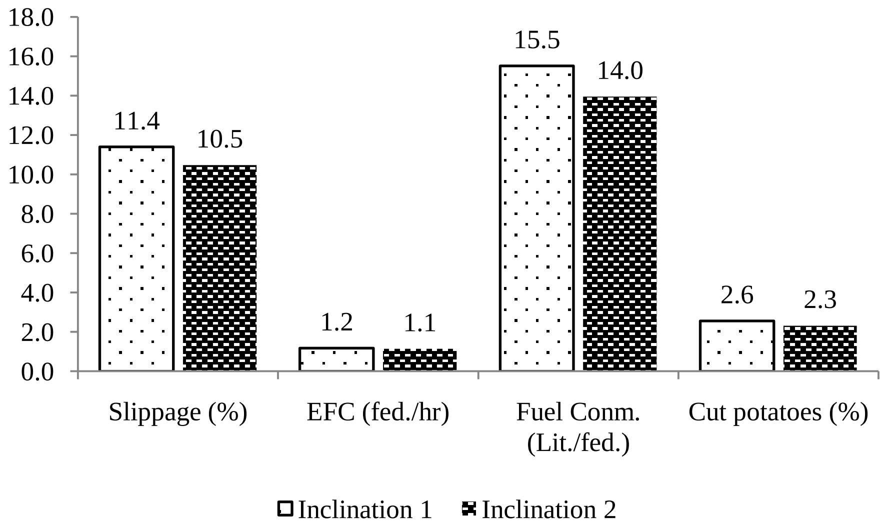

FIG. 6: Effect of different conveyer inclination on machine performance and percentage of cut potatoes

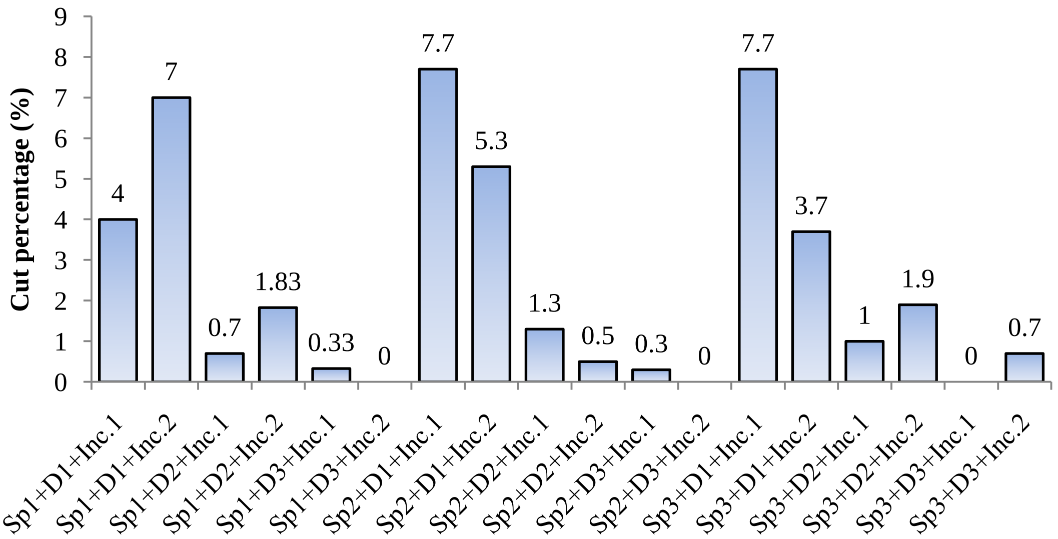

FIG. 7: Effect of interaction of operating variables on Tubers Cut percentage (%).

3.3 Effect of operating variables of Potato Digger with Double Chain Conveyors on Bruised and Total Damage (Bruised)index of potatoes tubers

The results indicated that, the increase of tractor forward speed from 4.3 to 6.7 km/h was accompanied with decreased in each of scuffed damage tubers, peeler damage tubers, severe damage tubers, total damage index tubers of potato tubers for the experimented potato digger. (Fig. 8)

There was no significant decrease in the percentage of tubers damages with increase in the forward speed from Sp1 to Sp2 and Sp3 (P>0.05) as presented in Table (3). Less percentage of scuffed, peeler, severe damage tubers and total damage index of 0.2%, 0.0%, 1.6%and 21.9 were recorded at Sp3 of 6.7km/hr, while the highest percentage of scuffed, peeler and severe damage tubers of2.1%, 0.3% and 2.7% was recorded at Sp1 of 4.3km/hr,Fig.8. This result is agrees with finding by [25], who stated that, the increase in forward speed led to decrease the bruised of the potatoes.

