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Investigation on Field Performance of Plowing and Harvesting Potatoes in Southern Baghdad

Ahmed A. A. Hamid

Department of Dormitories Affairs, University of Baghdad, Baghdad, Iraq

Corresponding author email: ahmed.hamid@uobaghdad.edu.iq

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Abstract: This field experiment, was conducted to investigate a comparison of two methods for harvesting potatoes: mechanical and handy when using moldboard and chisel plow for primary tillage and three different distances for planting tubers in the rows 15, 25, and 35 cm in silt clay loam soil south of Baghdad. The factorial experiment followed a randomized complete block design with three replications using L.S.D. 5 % and 1 %. Mechanical harvest recorded the best valid potato tubers at 88.78 %, marketable yield of 31.74 ton. ha^{-1}, efficiency lifted 95.68 %, tubers damage index 28.41, speeding up the harvesting process and reducing time and effort. Handy harvest gave the least damage to potato tubers, 6.02 %, and unlifted potato tubers, 4.32 %. However, this method requires effort and more specialized labor, whether from men or young women, and leaded to delays in the harvesting process. Regarding planting distance of 15 cm between one tuber and another gave the highest total productivity, 46.92 ton. ha^{-1} and the greatest number of plants, but most of the tubers were small in size. A planting distance 25 cm produced good quality in size of potatoes with yield of 36.19 ton. ha^{-1}, 90.99 % best valid tubers, 5.43 % least total damage tubers, 3.57 % least unlifted potato, 96.42 % best efficiency lifting, and least tuber damage index 22.39. Most interaction among the treatments was significant. The most influential factor in the experiment traits was the planting distances of potatoes in the rows. The shape of the potatoes was Spheroid. Mechanical potato harvesting saves effort saves effort, time, harvest speed, reduce the labors and increasing efficiency.

Keywords: Mechanical harvesting, Potato harvest, Potato marketable, Soil tillage.

Introduction

The potato (*Solanum tuberosum* L.) Solanaceae is the most important agricultural product in the world. It represents the fourth largest source of human food after rice, wheat, and corn. More than a billion people eat potatoes every day around the world (Tofeq, 2023). The production of potatoes was almost 359 million tons in 2020, more than 20 million hectares in about 150 countries around the world are planted potatoes and it considered the most popular crops in 160 nations around the world (World Potato Congress 2022). In Iraq, potatoes are harvested manually or semi-mechanically, in semi-mechanically harvesting, diggers, which are attached behind the Tractor, are used which degrade the furrows and expose the potatoes above the soil surface, later the potatoes will be collected by men or young women. In Iraq, potato is grown with an area of 19159 hectors (76636 donum), which produce production 466127 tons, and in

average yield of 24317 kg.ha^{-1} (6079 kg. donum^{-1}) (Al-Hashimi *et al*., 2020). Many researchers have carried out research on the potato crop due to its great importance and consumption as a food (Mahood, *et al.*, 2011; Al-Jorany *et al.,* 2016; Alansari, 2020; Al-Zaidi & Al-Jumaili, 2022; Al-Rubaie & Al-Jubouri, 2023; Altinawi *et al.*, 2023; Zaen *et al.,* 2023). In general, the quantities of potato production are less than the actual need for local consumption in Iraq (Al-Hashami *et al*., 2020).

The way of harvesting potatoes is essential because of its effect on the speed and time of harvesting, damage ratio, lifted amount, and marketable tubers. Iraqi farmers are still plowing by using the moldboard, chisel, and disc plow to prepare the field cultivating (Dowad & Jasim, 2023; Hamid & Alsabbagh, 2023). Doing primary tillage and choosing the plow types, such as moldboard or chisel plow, before any planting is necessary to prepare a suitable seedbed (Jebur *&* Al-Halfi, 2022).

Singh (2006) found that when potatoes were harvested manually, the damage of potatoes was 4.3%, also increasing the speed of the tractor led to increase un the damage rate, moreover, concluded the planting distance between tubers affects the production, number, and size of tubers. Potatoes losses of mechanical harvesting were 11.8 % (Tofeq, 2023). The rate of potato losses of (20-25 %) is one of the major problems in the production of potatoes and the most important reason for these losses is the mechanical damage that happens during the digging (lifting) of potato tubers or the local plow. Sedeeq & Al-Tahan (2011) found that the total production of potatoes was 98 tons for in area 5 hectares. Ati et al (2012) concluded that regular fertilization and irrigation of potatoes during growth increases productivity, tuber weight and quality. They obtained the highest productivity of 36.65 ton.ha^{-1} when planting tubers at distance of 30×75 cm. Al-Dosary (2016) found that the ratio of lifted tubers, un-lifted tubers and total damage were 85.56 %,14.44 %, and 4.36 %, respectively, and the damage index of 22.87 when the harvested forward speed was 2 km. hr^{-1} and digging depth 17 cm. Al-Bayati & Ali (2019) they concluded that when planting tubers at a distance of 10 and 15 cm between one tuber and another, the production yields were 54.02 and 58.96 ton.ha^{-1}, respectively.

Limeneh *et al*. (2021) when agricultural spacing 75 × 20 cm, and 75 × 30 cm, they found productivity of potatoes was 57.07 and 53.31 ton.ha^{-1} and marketable yield of 46,39 and 44.23 ton.ha^{-1}, respectively. Sedeeq *et al.* (2022) found 25.49 ton.ha^{-1} and 24.9 ton.ha^{-1} when using semi-mechanized harvest and manual harvest, respectively. Masood *et al* (2023) planted potato tubers at a distance of 30 cm within one line and a depth of 10 cm, and the distance between one line and another was 75 cm, and gave a production yield of 26.29 tons.ha^{-1}. Salim et al (2023) planted tubers at a depth of 10 cm, with a spacing of 25 cm between plants and the maximum yield was 40.53 ton.ha^{-1}, also they concluded increasing the total yield when fertilizer and organize field irrigation interval.

The main objective of this study was to compare the effects of two harvesting approaches (Mechanical and Manual), different plow types (moldboard and chisel plow), and various planting distances between the tubers (15, 25, and 35 cm) on key parameters including total production, valid potato tubers, total damage potato tubers, unlifted potato tubers, marketable tuber yield, efficiency of lifting, tuber damage index, and the overall shape of the potatoes.

Materials & Methods

Site, soil, climate, and potato cultivation

An experiment was carried out in Al-Youssefia region (33.079408° N 44.251662° E and 31.8 m above sea level), about 25 km to the South of Baghdad, the capital of Iraq. The field area was 12000 m^2 (120 m × 100 m) and its soil was silt clay loam (454, 434, and 112 $g.kg^{-1}$). The soil was prepared for planting tubers using a moldboard and a chisel plow according to the experimental design. Soil moisture was 16-19 % when was tilled at 25 cm, then a disc harrow was used.

The planted potato variety was BURREN, and the characteristics of *BURREN* potato are long oval potato with a shallow depth of eyes, cream color skin, medium yellow flesh, medium smoothness of skin, medium plant height, white flower, good drought resistance, high storability and high germination rate. According to Köppen climate classification, Iraq is located within an arid climate. The potato was planted on 11 -14 February 2023, and the harvesting began on 6th June 2023. The temperature in the field was recorded during the growth of potato crop (Table1).

Table (1): Monthly average of temperatures of the experiment site.

