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Comparative Field Performance Evaluation of Potato Crop Mechanical and Manual Harvesting, Khartoum State, Sudan

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ABSTRACT: Potato is the fourth most important food crop in the world. The present study was carried out at Wadi Seidna area, Khartoum state, to study and evaluate methods and deptj of harvesting the potato crop. The manual harvest was done by hand hoe and the mechanical was by a digger shaker machine. The measured parameters were field capacity, efficiency, total yield, damage and harvest losses and cost of harvest. The results obtained revealed that the highest total yields obtained was 1.93 ton/ha for mechanical harvest. The average highest lifting percentage (92.91%) was given by manual. The lowest percentage of damage tubers (0.73%) and highest total harvest loss percentage (17.6%) was obtained by mechanical at 15cm depth. The results also showed that mechanical harvesting recorded high field efficiency, field capacity and lower cost of harvest as, 81.3%, 0.58 ha/h and 868SDG ha respectively, It can be concluded that although the mechanical harvesting showed higher harvest losses, but it was more economical because of lower cost of harvesting, higher efficiency ,capacity and yield compared to the manual method.

KEY WORDS: Potato, Mechanical Harvest, Manual, Damage, Losses

1. INTRODUCTION

Agricultural mechanization includes the use of hand, animal, engine-powered implements and machines in the production processes (Hunt 2015). In many parts of the world, mechanization has been one of the critical inputs to the increased production and preservation of food and it is a key input in any farming system FAO (2015). Farm machinery is an important element for agricultural development and crop production in many developed and developing countries. The use of machines for agricultural operations has been one of the outstanding developments in global agriculture during the last decade (FAO 2006). Therefore, it is important to apply mechanization in agricultural production processes for better outputs. Cultivation of crops in large areas may involve labour intensive work especially during the harvesting operation. The manual labour cost for the harvesting operation of some crops constitutes about 30 - 40% of the total operational cost (Md. Akhir, et al (2005)

Potato (Solanum tuberosum L.) is the fourth most important food crop in the world after wheat, maize and rice. The annual global production of potatoes is around 321 million tons produced from 19 million hectares, being cultivated in about 125 countries. (FAO,2011). Potato can be planted in two seasons, winter and autumn cultivation, and also used in industry and animal feed (Ismail, 1991). Potato production in Sudan is a relatively recent agricultural activity and currently more than 70% of Potato are produced and consumed in Khartoum state, and the cultivation is concentrated in the east and west banks of the River Nile. (Geneif and Sadik, 1989). Sudan's production of potatoes in 2015, was about 413.8 tons in an area of 30 thousand hectares (M A F, 2015). The crop is mainly produced on areas ranging from 0.5ha to 5ha of land using manual methods both at planting and harvesting. Such methods lead to increased losses especially at harvest where hand hoes are used to dig out and lift the potato tubers (IFAD 2017). Harvesting is the most complex and expensive operation for potato production. (Daniel, et al., 2011). It is a critical part of the entire potato production and marketing operation. Crop yield and quality can be affected during harvest, and they can be decreased, sometimes drastically. So harvesting operation is highly important practice and operation that should be given especial consideration. Harvesting potatoes to be carried out timely with minimum damage, loss and cost (Mutasim,2009). The harvest losses of potato is affected by some factors such as digging tool or equipment type, forward speed, depth of digging, weather and soil type and condition and degree of tuber maturity (Devesh and Ashok, 2017, Hilal Kazem et al., 2010, Arfa, 2007, Khater,2009, Abdalla et al, 2018, Naji. et al., 2016). There are also many factors that directly affect the damage of potato tubers, such as: digger shape, digger forward speed and chain speed, soil load level in the primary chain, potato variety, soil conditions. (Azizi et al., 2014. Tawfik, et al., 2012).

In Sudan potato crop Harvesting is usually performed manually or semi mechanized, in small holdings. The method used was very simple, by using the hoe for digging,

and later, the collection is done manually. The farmers were complaining about the need for so much work force for harvesting, lack of skilled labor, higher labor cost and the time spend for harvesting process is too long (Ismail et al., 2015). However, many farmers left producing potatoes due to the increased production costs, specifically the harvesting. Since the crop have the potential to be grown in Sudan as food and cash crop, mechanical harvesting (Younis et al., 2006), can help in solving some problems facing crop production. Therefore, the main objective of this study is to compare and evaluate the manual and mechanical harvest of potato crop at different depths in small holdings of Sudanese farms.