The digging (harvesting) depths had a highly significant effect on tubers severe and scuffed damage while showed no significant effect on peeler damage and total damage index Table (3). As shown in Fig.9 the depth of 21cm produced higher scuffed, peeler and severe damage tubers and total bruised (damage) index of 2.2%, 0.5%, 5.1% and 43.6 respectively, while the lowest scuffed, peeler and severe damage tubers and total damage index produced with the depth of 18cm. The increase in the percentage of the potatoes total damage index with decrease in digging depth of the root crop digger may be attributed to disturbed big soil clods resulted depth increasing.

Percentage of scuffed damage tubers, peeler damage tubers, severe damage tubers, total damage index showed no significant variation due to two different conveyer inclination (inclination 1 and inclination 2), (P>0.05), Table (3). Fig. 10 showed that, the mean values of percentage of scuffed damage tubers, peeler damage tubers, severe damage tubers, total damage index at two different conveyer inclination((inclination 1 and inclination 2) which are 0.64% and 1.31%, respectively for the scuffed, 0.16 and 0.17% for peeler, 1.9 and 2.5% for severe and 14.5 and 20.1 for total damage index of different conveyer inclination respectively, this results are inline with finding by [25]who found that, the increase in chain inclination led to increase the damage of tubers.

The interaction of forward speed and harvesting depth and conveyers inclination were non- significant (P>0.05), as shown in Table (3).

Fig. 11 showed that, the best optimized values of speed-inclination combination with respect to total damage index were Sp1 + harvesting depth3 + conveyer inclination 2, Sp2 + harvesting depth3 + conveyer inclination 2 and Sp3 + harvesting depth3 + conveyer inclination 1.

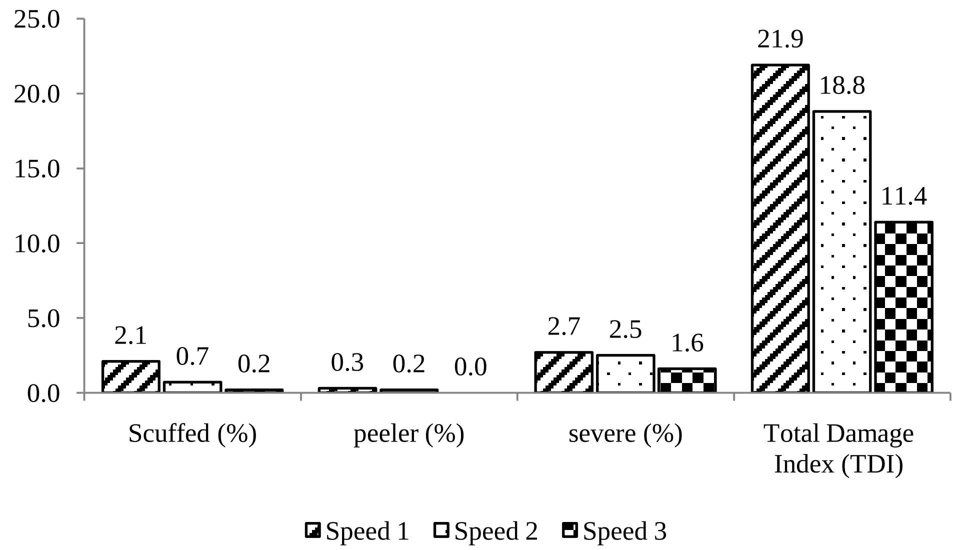

FIG. 8: Effect of different forward speed on bruised potatoes parameters and potato total damage index