Month*	Max. temperature	Min. temperature
February	22 °	8 °
March	27 °	11 °
April	32 °	15 °
May	40 °	21 °
Jun	44 °	25 °

After soil preparation (plowing, harrowing, and furrow opening), the purity of the cultivars and healthy potato tubers were chosen and planted manually in the furrows with three different distances of 15, 25, and 35 cm in the rows (Table 2).

Table (2): Distance and number of the plants in each treatment.

Planting distance (cm)	Planting depth (cm)	Row distance (cm)	Row length (m)	Lines of each treatment unit	Area of treatment unit m^2	Plants in each treatment unit	Planting density (plant. ha^{-1})
15	10	75	20	2	30	266	88666 *
25	10	75	20	2	30	160	53333
35	10	75	20	2	30	114	38000

* 10000 m^2 / 30 m^2 = 333.33, then 333.33 × 266 = 88666 plant. ha^{-1}

Multi agriculture operations were used, such as irrigation and grubbing. Nitrogen (N) fertilize increases the weight of tuber potatoes and reduces the number of non-marketable tubers (Umar *et al.,* 2016; Zainaldeen & Abdul Rasool, 2023). N 46 %, at a rate of 65 $kg.hactare^{-1}$ was added at three stages; planting, tuber formation, and tuber maturity, Trisodium phosphate (T.S.P.) fertilizer was added at a rate of 65 $kg.hectare^{-1}$ when preparing the soil for tuber planting (Oliveira *et al*., 2021). During the 115-day potato cultivation period (see fig. 1), four key stages were observed. Signs of potato tuber maturity became evident, including the cessation of vegetative growth, yellowing of the leaves, tuber hardening, stiffening of plant stems, and skin toughening. At this point, all vegetative parts (stems and leaves) were cut and removed. Irrigation was halted two weeks before harvest. The final step involved harvesting the potatoes, employing two methods: mechanical harvesting and manual harvesting using hoes (Handy method).

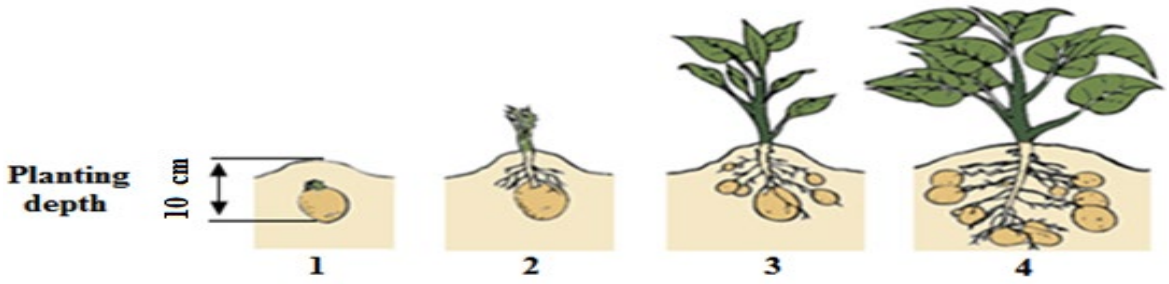

Fig. (1): Stages of potato growing: 1. Planted tuber, 2. Vegetative growth 3. Tuber initiation, 4. Tuber bulking.

Machines used in the experiment

Massy Ferguson tractor and two types of plows, moldboard and chisel plow were used for soil tilled at depth 25 cm, then disc harrow used for moldering. Potato diggers were used for mechanical harvest, while the handy (manual) harvest was done by hand using a digging tool (hoes) (Table 3).

Table (3): Technical specifications for machines used in the experiment.

Tractor	Moldboard plow	Chisel Plow	Disc Harrow	Potato Digger
Model: MF385 (2WD)	No. ploughs : 3	No. Tines : 7	No. Disc: 16	No. Rows : 2
Diesel 4 cylinders	Width : 90 cm	Width : 140 cm	Width: 180 cm	Width : 185 cm
Torque : 350 N.m	Depth : 30 cm	Depth : 40 cm	Disc Angele: 25	P.T.O: 540 rpm
P.T.O: 540/1000 rpm	Weight : 350 kg	Weight : 390 cm	Weight : 440 kg	Weight : 600 kg
Power:85 hp (63.3 kW)	Re. power:30-40 hp	Re. power:25-40 hp	Re. power:20-30 hp	Re. power:35-50 hp

Experimental design

Factorial experiments under Randomized Complete Block Design (RCBD) with three replications, were used. The least significant difference (L.S.D.) of 5 % and 1 % was used to compare the treatments means. Statistical analysis system software (S.A.S) was used. Three factors of potato harvesting methods mechanical and handy harvest, plows types moldboard and chisel, and planting distances in rows 15, 25, and 35 cm were used in this experiment. The experiment included 36 treatments (2 methods of harvesting × 2 plows × 3 distances × 3 replications).

Performance parameters

Total production

Total production was calculated by the following equation (Al-Dosary 2005):

$$P = \frac{Y \times 10000}{A \times B \times 1000} \qquad (1)$$

$$Y = \frac{T}{N} \qquad (2)$$

Where P is total production (ton. ha^{-1}), A is the rows distance (0.75 m), B is the planting distance in the row (m), 10000 and 1000 conversion factor, Y is the average yield of one plant (kg), T is the mass of five plants of potato for each treatment (kg), and N is the number of plants (five).

Valid potato tubers

After harvesting, the potatoes of ten meters of each treatment were collected and weighed, and then divided into two groups: one was the valid potato tuber and the second was the damaged tuber due to harvesting operation. The two groups were weighted individually, and the valid potato tubers were calculated by the following equation (Mcgechan, 1977):

$$V = \frac{m_1}{m_2} \times 100 \qquad (3)$$

Where V is the valid tubers percentage (%), m_1 is the mass of a valid tuber for ten meters for each treatment (kg), m_2 is the total mass of the potato plant for ten meters (kg).

Total damage of potato tubers

It was calculated by the following equation (Mcgechan, 1977)

$$D = \frac{m_3}{m_2} \times 100 \qquad (4)$$

Where *D* is the Total Damage Potato Tubers (%), m_3 is the mass of damaged tubers for ten meters for each treatment (kg).

Un-lifted potato tubers

$$U = \frac{m_4}{m_2} \times 100 \qquad (5)$$

When *U* is the unlifted tubers potato %, m4 is the mass of unlifted potato tubers for ten meters (kg).

Marketable tuber yield

$$K = P - (G + S) \qquad (6)$$

When

$$G = D \times P \qquad (7)$$

So, the equation (6) becomes:

$$K = P - [\,(D \times P) + S\,] \qquad (8)$$

Where *K* is the marketable tuber yield (ton. ha^{-1}), *G* is damage tubers (ton.ha^{-1}), *D* is the total percentage % of the damaged potato tuber, *S* is the small tubers with a diameter at least 2.5 cm or mass of least 25 g.

Efficiency lifting

Efficiency lifting was calculated by the follow Abo-Hababa (2000) and Al-Dosary (2005):

$$E = \frac{m_2}{m_2 + m_3} \times 100 \qquad (9)$$

Alternatively, we can calculate:

$$E = V + D \qquad (10)$$

Where *E* is efficiency lifting (%).

Tuber Damage Index

Random samples of potatoes were selected from each treatment, classified and weighted separately; the first ones were scratched (scuffed surface); were only the tuber crust was affected, and there was no damage in the tissues; the second ones were peel damaged, which can be removed by a stroke of 3 mm deep of hand potato peeler or superficial cuts with no damage to the internal tuber, and the third ones were severe damaged which cannot be removed by a 3 mm deep stroke of a hand peeler and the internal tissue was damaged or cut off, and they were turning black or blue after several days (Fig. 2).