2. MATERIALS AND METHODS

2.1 Location

The experiment was conducted at Wadi Seidna North of Omdurman at Khartoum state. The potato crop was grown manually in an area of 1.6 ha. The variety grown was Bellini. The crop was harvested four months after planting. The soil of the experiment site in the location is generally clay loam with moisture content of 10.54% and the bulk density 1.45 gm/cm^3 during the experimental time.

2.2 Equipment used:

The two main machineries were, Potato harvesting machine of two rows, and were adjusted and tested at Masaad Training and Testing Center. It was used as tractor mounted, P.T.O driven. The specification of the machine is given in Table (1). The tractor used in the experiment was M F Giad 285. Specifications of the tractor are shown in Table (2) and show in plate (1).

Table (1) Harvester machine specifications:

Mark	Turkey
Type	Tractor (PTO driven)
Model	ILGI 2005
Number of row	Two –row
Width	1540mm
Length	1450mm
Height	1250mm
Weight	450 kg
Digging width	1200 mm
Digging blades	9
Riddle chain	2
Power	70-90 hp

Table (2) Tractor used specifications:

Mark	Sudan
Make	MF Giad 285
Power	75 hp, 2WD
Cooling	Water
Weight	2.8 ton
PTO power	63.4 hp
Fuel tank	90 liter
Engine type	Diesel

Plate (1) Potato harvesting machine linked to the tractor

2.3 Hand hoe tool and labour

Used for manual harvesting of potato crop. It consists of an iron part to dig and lift the tubers from the soil and a wooden part to control the lifting process as shown in plate (2). Ten laborers were used for manual harvesting, and collection of harvested tubers.

2.4 Other materials used

Fifty meters long measuring tape was used for measuring distances and depths, stopwatch for recording of times, notebook for recording the data and drawing the map of work**. s**cale(balance) for measuring the weight of potato tubers obtained, lost, and damage during harvest. as shown in the plate (3) and Scuttle (basket), used to collect harvested and loss tubers. as shown in the plate (3)

2.5 Experimental design and layout

The experiment was randomized complete block design (RCBD) with three replications, and six treatments (two harvesting methods and three digging depths). The total area of experiment was 1.6 ha, divided into 18 plots
100m x 2.4m each, as shown in fig (1).

Plate (3) Scale and basket

Plate (2) Hand hoe for manual harvesting

2.6 Field conditioning

The total vegetation of the crop was removed before manual and automatic harvesting. As the process of removing the total Vegetable and cut of irrigation from the crop before 7-10 days of harvesting helps to form a dry crust and resistant to mechanical scratch

2.7 Field measurements

a. Total production

$$(Y) = \frac{w \times 10}{A \times B}$$ (Hamad *et al.*, 1991)

Where:
Y= yield (ton/ha).
W= mass of tubers per plants (gm).
A= distance between the lines of plat (m).
B= distance between plants per line (m**).**
10=factor after 3-4 months later of planting,
The productivity of the area was analyzed by collecting and weighing up all the tubers per plot of 240m^2, area to be harvested mechanically and manually.