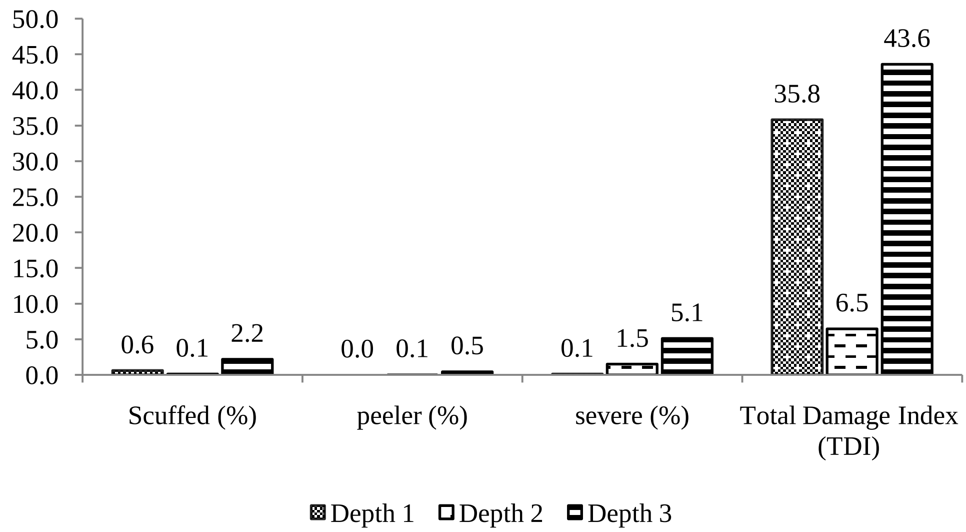

FIG. 9: Effect of different harvesting (digging) depths on bruised potatoes parameters and potato total damage index

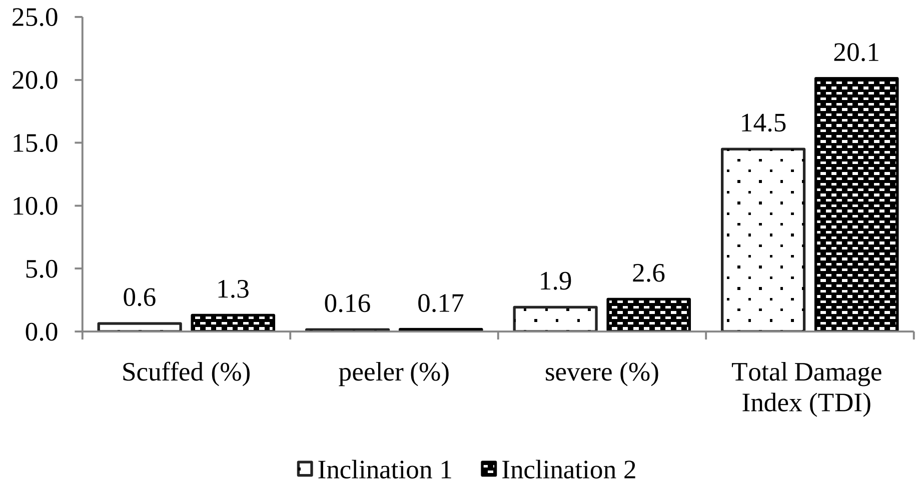

FIG. 10: Effect of different conveyer inclination on bruised potatoes parameters and potato total damage index