A B

Fig. (2): A- Potatoes damaged due to harvest, B- Marketable potatoes tuber.

According to the estimate, the percentage of scratched, peeled, and severe damage was separately weighted by dividing the mass tuber lifted. Tuber Damage Index (TDI) was calculated as follows (Mcgechan, 1977; Abo-Hababa & Al-Yahya 2000):

$$TDI = Scratched \times 1 + Peeler \times 3 + Severe \times 7 \qquad (11)$$

Based on the Tuber Damage Index (TDI), the damage rate can be described in table (4)

Table (4): The values of the Tuber Damage Index (TDI) and the description of the damage rate.

Description	Damage Index
The damage rate is high and unacceptable, and the harvest process must stop	More than 300
The rate of damage is high with caution in the mechanical harvest	200 – 300
The rate of damage is medium	150 - 200
The damage rate is acceptable	100 - 150
The damage rate is allowed.	Less than 100

Shape of potatoes tuber

The tuber shape was determined after harvesting based on the shape index of the potato tuber according to IOS (1981) (Table 5).

Table (5): The relation between the Index and Shape of the potato tuber.

Index Shape of tuber	Shape of tuber
100 - 160	Circularly
160 – 240	Spheroid
240 – 340	Longitudinal
More than 340	Very Longitudinal

The Index shape of the tuber can be calculated using the following equation (Al-Dosary, 2005):

$$I = \frac{L^2}{W \times T} \times 100 \qquad (12)$$

Where I is the index shape of a potato tuber, L is the maximum length of the tuber (mm), W is the maximum width of the tuber (mm), and T is the maximum thickness (mm).

Results & Discussion

Results as showed in table (6) that there were no significant differences between mechanical and manual harvesting in total production, although the result was Non-significant, but it was observed during the field harvesting process that mechanical harvest of potatoes was quick, less effort, and did not require workers to carry out the process of extracting tubers from the soil comparing with handy harvesting, this results agree with the same line of the Cunha *et al.* (2011) and Sadeeq *et al*. (2022). Results showed significant differences in valid potato tuber, where mechanical harvesting achieved higher valid tuber of 88.32 %, comparing with manual harvesting of 86.99 %, because the blades of the potato digger cut the soil at a regular depth below the tubers, which reduced the amount of physical damage to the tuber during the harvesting process. Addition, Al-Dosary. (2016) found lifting percentage 87.72%. The current result showed there are significant differences in mechanical and manual harvesting in damage potato tuber where 8.66 and 6.02 %, and unlifited tuber where 5.59 % and 4.32 %, respectively, because the tubers are exposed to friction with the soil and the harvesting machine during the harvesting process, this result are same line with Cunha *et al*.(2011), Al-Dosary. (2016), and Sadeeq *et al*. (2022).

The significant differences in the mechanical and manual harvesting in marketable yield were 31.74 and 30.77 ton. ha^{-1} and efficiency lifted 95.41 and 94.40 %, and this is due to the ease and speed of lifting and separating the tubers from the soil when harvested mechanically. However, Cunha *et al.* (2011) obtained efficiency of 86 % when used the mechanical harvesting. There are significant differences between mechanical and manual harvesting in the tuber damage index, of 28.41 and 31.41, however they remained within the permissible damage rate (tuber damage index less than 100, according to table (4), and this result agree with Al-Dosary (2016). Also it was noted the mechanical harvesting, in addition to the speedy completion of the harvesting process, there is a reduction of wasted time and the

saving of great effort compared with the manual harvesting of potatoes. The result showed no significant differences in the effect of the moldboard and chisel plow on the total production of potatoes, damaged tuber, and marketable yield potatoes. Yaroson *et al*. (2019) explained the highest yield obtained when soil was tilled. There simple significant differences in effect in valid potato tuber and unlifted tubers, where the treatment tillage plowed by moldboard plow was least from the chisel plow in valid potato tuber 7.30 % and 7.38 % and unlifted tubers 5.59 % and 5.31 % respectively. The moldboard plow superior significantly in efficiency, with lifted recorded at 95.40 %, while the chisel plow recorded at 94.68 %, and because the plowing soil by moldboard, pulverization of the soil by disc harrow disk makes the soil more suitable tubers bed compared to the chisel plow. Decreasing the planting distances between the tubers contributed to achieving higher productivity, where the planting distance was 15 cm, the highest total productivity achieved of 46.92 ton.ha^{-1}, and this is due to the increase in the number of plants per hectare when reducing the distance between one plant and another. However, Limeneh *et al.* (2021) conducted a field experiment, showed that total yield was tendency to increasing when distance of the planting decreased. The planting distance of 25 cm between the tubers and the other superior on the planting distances 15 and 35 cm recorded the best results in valid potato tuber, damaged potato tuber, unlifted tuber, marketable yield, efficiency lifted, and tuber damage index 90.99 %, 5.43 %, 3.57 %, 31.21 ton.ha^{-1}, 96.42% and 22.39 respectively; this is because the planting distance of 25 cm between the tubers gives the best growth for the tubers, prevents the tubers from competing for nutrients, and reduces the friction of tubers with each other and their friction with the soil during the harvesting process, this result agree with results (Limeneh *et al*. (2021), Al-Rubaie & Al-Jubour. (2023), and Tofeq. (2023).

Table (6): The results of the studied traits of the field experiment factors.

Experiment Factors	Total productivity ton. ha^{-1}	Valid potato tuber %	Damage potato tuber %	Unlifted tuber %	Marketable Yield ton. ha^{1}	Efficiency lifted %	Tuber damage index
Mechanical	37.11a	88.32a	8.66a	5.59a	31.74a	95.68a	28.41b
Manual	37.14a	86.99b	6.02b	4.32b	30.77b	94.40b	31.41a
Moldboard	37.12b	87.98a	7.30a	5.59b	31.25a	95.40a	32.17a
Chisel	37.13b	87.34b	7.38a	5.31a	31.26a	94.68b	27.71b
15 cm	46.92a	87.66b	7.62b	4.69b	38.84a	95.30b	28.85b
25 cm	36.19b	90.99a	5.43c	3.57c	31.21b	96.42a	22.39c
35 cm	28.26c	84.32c	8.97a	6.59a	23.72c	93.40c	38.59a

Means with same Letters was no significant according to L.S.D 0.05

Planting distance of 15 cm between the tubers makes tubers highly competitive for nutrients due to the small space; therefore, most of the potato tubers were small in size and numerous in number, and the total productivity was higher at 46.92 tons. ha^{-1} compared with other distances which was less form that, due to the plants in the rows being higher than planting distances of 25 and 35 cm. These results are agreed with some studies Rex & Russel. (1987), and Tesfaye *et al*. (2013) were obtained in their experiments, the highest total productivity when planting potato tubers closed in the rows.