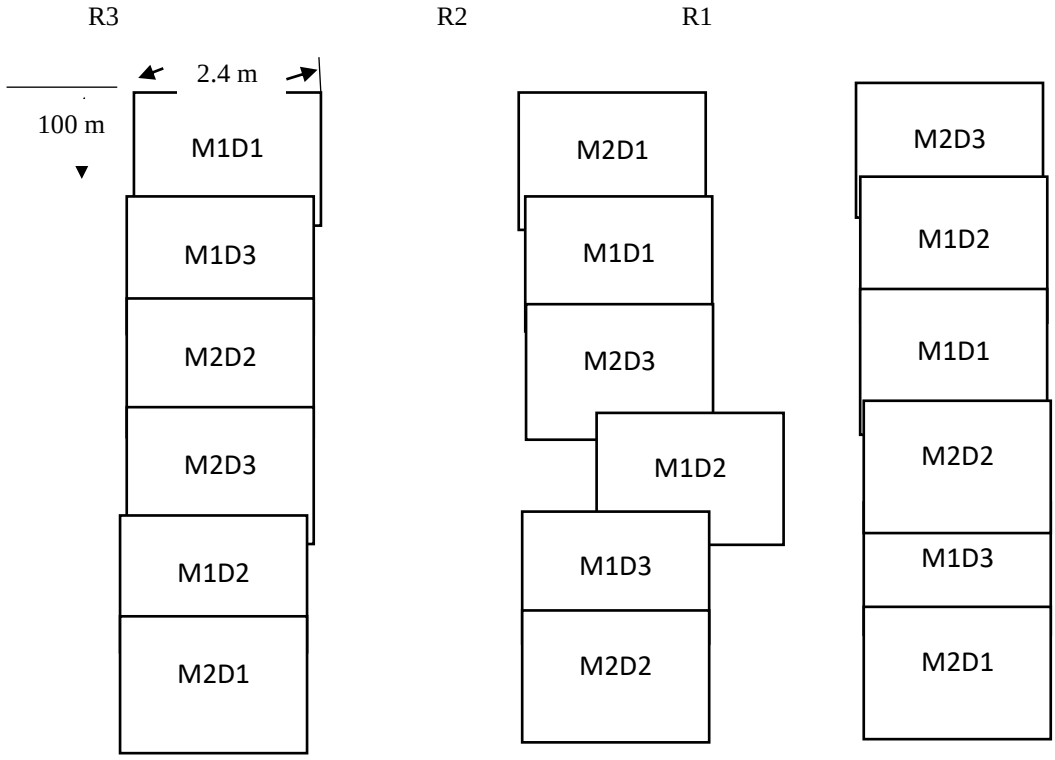

Figure (1). The layout of the field experiment

Where:

R= Replicate, D= Depths, M1= manual, M2= mechanical, D = Digging depth

b. Lifting percentage

The lifted tuber percentage estimated using the following equation (Hamad *et at.*, 1991):

$$\text{Lift\%} = \frac{w1}{w1+w2} x100$$

Where:

w_1: mass of the lifted potato tubers (kg/m²)

w_2: mass of the un-lifted potato tubers (kg/m²)

c. Loss percentage (un-harvested)

The tubers which have not been harvested manually and mechanically and lifted from the soil. After collecting the tubers from the ground, the tubers left in the soil were harvested using tillage machine.

The weight was estimated using the following formula (Hamad *et at*., 1991):

$$\text{Losses \%} = \frac{w2}{w1+w2} x100$$

Where:

W_1= Mass tubers that have been harvested (kg/m²)

W_2= Mass tubers in soil (kg/m²).

d. Damage percentage

After collecting the tubers that were harvested mechanically and manually for 100 meters, these tubers were classified as un-damaged and damaged tubers because of the harvesting process and were weighed separately. The percentage of total damage to potato tubers (D) is calculated from the following equation (Muhammad et al., 2003).

$$\mathbf{D} = \frac{w4}{w3} x100$$

Where:

D = Percentage of damage.

W_3= Mass tubers that have been harvested (kg/m²).

W_4= Mass tubers damaged (kg/m²).

e. Field capacity and efficiency

The theoretical and effective field capacities (TFC, EFC) and field efficiency were calculated as follows (Hunt 2015:

$$\mathbf{TFC} = \frac{\text{Averages speed(m/sce)xwidth of cut(m)x3600(sce)}}{10000(\text{m}^2)}$$

$$\mathbf{EFC\ (ha/h)} = \frac{\text{Araa of plat}(\text{m}^2)}{\text{Total time of plot(h)x10000}(\text{m}^2)}$$

$$\mathbf{FE\ (\%)} = \frac{\text{EFC}}{\text{TFC}} X100$$

f. Cost

The total cost of the mechanical harvesting is mainly digging cost, manual collecting cost, whereas the manual harvesting included the cost of labor for digging and tubers collection costs, in addition to the cost of removing the total vegetation.

2.8 Statistical analysis:

The collected data was analyzed using the analysis of variance technique programmed by Excel computer package version 2007. Least significance difference (LSD) was also calculated.