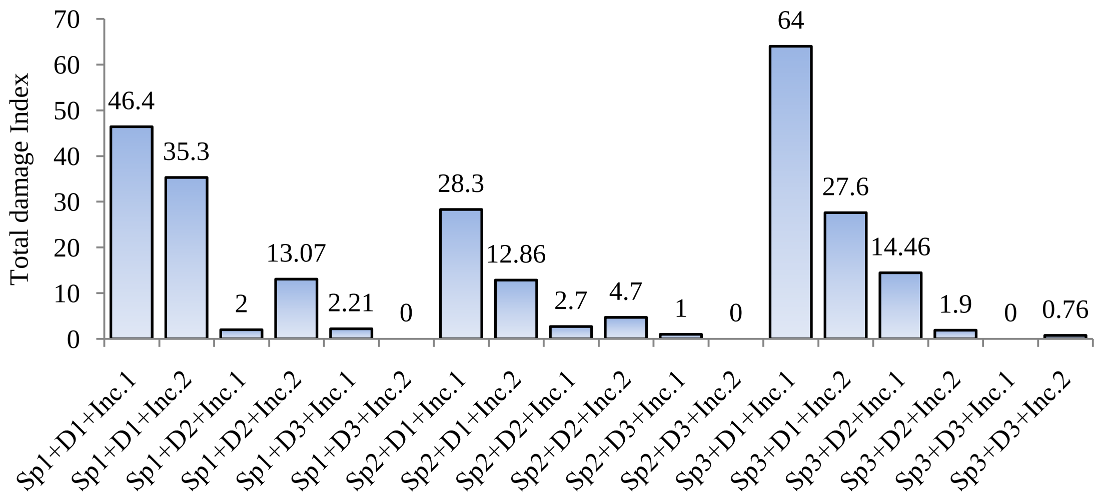

FIG. 11: Effect of interaction of operating variables on Total Damage Index (%)

3.4 Effect of operating variables of Potato Digger with Double Chain Conveyors on wheel slippage

Mean comparison between the averages of Travel reduction or wheel slippage in different forward speed by statistical analysis showed that increasing the forward speed, increased wheel slippage not significantly (Table 3). These results are in agreement with the findings of other researchers[26],[27]and [28]. The interaction effect of forward speed and digging depth was not- significant as indicated in Table (3).

Travel reduction or wheel slip is one of the major parameters affecting the tractive efficiency of a pulling machine. Wheel slippage at different levels of speed designated as Sp1, Sp2 and Sp3 for 4.4, 5.6 and 6.7 km/hr, respectively are shown in Fig. 4which are 9.8%, 11.3% and 11.7%. There was positive linear correlation between speed and travel reduction. Travel reduction was high at high speeds and decreased with decrease in speed.

The statistical analysis performed on travel reduction as affected by digging depth showed there is no significant difference (P<0.05). The interaction effect of digging depth and conveyer shaking showed also no- significance different which was presented in (P<0.05) Table (3).Fig. 5 shows the mean comparison between travel reductions (wheel slippage) in different digging depth. It is clear that by increasing digging depth the travel reduction of potatoes digger increases. The travel reduction of potatoes crop digger as shown in Fig 5 were 9.4, 10.5 and 12.9% were obtained at depth 1, depth2 and depth3, respectively. It may be due to this reason that increasing the digging depth resulted in an increase in dimension and soil tear.

The percentage increases in travel reduction with changing in inclination 1 to inclination 2 were 11.4 and 10.5%, respectively Fig 6. The values of travel reduction were non-significant at two different of conveyer inclination ($P<0.05$) as indicated in Table 3.

The interaction effect of forward speed, digging depth and conveyer inclination were also show not-significant as indicated ($P>0.05$) in Table (3).

Fig. 12 showed that, the treatment of Sp2 + harvesting depth2 + conveyer inclination 1, may be considered as best optimized value for wheel slippage percentage (5.9%) of the potato crop digger.