Table (7) explained simple statistics analysis of the data in the field experiment showed the maximum and minimum values obtained from 36 treatments; the mean total

production 37.1288 ton.ha^{-1}, even if we take in to account that the min value was 26.66 ton. ha^{-1}, this values were acceptable comabarison with many reserchers results Limeneh *et al.* (2021), and Al-Rubaie & Al-Jubouri. (2023). The mean of valid potato tubers 87.6119% with standard deviation (Std. Dev.) 2.90916, which was small standard devition value and this indicates that the data is less dispersed. Addition, the differance between the min and max value was 9.18%, and this agree with Al-Dosary (2016). The mean of the total damage tubers was 7.34556%, and this is acceptable value, althought the maximum value 10.65%, it is considered among the lower than the results reached by Tofeq. (2023), who obtained the highest percentage of damage of 15.34% and 12.05% when he planted potatoes at a a distance of 20 and 25 cm, respectively. Unlifted potato tubers mean was 4.95500% which was considered acceptable value, with Std.Dev of 1.63197. Morever, the maximum value was 8.360% noticed when mechanical harvesting potatoes planting with distance 35 cm. Mean of the marketable tuber yield was 31.2597 ton.ha^{-1}, noticed is a very good value according to the difference value 5.8691 ton.ha^{-1} from total productivity 37.1288 ton.ha^{-1}, this difference value considered permisible. The mean of potato efficiency lifting was 95.0450% with small Standard Deviation 1.63278, which means the values was less dispersed. Addition, the minimum efficiency lifting value obtained was acceptable 91.64% at planting distance 35 cm. The min and max tuber damage index (TDI) were 18.42 and 45.70, respectively, considered acceptable, and the damage rate is allowed because TDI is less than 100, according to table (4), and this result agree with Al-Dosary (2016). The standard deviation for most of the studied traits were close to the mean, so the dispersion is better. Result showed that the least Std.Dev was unlifted potato tubers, and efficiency lifting was 1.63197 and 1.63278, respectively.

Table (7): Simple statistics analysis of the field experiment.

Studied traits	N*	Mean	Std. Dev	Sum	Minimum	Maximum
Total production ton. ha^{-1}	36	37.1288	7.82322	1337	26.66	48.88
Valid potato tuber %	36	87.6119	2.90916	3156	83.15	92.33
Total damage potato tuber %	36	7.34556	2.04753	264.4	3.660	10.65
Unlifted potato tuber %	36	4.95500	1.63197	178.3	1.210	8.360
Marketable tuber yield ton.ha^{-1}	36	31.2597	6.35573	1125	21.88	41.29
Efficiency lifting %	36	95.0450	1.63278	3422	91.64	98.79
Tuber damage index	36	29.9463	7.93182	1078	18.42	45.70

* N are the treatments (2 × 2 × 3 × 3 replication = 36).

The triple interaction of harvesting method, type of the plow, and the planting distance on total productivity and marketable yield tuber which were significant differences for both of them (Figs. 3 and 4), interaction manual harvest, moldboard plow and planting distance 15 cm recorded higher total productivity 47.11 ton.ha^{-1}, while interaction the same way harvest, chisel plow, and planting distance 35 cm was 28.19 ton.ha^{-1}. Sedeeq & Al-Tahan (2011) found in study the productivity of potatoes when harvested five hectares was 98 tons. In addition, Sedeeq *et al*. (2022) found an experiment little difference between mechanical and manually harvesting which was 25.49 and 24.9 ton.ha^{-1}, respectively. Interaction mechanical harvest, moldboard, and planting distance 15 cm recorded higher marketable yield tuber 39.59 ton.ha^{-1}, while the handy harvest, moldboard

plow, and planting distance of 35 cm recorded the lowest value, 23.44 ton.ha^{-1}. Also, the result showed the greatest effect was the planting distances between tubers compared to the harvesting method and the type of plow, where the highest total production and marketable was at the planting distance of 15 cm, then 25 cm, and then 35 cm, respectively. Despite these result, Muhammad *et al*. (2003) mentioned that harvesting potatoes mechanically is superior in harvesting them manually by 65% frugality at harvest time and 45% at harvest costs. The triple interaction of harvesting method, type of the plow, and the planting distance were significant differences in valid potato tubers, total damaged potato tubers, and unlifted potato tuber (Figs. 5, 6 and 7), interaction the mechanical harvesting, moldboard plow and planting distance 25 cm on valid potato tuber was higher 92.25 % and least damage potato tuber was 3.87 %. In contrast, interaction manual harvesting, chisel, and planting distance of 35 cm gave the least valid potato tuber 83.50 %. Addition, the manual harvesting was got least unlifted potato tuber comparing with mechanical harvesting, this result agree with Sadeeq *et al*. (2022) result. In addition, Amare *et al.* (2015) in study founded the lowest losses was 7.61% when used a hoes in harvesting potatoes. Interaction manual harvesting, moldboard plow, and planting distance of 25 cm gave the least unlifted potato tuber was 2.94%, while interaction mechanical harvesting, chisel plow, and planting distance of 35 cm was 7.61 %. Al-Dosary (2016) found unlifted potato tubers was 14.44%. The result showed that the highest damage was when potato tubers were planted at a distance of 35 cm between tuber and another; this was due to the increased friction of potato tubers with soil during harvesting process, which damage caused the highest percentage of unlifted potatoes tuber and that due to more distances between the tubers which below the surface of the soil compared with a planting distance of 15 and 25 cm. The triple interaction of harvesting method, type of the plow, and planting distance were the significant differences on efficiency lifting (Fig. 8), and the interaction of the manual harvesting, moldboard plow, and planting distance 25 cm on efficiency lifting was 97.06 %. Moreover, Al-Dosary (2016) obtained the lifting percentage was 97.02% when used a mechanical harvesting. In contrast, interaction mechanical harvesting, chisel plow, and planting distance 35 cm gave a slight difference in efficiency lifting of 92.38 %, and this because the manual lifting of potato tuber by using hoes was kind of controlled in the small area which infields (surrounded) the tubers, so the almost tuber was raising with the soil to the surface. However, on the other hand, this method is slow and needs more special labor (workers) in a field. In addition, Amare *et al.* (2015) obtained efficiency lifting of 92.40% when used manually harvested. The triple interaction of harvesting method, type of the plow, and planting distance was the significant difference in tuber damage index (Fig. 9); an interaction of the mechanical harvesting, moldboard plow, and planting distance of 25 cm recorded most minor tuber damage index of 18.79. In contrast, manual harvesting, chisel plow, and planting distance of 35 cm gave a higher value of 40.65, this result is agreed with Al-Dosary (2016). The rest of the Tuber Damage Index (TDI) in this experiment was allowed and acceptable values according to table (4) because the damage rate was less than 100 for all treatment in the field experiment.

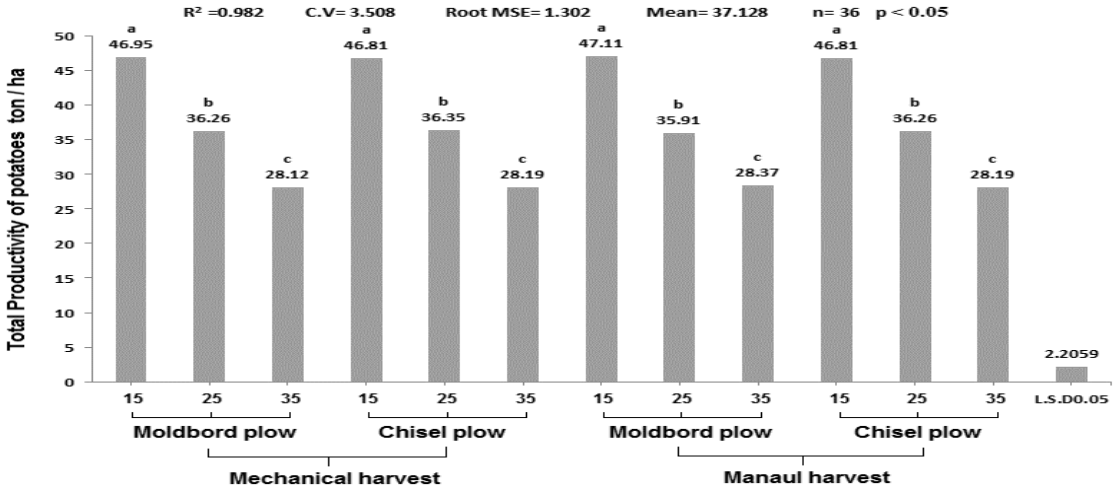

Fig. (3): Interaction of harvesting method, type of the plow, and the planting distance on the total productivity (Means with the same letter are insignificant different).

