Effect of Potato Digger Speed Ratios and Elevator Agitation on Harvesting Efficiency, Cost and Tuber Losses

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ABSTRACT

A field experiment was conducted at the Faculty of Agriculture Farm, University of Alfateh, Tripoli, Socialist People's Libyan Arab Jamahiriya, during 1976. The objective was to study the theoretical field capacity, labor used and cost of harvesting by a mechanical potato digger at 4 elevator speed to forward speed ratios, with and without elevator agitation.

The digger had 7.9 times more theoretical field capacity, required 12.8% labor and 38.4 % of the cost of the manual harvesting. The elevator agitation increased the capacity and reduced the labor and cost as compared to no agitation. The speed ratios of 0.57:1 and 0.85:1 seemed more effective to give increased capacity, and to reduce labor and cost.

The tuber damage with speed ratio of 1.55:1 was significantly higher than the manual method. The speed ratios of 1.04:1 and 0.85:1 without agitation, and 0.57:1 were not significantly different. The tuber damage was higher with agitation than without agitation of the elevator chain.

The skinning, total tuber damage and total damage excluding skinning were significantly increased by elevator agitation. The speed ratios had a significant effect on serious damage, total tuber damage and total damage excluding skinning. There was no effect of speed ratios and agitations on slight tuber damage and field leavings. The interaction between the speed ratios and the elevator agitations was not significant.

The digger under study has poor manoeuvrability, cushionless elevator chain and instability of different components due to enormous vibrations at higher speeds. These drawbacks adversely affected its performance and require redesigning of the related components.

INTRODUCTION

The potato (*Solanum tuberosum* L.) is an important crop in the Socialist People's Libyan Arab Jamahiriya. It is mostly planted in the coastal belt as the fall and the spring crop. The area and production of potato has increased six-folds since 1965 (3).

The prevailing shortage of farm hands becomes acute and expensive during the harvest season. The uncertainty and transient nature of the farm labor further aggrev-

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ates the situation. This adversely affects the efficiency and timeliness of harvesting operations, increases the costs and reduces the farmer's returns. The Jamahiriya is mechanizing her agriculture very rapidly. It is quite unfortunate that the machine-use in potato cultivation is still under neglect. The benefits of mechanization: to reduce the cost of harvesting and handling, to minimize the labor input, to eliminate the arduous nature of the work and to improve the efficiency, need immediate attention.

The mechanization of potato harvesting for labor scarcity areas is an economical proposition. The cushioning of all metal parts en route of tubers and easy manoeuvrability of potato diggers for reduced tuber damage and increased efficiency, was also stressed (2, 5, 12).

Humphery (7) recommended the elevator speed of about 45 meters per minute and minimum use of agitators to reduce tuber injuries during mechanical potato harvesting. An increased tuber damage was caused by agitation of the elevator chain (4,7,10). Cashmore (2) found slightly more tuber damage by machine than by man. He further noted the minimum tuber damage for ratios of 0.7:1 and 1.0:1.0 between the elevator speed and the forward speed. Magee (10) observed 7 times more damage due to chain agitation and non-significant effect of elevator speed. A significant interaction between elevator speed and agitations was found by Hopkins (6) regarding the tuber damage. There was significantly more slight tuber damage with either an increase in elevator speed or agitation. The chain speed to ground speed ratio was significantly correlated with tuber injuries and negligible field losses occurred under good operating conditions (11). Rennie (12) observed 13.8% field leavings with the potato harvester as against 11.9 % with the manual harvesting operations.

This work was undertaken to find the most effective elevator speed to forward speed ratios, with or without elevator agitation, for an imported mechanical potato digger.

MATERIALS AND METHODS

The experiment was conducted at the Faculty of Agriculture Farm, University of Alfateh, Tripoli, Socialist People's Libyan Arab Jamahiriya, during the fall season of 1976. The soil of the site is sandy loam. A randomized complete block design with 4 replications was used. The plot size was 0.75 × 25 m. The data were analysed according to Le Clerg *et al.* (9).

The potato cultivar "Cardinal" imported from Holland was propagated locally during 1976 as the spring crop. The seed tubers taken from it were planted manually on September 9, 1976 at the rate of 2 tons per hectare. The ridges were made 75 cm apart with a mechanical ridger. The seed tubers were spaced at 25 cm in the ridge at about 10 cm depth. A compound fertilizer (12–24–12) was applied in two equal instalments, each at the rate of 300 kg per hectare, after complete emergence of plants and before ridging up. The chemical pest control and manual weeding was practised. The field was irrigated by sprinklers.