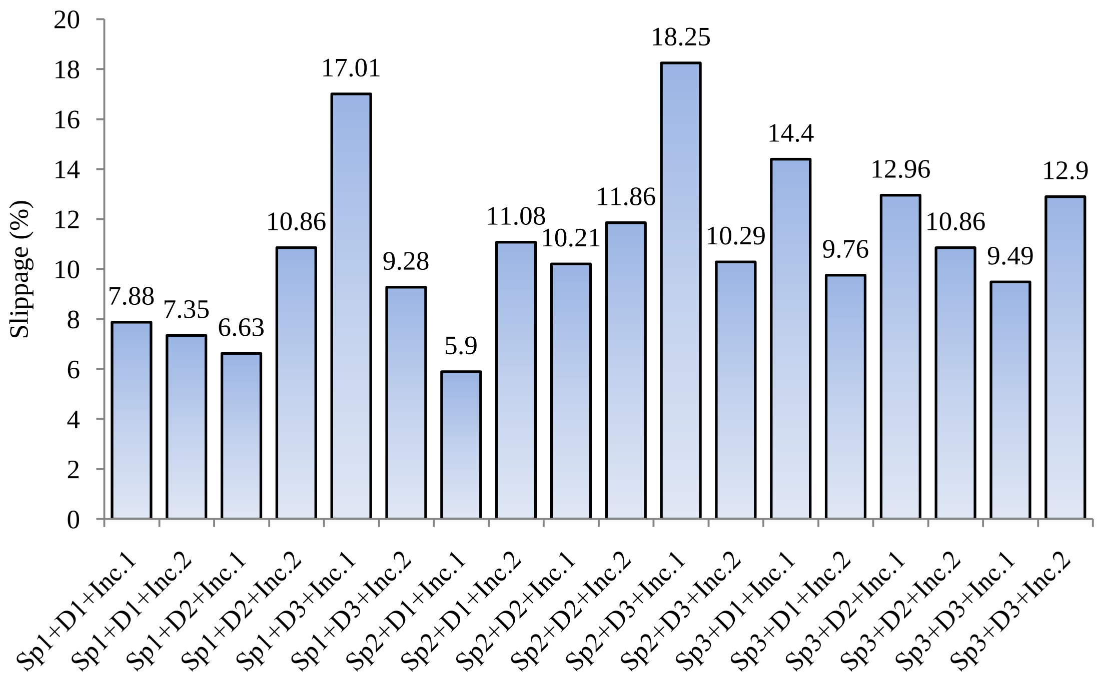

FIG. 12: Effect of interaction of operating variables on wheel slippage (%).

3.5 Effect of operating variables of Double Chain Conveyors Potato Digger on effective field capacity

Effective field capacity (EFC) showed highly significant different due to forward speed Table (3).. There was an increasing in the effective field capacity with increase in forward speed from Sp1 to Sp2 and Sp3. Collected data of EFC indicated that the highest EFC of 1.4 ha/hr was recorded by Sp3 of 6.7km/hr which was 21.4% and 35.7% greater than that at Sp2 5.6km/hr and Sp1 4.4km/hr, respectively, as shown in Fig.4. This increase in the EFC with increase in the forward speed might be due to that fact, field capacity is mainly affected by speed travels in the field, time losses and width of machine and this agrees with [29]and [26].

Over the course of the study, different digging depths of the potatoes digger significantly different ($P<0.05$) affected EFC (Table 3) and Fig. 5. The EFC as affected by different digging depths (depth 1, depth2 and depth 3 are displayed in Fig. 5. There was a trend for EFC to decrease with increasing digging depth. From Fig. 4 it can be seen that as the digging depth of digger increased from 16cm to 21cm, the EFC decreased from 1.3ha/hr to 1.2ha/hr, respectively. This decrease in the EFC with increase in the digging depths might be due to; by increasing the depth, soil texture becomes more coherent. Also, traction force is related to the friction between blades and soil, so that by increasing the plowing depth, the force of soil weight on blades increases and it resulted to increase in friction.

In order to determine the effect of conveyer inclination on effective field capacity the variance analysis was presented in Table (3). The analysis showed that the conveyer inclination has no significant on effective field capacity. The maximum EFC of 1.2ha/hr was obtained by inclination 1 while inclination 2 recorded lowest EFC (1.1ha/hr) as shown in Fig. 6, It’s clear that the average EFC of inclination 1 was found slightly superior than that of inclination 2 by8.3%.

The interaction effect of forward speed and digging depth also the interaction effect of digging depth and conveyer inclination were also non-significant as indicated in Table (3).

As shown in Table 3, the interaction between forward speed, harvesting depth and conveyer inclination were not significant different (P>0.05).

From the obvious results shown in Fig.13, it may be considered that, the better EFC value of (1.56fed/hr) could be obtained under the following treatments of Sp1 + harvesting depth3+ conveyer inclination 1.