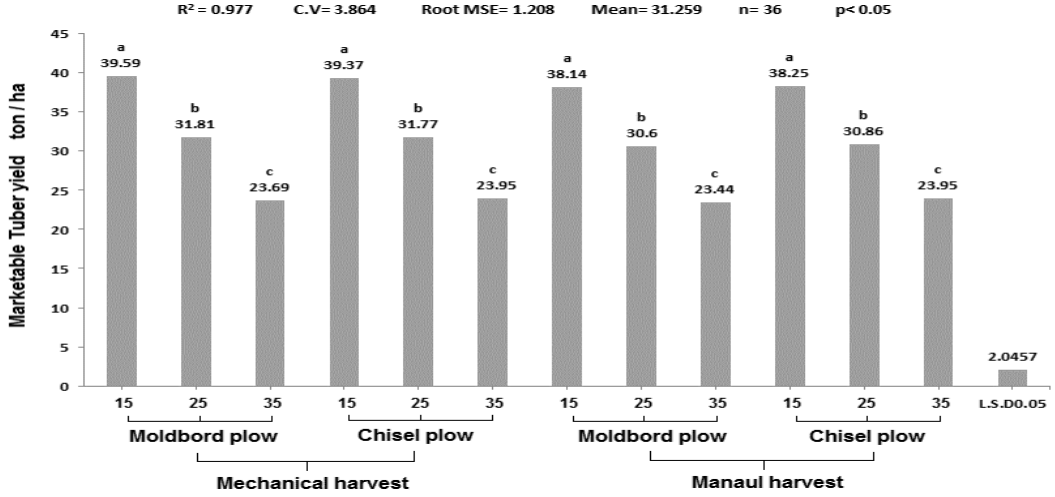

Fig. (4): Interaction of harvesting method, type of the plow, and the planting distance on marketable yield tuber.

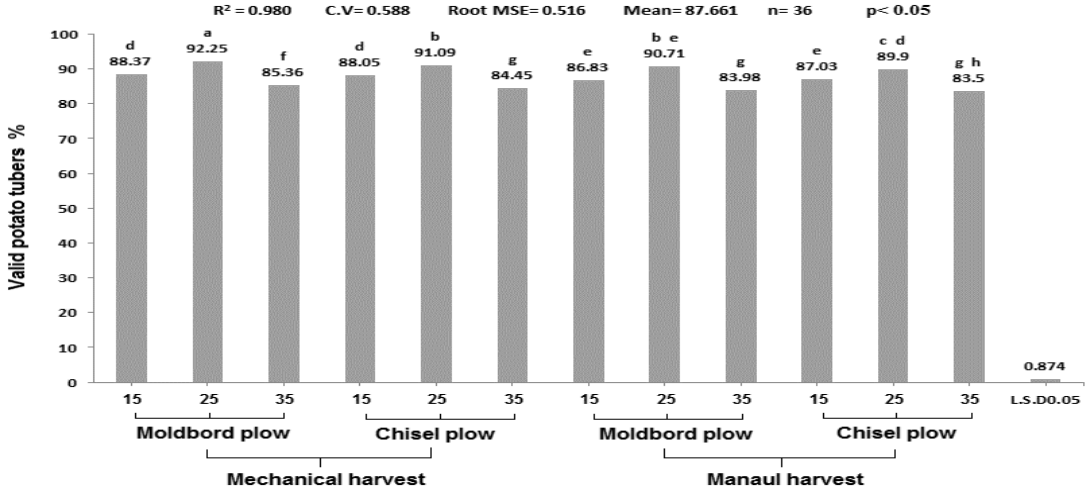

Fig. (5): Interaction of harvesting method, type of the plow, and the planting distance on valid potato tubers %.

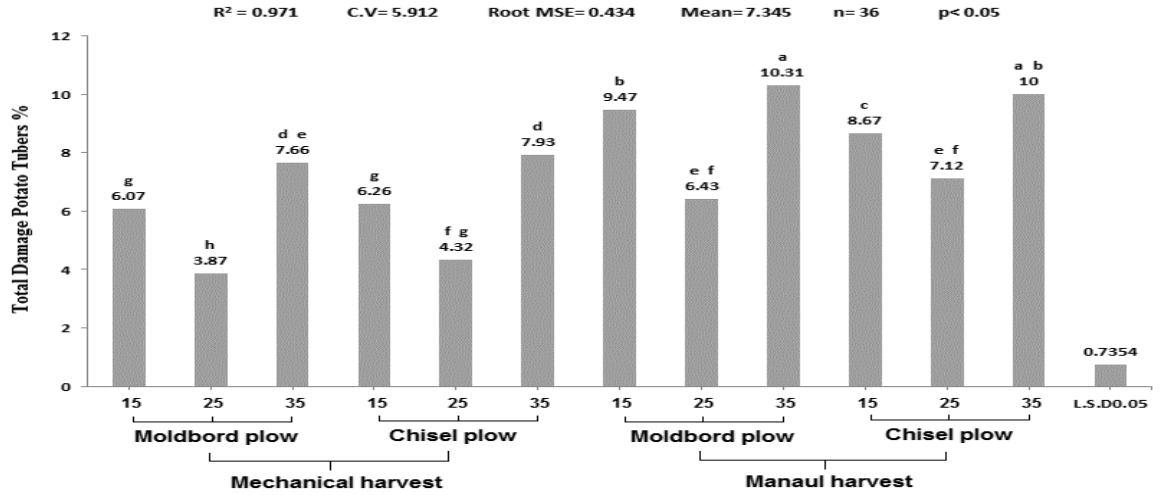

Fig. (6): Interaction of harvesting method, type of the plow, and the planting distance on total damage potato tubers %.

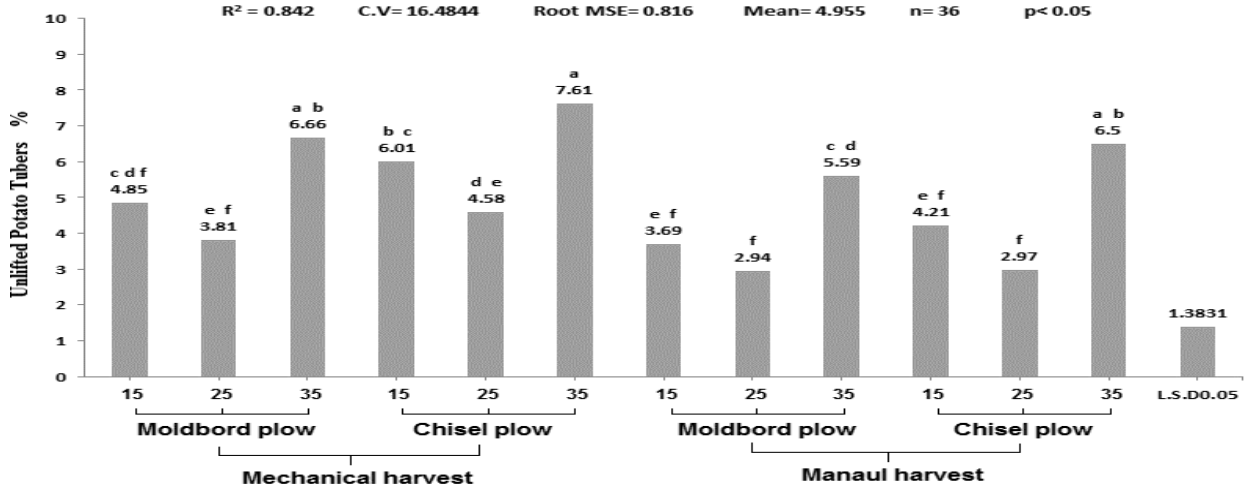

Fig. (7): Interaction of harvesting method, type of the plow, and the planting distance on unlifting potato tubers %.