3. RESULTS AND DISCUSTION

3.1 Effect of harvesting method on measured parameters

Table 1. shows the measured parameters as affected by mechanical and manual harvesting methods. It can be observed that the total yield and lifting were higher for mechanical harvesting, but total losses was higher by 130% compared to manual harvesting. Crop injuring and damage was higher for manual (Fig.1). Generally, it was clear that the harvest losses percentages were higher for mechanical harvesting and were increased with depth (table 2).

Table 3. Total yield and other measured parameters as affected by harvesting methods

parameter	Manual	Mechanical
Total crop yield(kg/ha)	10335.29	15866.6
Lifting (kg/ha)	9653.33	12209.86
Lifting (%)	92.91	84.96
Damage (kg/ha)	697.30	156.49
Damage (%)	9.82	1.37
Total loss (kg/ha)	881.96	2745.68
Total loss (%)	7.36	16.12

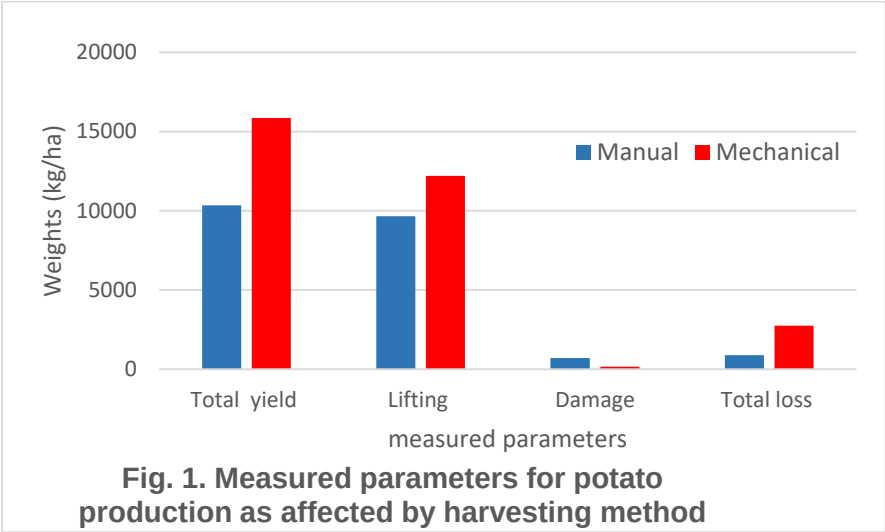

Fig. 1. Measured parameters for potato production as affected by harvesting method

Table 4, Potato tubers harvest losses percentages as affected by harvest method and depth

parameter	Manual harvest			Mechanical harvest		
Depths	5cm	10cm	15cm	5cm	10cm	15cm
Lifting losses %	3.5	3.3	7.1	9.4	9.2	16.5
Damage %	8.5	3.4	9.6	1.7	0.7	1.9
Total losses %	5.9	5.7	9.4	11.6	11.4	17.4

3.2. Effects of method and depth of harvesting on Total potato yield

Analysis of variance showed significant differences among the two harvesting methods at 5% level.it can be observed that as the depth of digging increased from 7cm to 10cm and then to 15cm, the tuber production was increased and then was decreased for both harvesting methods (Fig. 2). The yield was significantly greater for mechanical than the manual harvesting. This is in line with the findings of Hilal Kazem et al., (2010). On the other hand, the lowest tuber production (6584.7kg/ha) was obtained by manual harvesting at the depth of 5cm.

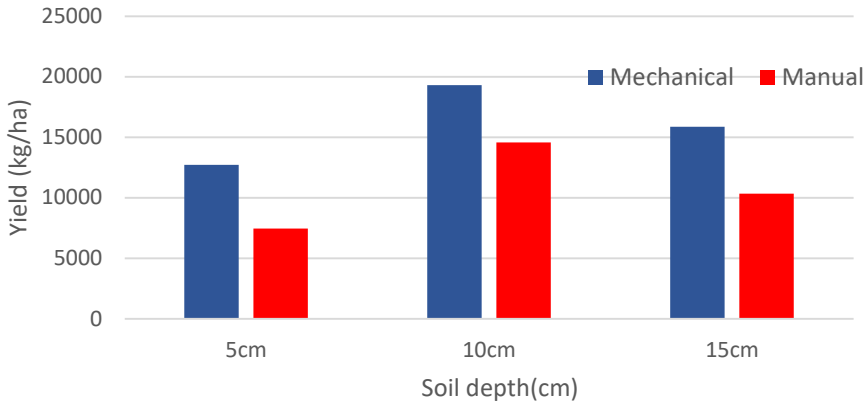

Fig. 2. Total yield of potato as affected by harvesting method and depth of harvest