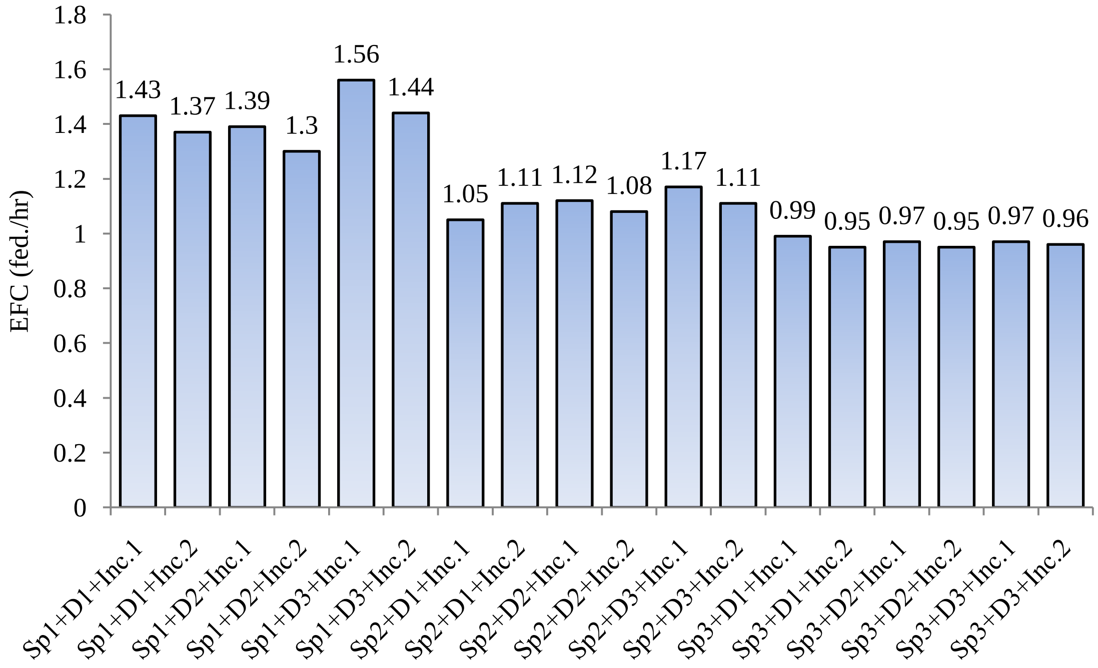

FIG. 13: Effect of interaction of operating variables on EFC (fed.hr)

3.6 Effect of operating variables of Potato Digger with Double Chain Conveyors on Fuel consumption

The values of fuel consumption were highly significant for different forward speed as indicated in Table (3). The interaction effect of forward speed and Harvesting depth and interaction of forward speed and conveyer inclinations and other interactions were also highly significant as indicated in Table (3). The details of the values of fuel consumption affecting by forward speed are given in Fig. 4. From Fig. 4 it can be seen that as the forward speed increased from Sp1 to Sp2, and from Sp2 to Sp3 the fuel consumption increased from 12.3 to 15.7 lit/ha and from 15.7 to 16.3 lit/ha, respectively. This result is agrees with[27];[26] who found that, there were a positive relation between forward speed and fuel consumption.

The effect of harvesting depth was also highly significant for different depth affecting the fuel consumption as indicated in Table (3). The interaction effect of harvesting depth and conveyer inclination was also showed non- significant different as indicated in Table (3).

The result showed that the average fuel consumption in the deepest depth was generally higher compared to lower depths. The average fuel consumption of 18.5 Lit/ha which recorded for the depth3 was observed to be higher than (Depth 2) and (Depth 1) by 28.6% and 32.4%, respectively, (Fig. 5). This result may be due to, By increasing the harvesting depth, more power is need to cut and transfer soil, so that lead to increase the fuel consumption and wheel slippage [30]. Similar results were found by [31]. Another reason for increasing the fuel consumption which is the tractor draught would be this fact that increasing digging depth will cause increasing the soil tear, bulk and mass, so that more power is need to cut the soil

Similarly a decreasing trend was observed for the fuel consumptions from 15.5 Lit/ha to 14 Lit/ha as the conveyer inclination changing from inclination 1 to inclination 2, Fig.6. Table (3) indicates that the influence of conveyer inclination on fuel consumptions is significant at 5 percent level of confidence.

The interaction effect of forward speed, digging depth and conveyer inclination was also significant as indicated in Table (3). The best optimized values of fuel consumption of (7.95lit/ha) may obtained from the combination of the following treatments Sp1, Depth 2and Inclination2 (Fig.14).