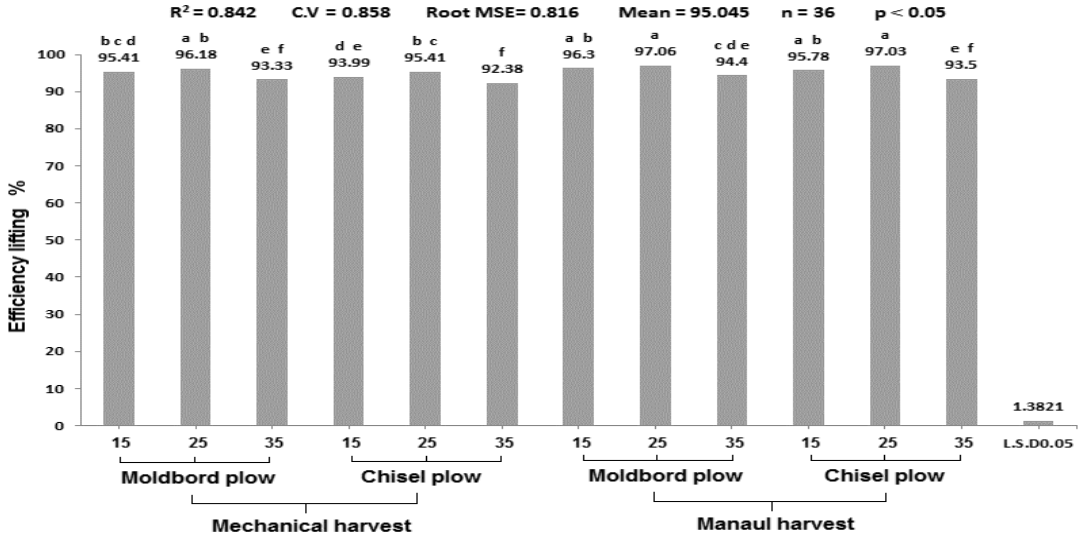

Fig. (8): Interaction of harvesting method, type of plow, and the planting distance on efficiency lifting.

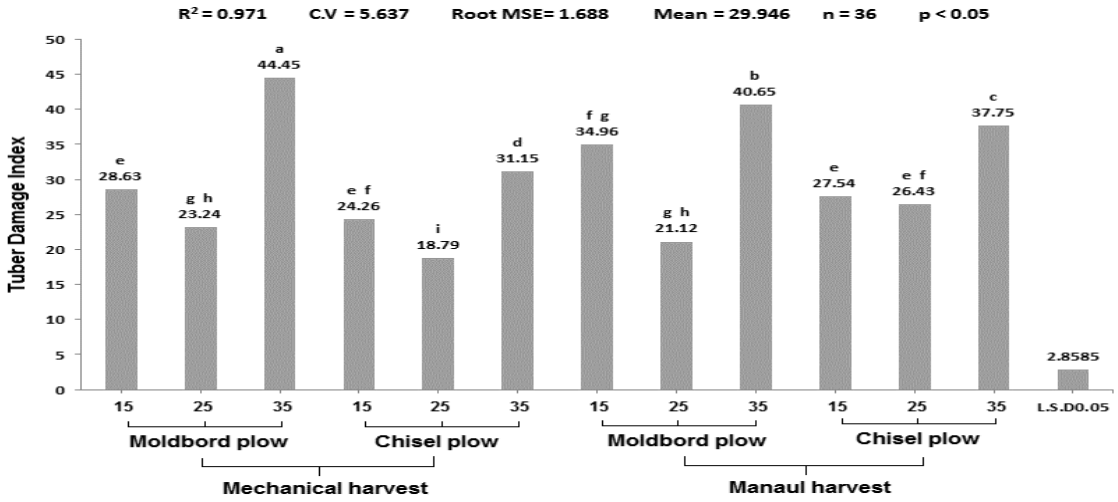

Fig. (9): Interaction of harvesting method, type of the plow, and the planting distance on tuber damage index.

Shape of potato tuber

After harvesting potatoes, a hundred potato tubers were randomly selected from different field treatments, and there length, width, and thickness were recorded (Table 8), Similar techniques and same method is approved by many researchers Al-Dosary (2005), Gamea *et al*. (2009), and Bubenickova *et al*. (2011).

Table (8): The average dimensions of 100 potato tubers selected randomly.

Class	Dimension	Unit	Mean	Minimum value	Maximum value*
BURREN	Length	mm	77.45	31.26	112.34
	Width	mm	45.86	27.32	67.75
	Thickness	mm	62.72	29.60	85.21

* Maximum value is the number used in equation (12).

According to equation (12), the shape of the potato tuber was equal to 218.60 for the harvested *BURREN* potato class. Thus, based in table (5), the shape of potatoes, used in this experiment was spheroid.

$$F = \frac{L^2}{W \times T} \times 100$$

$$F = \frac{(112.34)^2}{67.75 \times 85.21} \times 100$$

$$F = 218.60$$

Correlation A correlation of studied traits was significant and non-significant, as well as the presence of a direct (positive) and an inverse (Negative) correlation (Table 9). The highest positive correlation was between the total productions and marketable tuber yields at 0.9929, at least significantly different ($L.S.D_{0.01}$), and the highest negative correlation was between unlifted potato tuber and efficiency lifting – 0.9999 at $L.S.D_{0.01}$. Same highly significant correlation up to 0.9972 $L.S.D_{0.01}$ between the studied characteristics was obtained by Bubenickova *et al*. (2011).

The least significant direct (positive) correlation between total production and valid potato tuber was 0.39737 at $L.S.D_{0.05}$. Also, between the valid potato tuber and the total damaged tuber, it was 0.3973 at $L.S.D_{0.05}$. Limeneh *et al.* (2021) obtained positive and strong significant correlation in total productivity and marketable yield. The least inverse (negative) correlation was between the total production and tuber damage index – 0.43691 at $L.S.D_{0.01}$. Non-significant

correlations were between total damaged potato tuber and unlifted potato, marketable yield, and efficiency lifting.

Table (9): Correlation of studied traits.

Studied traits	Total production	Valid potato tuber	Total damage potato tuber	Unlifted potato tuber	Marketable tuber yield	Efficiency lifting	Tuber damage index
Total production	1.0000						
Valid potato tuber	0.3973 a	1.0000					
Total damage tuber	- 0.2122	0.3973 a	1.0000				
Unlifted potato	- 0.4285 ab	-0.7157 ab	0.2365	1.0000			
Marketable yield	0.9929 ab	0.4818 ab	-0.3237	-0.4394 ab	1.0000		
Efficiency lifting	0.4279 ab	0.7156 ab	-0.2362	-0.9999 ab	0.4387 ab	1.0000	
Tuber damage index	- 0.4369 ab	-0.8172 ab	0.7554 ab	0.4661 ab	-0.5109 ab	-0.4670ab	1.0000

Means with same Letters was no significant according to L.S.D 0.05 and 0.01.