3.3 Effects of potato harvesting method and depth on tubers lifting (kg/ha)

Statistical analysis revealed significant differences between the two harvesting methods lifting. The highest lifted tuber was obtained at 10cm depth for both harvesting methods. The difference between depths was small, although the 15cm depth recorded the highest lifted tubers for both methods (Fig. 3). The lowest percentage of tubers lifted (84.5%) was obtained at 15 cm depth of harvesting. This in line with that reported by Naji. et al., (2016) and Abdalla et al., (2018). The difference between depths was insignificant at 5% level of significance

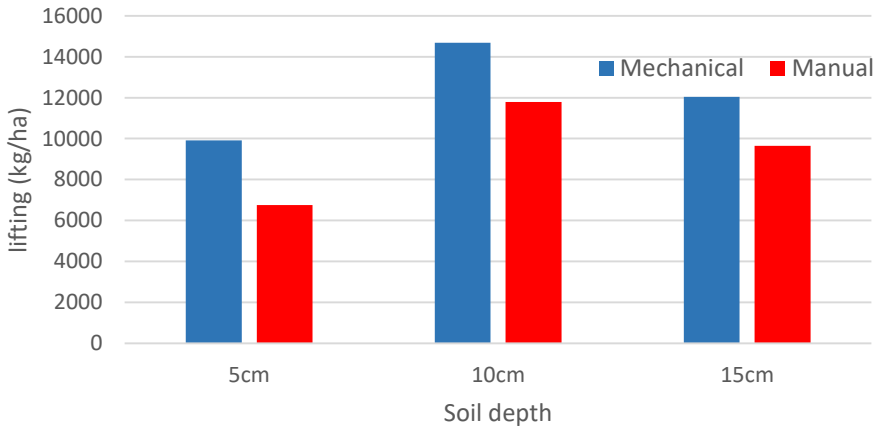

Fig. 3. Amounts of lifted potato as affected by depth and method of harvest

3.4. Effects of potato harvesting methods with depth on tuber harvest loss (kg/ha)

Statistical analysis of harvest losses (kg/ha) revealed significant differences between the two harvesting methods ($P<0.0\ 5$). For all depth mechanical harvest recorded higher harvest loss (Fig. 4). The highest loss of tuber was obtained at 10cm depth. The difference between depths was not significant. On the other hand, the lowest harvest loss of tubers (564.3kg/ha) was obtained by manual harvesting at 5cm depth. This is in line with that reported by Henderson, et al. (2003) and controversy to that reported by IFAD (2017). Table 4 showed that the highest harvest losses as percentage (17.5%) were obtained at 15 cm depth. For mechanical harvesting, It was significantly greater than that of manual harvesting, while the lowest losses of tubers as percentage (5.7%) was recorded for manual harvesting at 10cm depth.