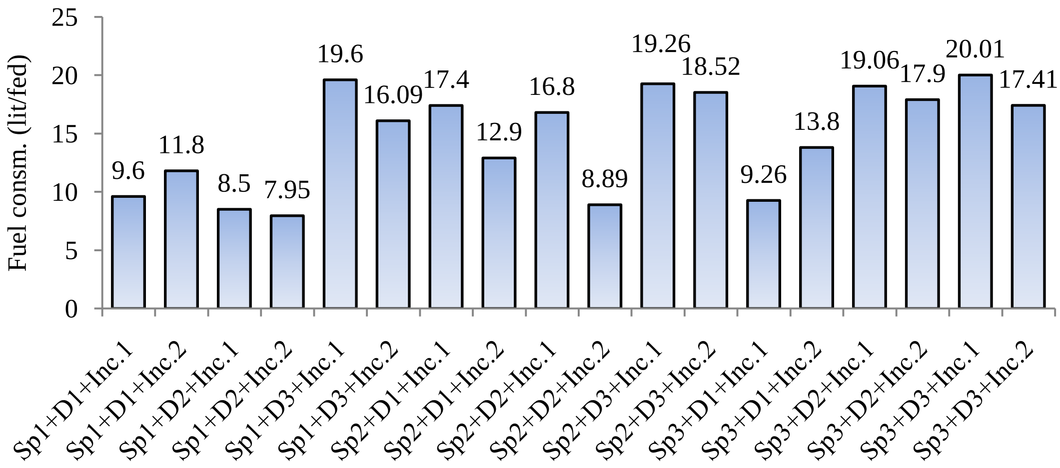

FIG. 14: Effect of interaction of operating variables on Fuel consumption (lit./ha)

IV. CONCLUSION

1) The percentage of lifting potatoes, cut of potatoes, Bruised and Total Damage index potato and some of machine performance such as travel reduction (wheel slippage), effective field capacity and fuel consumption as affecting by different forward speed, harvesting (digging) depth and conveyer inclination were measured and evaluated.
2) Forward speed Sp2 of (5.6km/hr) was having the highest tubers lifting percentage of 93% which was nearly 0.2% and 3.5% more than that at (Sp1 of 4.4km/hr) and (Sp3 of 6.7km/hr). furthermore, as the forward speed increased from Sp1 to Sp3 the cut potatoes increased from 2.3% to 2.5%, on the other hand, less percentage of scuffed, peeler, severe damage tubers and total damage index of 0.2%, 0.0%, 1.6% and 21.9 were recorded at high speed of 6.7km/hr, while the highest percentage of scuffed, peeler and severe damage tubers of 2.1%, 0.3% and 2.7% was recorded at lower of 4.3km/hr.
3) the treatment of Sp2 + harvesting depth2 + conveyer inclination 1, may be considered as best optimized value for potato lifting percentage (97.6%) of the potato crop.
4) The best optimized values of speed-inclination combination with respect to total damage index were Sp1 + harvesting depth3 + conveyer inclination 2, Sp2 + harvesting depth3 + conveyer inclination 2 and Sp3 + harvesting depth3 + conveyer inclination 1.
5) The best optimized values of fuel consumption of (7.95lit/ha) may obtained from the combination of the following treatments Sp1, Depth 2and Inclination2 and the better EFC value of (1.56fed/hr) could be obtained under the following treatments of Sp1 + harvesting depth3+ conveyer inclination 1.
6) With increase in harvesting (digging) depth, the tubers' lifting goes on increasing, while the cut of potatoes was decreased from to 5.9% to 1.2% and from 1.2% to 0.2% as the harvesting depth increased from 16cm to 18cm and from 18cm to 21cm, respectively. The depth of 21cm produced higher scuffed, peeler and severe damage tubers and total bruised (damage) index of 2.2%, 0.5%, 5.1% and 43.6 respectively.
7) Consistent increase in tubers lifting percentage, the mean values of percentage of scuffed damage tubers, peeler damage tubers, severe damage tubers, total damage index were recorded due to change in conveyer inclination from inclination 1 to inclination 2, while decreased from 2.6% to 2.3% as the inclination changed from inclination1 to inclination 2.

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