Conclusion

Finally, in light of these findings, it can be concluded that mechanical harvest gives higher marketable tuber yield, valid potato tubers, and incurs the least total damage to potato tubers. Mechanical harvesting of potatoes saves the time, effort and reduces the number of required workers during the harvesting process. Handy harvest, on the other hand, recorded the fewest unlifted potato tubers. In addition, manual harvesting demands a significant number of specialized workers, leading to slower harvesting process, and it is useless when harvesting large areas. Moldboard plow showed higher valid potato tubers, less total damage potato tubers, fewer un-lifted potato, and increased efficiency in lifting. It also concluded that the total production decreased with in increasing the planting distance between potato tubers. Competes in growing potato tubers and minimal growth of potato was planting distance of 15 cm. The most influential factor in the studied traits was the planting distances of potatoes in the rows. All Tuber Damage Index (TDI) were within acceptable limits, as indicated in table (4). The harvested potatoes conformed to spheroid shape according to the International Organization for Standards (Table 5). Additionally, the correlation of the studied traits revealed both significant and non-significant relationships.

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ORCID

A. H., https://orcid.org/0009-0002-7961-543X

Conflicts of Interest

The author declares no conflicts of interest in this original research.

References

Abo-Hababa, M. M., & Al-Yahya, S. A. (2000). *Agricultural Machinery Practices*. Oxford University Press, Al-Mansoura, Egypt. (In Arabic). 420pp.

Alansari, B. M. (2020). Development of antioxidant activity of potato starch edible films incorporating with rosemary *Rosmarinus officinalis* L. oil and using it in packaging beef pattis. *Basrah Journal Agricultural Science*, *33*(2), 67-79. https://doi.org/10.37077/25200860.2020.33.2.06

Al-Bayati, H. J. M., & Ali, K. R. (2019). Effect of planting depth and zinc sulphate spraying on growth and yield of potato (*Solanum tuberosum* L.). *Basrah Journal Agricultural Science*, *32*(Special Issue), 90-97. https://doi.org/10.37077/25200860.2019.143

Al-Dosary, N. M. N. (2005). *Effect of operating variables of potato harvester on tuber damage*. M. Sc. Thesis. Saud King University. 129pp.

Al-Dosary, N. M. N. (2016). Potato harvest performance on tuber damage at the eastern of

Saudi Arabia. *International Commission of Agricultural Engineering CIGR Journal, 18*(2), 32-42. https://cigrjournal.org/index.php/Ejounral/article/view/3401

Al-Jorany, R. S., Yousif, A. H., & Sadik, F. H. (2016). Population density and susceptibility of some varieties of potato to infested by aphid and thrips on spring plantation in the middle of Iraq. *Baghdad Science Journal, 13*(2), 234-239. http://doi.org/10.21123/bsj.2016.13.2.0234

Al-Hashami, I. S. A., Al-Bahadely, F. H. N., & Jbara, O. K. (2020). Measuring the technical efficiency of potato production and its determinates (sic) in Iraq (Baghdad Province as case). *Iraqi Journal of Agricultural Sciences, 51*(6), 1634-1643. https://doi.org/10.36103/ijas.v51i6.1190

Al-Rubaie, A. H. Sh., & Al-Jubouri, K. D. H. (2023). Response of growth and yield of industrial potatoes to soil improvement and spraying with tocopherol and trehalose under water stress. *Iraqi Journal of Agricultural Sciences, 54*(4), 963-978. https://doi.org/10.36103/ijas.v54i4.1786

Altinawi, E. A., Albiski, F., Faddoul, I. (2023). Effect of fusaric acid (FA) bio-stress on certain morphological parameters for potato (*Solanum tuberosum*. L) cultivars *in vitro*. *Iraqi Journal of Science*, *64*(4), 1635-1650. http://doi.org/10.24996/ijs.2023.64.4.7

Al-Zaidi, M. A. H., & Al-Jumaili, M. A. H. (2022). Impact safe nutrients in raising production and chemical contents of potato. *Iraqi Journal of Agricultural Sciences*, *53*(6), 1397-1406. https://doi.org/10.36103/ijas.v53i6.1655

Amare, D., Kidanemariam, G., Endalew, W., & Yilma, S. (2015). Potato harvester for smallholder producers. *International Journal of Mechanical Engineering and Applications*, *3*(6), 103-108. https://doi.org/10.11648/j.ijmea.20150306.11

Ati, A. S., Iydam, A. D., Najim, S. M. (2012). Water use efficiency of potato (*Solanum tuberosum* L.) under different irrigation methods and potassium fertilizer rates. *Annals of Agricultural Science*, 57(2), 939-103. https:/doi.org/10.1016/j.aoas.2012.08.002

Bubenickova, A., Simeonovova, J., Kumbar, V., Juzl, M., & Nedomova, S. (2011). Mathmatical descriptive characteristics of potato tubers' shape. *ACTA University Agricultural Et Silvicultura Mendelianae Brunensis, 59*(6), 63-68. https://doi.org/10.11118/actaun201159060063

Cunha, J. P. A., Martins, D. H, & Cunha, W. G. (2011). Operational performance of the mechanized and semi-mechanized potato harvest. *Engineering. Agricultural Jaboticabal, 31*(4), 826-834. http://doi.org/10.1590/S0100-69162011000400020

Dowad, S. S., & Jasim, A. A. (2023). Evaluation of the performance of locally developed combine equipment used for several agricultural operations at once. *Diyala Agricultural Sciences Journal*, *15*(1), 93-103. https://doi.org/10.52951/dasj.23150110

Gamea, G. R., Abd, El-Maksoud, M. A., Abd El-Gawad, A. M. (2009). Physical characteristics and chemical properties of potato tubers under different storage system. *Misr Journal Agricultural Engineering*, *26*(1), 385-408. .https://doi.org/10.21608/MJAE.2020.110155

Hamid, A. A. A., & Alsabbagh, A. R. A. (2023). Effect of moldboard types, two depths of tillage and two speeds of tractor in some physical properties and pulverization of soil. *Kufa journal for Agricultural Science, 15*(1), 105-116. https://doi.org/10.36077/kjas/2023/v15i1.10334

International Organization for Standards. (IOS) (1981). *Agriculture Machinery, Equipment for planting potato planters and method of testing*. Handbook.