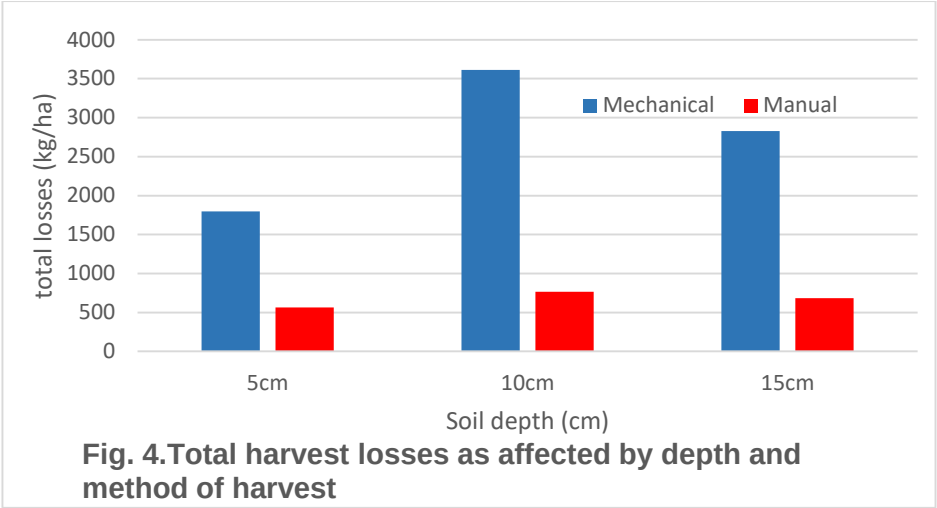

Fig. 4.Total harvest losses as affected by depth and method of harvest

3.5. Effects of potato harvesting method and depth on damaged tuber(kg/ha)

Statistical analysis of variance of damaged tubers data showed significant differences between the two harvesting methods with depth. The highest tuber damage (785.3 kg/ha) was obtained by manual harvesting. at 5cm depth. It was significantly greater than all harvested depths for both harvesting methods. This is in line with that reported by (Henderson, et al., (2003) On other hand, the lowest tubed damage (90.32 kg/ha) was obtained by mechanical harvesting at 10cm depth (Fig. 5).

The highest percentage of damaged tubers (9.6%) was recorded for the manual harvesting at 15cm depth. The lowest total damaged percentage was 0.7% at 10cm depth for mechanical harvest (table 3).

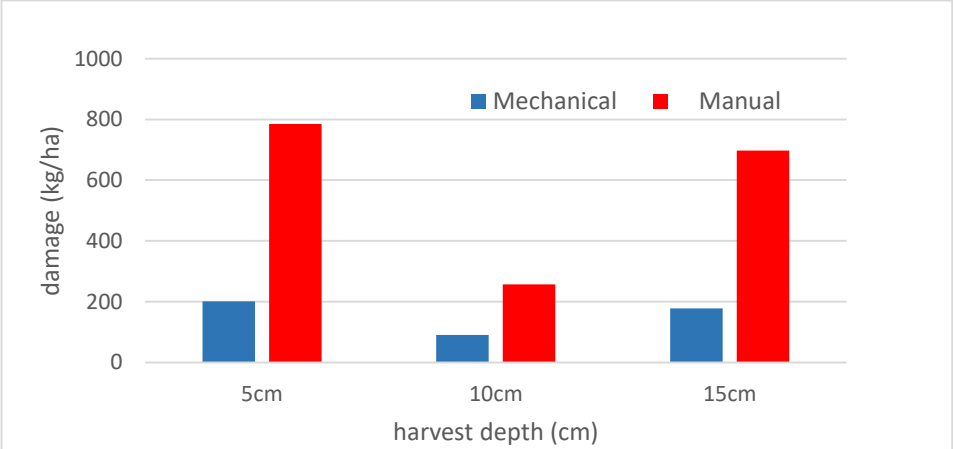

Fig. 5. Damage of potato tubers as affected by depth and method of harvest

3.6 Field efficiency and Capacity

Harvesting field efficiency mainly affects the field performance of labour and the machine. Table 5 showed that the field efficiency and capacity of the machinery used, very high compared to the labour used even if they are ten in number. It is important to point out that the collection of tubers was held in the morning, so that laborers have a higher efficiency of work. The cost of manual harvesting was about 2688 SDG/ha, while that of mechanical was 868SDGha. The high cost of manual digging and collecting was due to the low field capacity of labour and taking more field time. These significant differences mating in agreement with Muhammad *et al.*, (2003), Joaop. *et al.*, (2011), Tawfik, *et al.*, (2012) and Abdalla et al, (2017).

Table 5. Field capacity and Efficiency and cost of potato harvesting operation mechanically and manually

Parameter	machinery	labour
Field Capacity ha/h	0.58	0.029
Efficiency%	81.3	28.5
Cost SDG/ha	868.7	2689.4

4. CONCLUSIONS

The following conclusions may be drown from the present study:

- The total yield, lifting and harvest losses were increased with depth by mechanical harvesting compared to manual
- Comparing machine with manual harvesting showed that the rate of work can be increased by17 times, at an efficiency rate of 81%.
- Harvest damage was reduced to 0.7% where machine harvesting compared to manual.
- The total yield was increased, and the cost of production was reduced for mechanical harvesting compared to manual.

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