Jebur, H. A., & Al-Halfi, K. M. (2022). Studying some technical indicators of the local manufactured machine and its effect on the wheat crop "Tamuz cultivar". In *I.O.P. Conference Series: Earth and Environmental Science*, *106*(1), 18-25. http://doi.org/10.1088/1755-1315/1060/1/012135

Limeneh, D. F., Mengistu, F. G., Tilahun, G. W., Galalcha, D. T., Zeleke, A. A., & Hundie, N. F. (2021). Effects of plant spacing and time of harvesting on yield and tuber size distribution of potato (*Solanum tuberosum* L.) variety southeast Ethiopia. *American Journal of Bioscience and Bioengineering*, *9*(1), 1-7. https://doi.org/10.11648/j.bio.20210901.11

Mahood, E. A., Saleh, H. A. A., & Hameed, A. A. (2011). The effect of *Bacillus thuringiensis* in *Phthorimaea operculella* (Zeller) (Lepetoptera: Gelechiidae). *Baghdad Science Journal*, *8*(1), 7-12. https://doi.org/10.21123/bsj.2011.8.1.7-12

Masood, T. K., Ati, A. S., & Hammadi, Q. O. (2023). Effect of water stress and levels of bio-organic fertilizers on water productivity and potato *Solanum tuberosum* L. yield. *Basrah Journal Agricultural Sciences*, *36*(2), 134-143. https://doi.org/10.37077/25200860.2023.36.2.11

Mcgechan, M. B. (1977). An investigation into the relative effectiveness of various riddling motions

for removal of soil from potatoes. *Journal of Agricultural Engineering Research*, *22*(3), 229-245. https://doi.org/10.1016/0021-8634(77)90045-2

Muhammad, Y., Mehmood, A. M., & Rehman R. (2003). Design development and performance evaluation of rotary potato digger. *AMA, Agricultural Mechanization in Asia, Africa and Latin America, 34*(2), 43-46. https://eurekamag.com/research/003/703/003703844.php

Oliveira, R. C., da Silva, J. R. R., Lana, R. M. Q., de Azevedo Pereira, A. I., Castoldi, R., de Camargo, R., & Luz, J. M. Q. (2021). Fertilizer application levels in potato crops and the diagnosis and recommendation integrated system (DRIS). *Agronomy, 11*(1), 1-13. http://doi.org/10.3390/agronomy11010051

Rex, B. L., & Russell, W. A. (1987). The effect of spacing of seed species on yields quality and economic value for processing of Shepody potato in Manitoba. *American Potato Journal*, *64*(4), 177-189. https://www.cabidigitallibrary.org/doi/full/10.5555/19870702730

Salim, S., Ati, A. S., & Ali. A. (2023). Sustainability of agricultural productivity of potato crop in desert soils and evaluation of water productivity under drip irrigation system with future climate changes. *Earth and Environmental Science*. *1222*, 012029, 1-11. http://doi.org/10.1088/1755-1315/1222/1/012029

Sedeeq, A., Tofeq, O. M., & Ali, S. S. (2022). An investigation into the effect of using different harvesting methods on the indicators of potato loss. *Mesopotamia Journal of Agriculture*, *50*(3), 19-26. http://doi.org/10.33899/magrj.2022.133350.1168

Sedeeq, A. M. A., & Al-Tahan, Y. H. (2011). Potato production costs calculation for mechanization by different areas in Nineveh Gov. *Journal of Kirkuk University for Agricultural Sciences*, *2*(1), 94-107. https://kujas.uokirkuk.edu.iq/article_33350.html

Singh, S. (2006). Design, development and field testing of multipurpose potato digger. *Potato Journal*, *33*(3-4), 134-138. https://epubs.icar.org.in/index.php/PotatoJ/article/view/33227

Tesfaye, G., Derbew, B., & Solomon, T. (2013). Combined effects of plant spacing and time of earthing up on tuber quality parameters of potato (*Solanum tuberosum* L.*)* at Degem district, North Showa zone of Oromia regional state. *Asian Jouurnal of Crop Science*, *5*(1), 24-32. https://doi.org/10.3923/ajcs.2013.24.32

Tofeq, O. M. (2023). Study of the effect of potato lifter line on some properties at different depths and varieties of potatoes crop. *Acta Technologica Agriculturae, 2*, 108-114. https://doi.org/10.2478/ata-2023-0015

Umar, I. A., Yusuf, M. A., Ahmed, M., Mohammed, M. U., & Adamu, G. K. (2016). Soil N.P.K. requirements for Irish potatoes under fadama irrigation management in Rugu Tudun Wada local government area of Kano State, Nigeria. *International Journal Agricultural Environment Sciences*, *1*(1), 1-7.

World Potato Congress (WPC), (2022). The changing world of the potato. The 11th world Potato Congress. 30th May- 2nd June. Dublin, Ireland.

Yaroson, A. Y., Henry, U. I., Adeniyi, T. O., Ibrahim, I., & Adam, D. (2019). Effect of different tillage Practices on the performance of potato (*Solanum tuberosum*) on the Jos Plateau. *International Journal of Scientific and Research Publications*, *9*(2), 618-625. http://doi.org/10.29322/IJSRP.9.02.2019.p8679

Zaen, A. S., Dhedan, R. M., & Sharma, L. K. (2023). An application for smart phonesand computers to diagnose and control potatoes insects. *Iraqi Journal of Science*, *64*(8), 4302-4311. http://doi.org/10.24996/ijs.2023.64.8.46

Zainaldeen, M. A., & Abdul Rasool. I. J. (2023). Response of growth and yield of true potato seed plants to foliar application with organic nutrients. *Earth and Environmental Science*, *1158*, 042047, 1-6. http://doi.org/10.1088/1755-1315/1158/4/042047

دراسة الاداء الحقلي للحراثة وجني البطاطا في جنوب بغداد

أحمد عبد علي حامد

قسم شؤون الأقسام الداخلية، جامعة بغداد، بغداد، العراق

المستخلص: أجريت تجربة حقلية للمقارنة بين طريقتين لحصاد البطاطا الميكانيكية واليدوية عند استخدام المحراث المطرحي القلاب والمحراث الحفار في حراثة التربة، وثلاثة مسافات مختلفة لزراعة درنات البطاطا في الصفوف وكانت 15 ، 25 و 35 سم في تربة مزيجية طينية رملية في جنوب بغداد. أجري التحليل الإحصائي وفق تجربة عاملية بتصميم القطاعات العشوائية الكاملة وبثلاثة مكررات وباستخدام أقل فرق معنوي على مستوى احتمالية 5 و 1 %. الحصاد الميكانيكي حقق أفضل نسبة درنات سليمة 88.78 % وكمية حاصل قابل للتسويق 31.74 طن. هكتار$^{-1}$ وكفاءة رفع الدرنات 95.68 % و دليل ضرر الدرنات 28.41، وساهم في سرعة عملية الحصاد وتقليل الوقت والجهد. الحصاد اليدوي للبطاطا حقق أقل نسبة درنات متضررة 6.02 % ونسبة درنات مدفونة 4.32 % وتتطلب هذه الطريقة جهد ومزيد من العمالة المتخصصة سواء رجال أو نساء يافعات وتسبب تأخير في عملية الحصاد. مسافة الزراعة 15 سم بين درنة وأخرى أعطى أعلى إنتاجية كلية 46.92 طن. هكتار$^{-1}$ وعدد نباتات في الصف الواحد، لكن أغلب الدرنات صغيرة الحجم، بينما مسافة الزراعة بين الدرنات 25 سم أعطت إنتاجية تتصف بالنوعية الجيدة وقُدرت 36.19 طن. هكتار$^{-1}$، وأفضل نسبة درنات سليمة 90.99 % وأقل نسبة درنات متضررة 5.43 % وأقل درنات مدفونة 3.57 % وأفضل كفاءة رفع للدرنات 96.42 % وأقل دليل للدرنات المتضررة 22.39. أكثر عامل مؤثر في الصفات المدروسة في التجربة كان المسافة بين الدرنات في الصفوف. شكل درنات البطاطا كانت ذات نوع بيضوي. الحصاد الميكانيكي للبطاطا يوفر الجهد والوقت وسرعة الحصاد وتقليل عدد العمالة وزيادة الكفاءة.

الكلمات المفتاحية: الحصاد الميكانيكي، حصاد البطاطا، تسويق البطاطا، حراثة التربة.