The harvesting was done on December 28, 1976 with the A.V.R. 75 Universal potato digger imported from Holland. It is a single row, trailed and power take-off driven digger with two positions for elevator agitation. It has a vibrating lifting knife of 45 cm harvesting width. The manual harvesting was done with spade locally called 'Misha'.

The four elevator speed to forward speed rations used were: 1.55:1, 1.04:1, 0.85:1, and 0.57:1 with or without agitation of the elevator chain. The former two ratios were

at the forward speed of 2.75 kilometers per hour and the latter two at 3.75 kilometers per hour (computed on the basis of fast and slow speeds of the elevator chain). The theoretical field capacity (hectares per hour) and labor requirement in man-hours was calculated from the time taken to dig and pick (no sacking) the tubers from a 25-meter long ridge. The operational cost was calculated on the basis of prevailing seasonal rental rates of labor and machinery.

The theoretical field capacity (TFC), labor requirement and cost of harvesting was calculated by the following formulae:

$$\text{Theoretical field capacity (ha/hour)} = 0.00001 \times \frac{\text{Area harvested (m}^2\text{)}}{\text{Time taken to harvest (hours)}}$$

$$\text{Labor requirement (man-hours/ha)} = \frac{\text{Number of workers}}{\text{Theoretical field capacity}}$$

$$\text{Cost of harvesting (Libyan Dinars/ha)} = \text{Man-hours/ha} \times \text{wages of worker's team/hour}$$

The seasonal rental rates of labor and machinery were as under:

a. Mechanical harvesting

Tractor + potato digger +	operator	=	LD 2.500/hour
	One picker	=	LD 0.500/hour
	Total	=	LD 3.000/hour

b. Manual harvesting

One digger	=	LD 0.500/hour
One picker	=	LD 0.500/hour
Total	=	LD 1.000/hour

The potato tuber damage was evaluated as follows according to Larsen (8):

a. Skinning: One stroke of peeler, removing a 1.5 mm slice, removed the whole damage.
b. Slight: Three strokes of the peeler removed the whole damage.
c. Serious: More than three strokes were required to remove the whole damage. It also included the splits.

The tubers bigger than 2.5 cm in size, were picked up from the 25-meter long ridge and weighed for the plot yields. The damaged tubers were then sorted out and weighed to find out total tuber damage. The damaged tubers were separated by weight into skinned, slightly damaged and seriously damaged. The post-harvest leavings were collected from the ridge with hand tools after picking the tubers.

RESULTS AND DISCUSSION

Theoretical Field Capacity (TFC)

The mechanical digger had 6.50 to 9.50 times more TFC than the manual harvesting (Table 1). The TFCs of elevator speed to forward speed ratios without agitation varied from 0.039 to 0.052 as against 0.046 to 0.057 hectares per hour with agitation of the elevator chain. The TCCs, without agitating the chain, were less due to incomplete separation of the tubers from soil and vines. The speed ratio of 0.57:1 gave the highest field capacity.

Table 1 Effect of elevator speed to forward speed ratios with or without elevator agitation, and the manual potato harvesting on theoretical field capacity (TFC), labor requirement and cost of harvesting.

Elevator speed to forward speed ratios	Elevator agitations	TFC hectares per hour	Man-hours per hectare	Cost per hectare (L.D.)	Yield per hectare (Tons)	Man-hours per ton	Cost per ton (L.D.)
1.55:1	With agitation	0.047	42.55	127.65	11.977	3.55	10.658
	Without agitation	0.042	47.62	142.86	12.784	3.72	11.175
1.04:1	With agitation	0.046	43.48	130.44	13.360	3.25	9.763
	Without agitation	0.039	51.28	153.84	14.459	3.55	10.640
0.85:1	With agitation	0.050	40.00	120.00	13.280	3.01	9.036
	Without agitation	0.047	42.55	127.65	12.740	3.34	10.020
0.57:1	With agitation	0.057	35.09	105.27	12.715	2.76	8.279
	Without agitation	0.052	38.46	115.38	13.491	2.85	8.552
Manual harvesting		0.006	333.33	333.33	12.745	26.15	26.154

Labor Requirement

The labor required by the digger in man-hours per hectare was 10.5 to 15.4% and in man-hours per ton of tubers was 10.6 to 14.2% of the manual method. The harvesting at speed ratio of 0.57:1 required the minimum labor. The labor consumption was slightly reduced with the elevator agitation as it gave a clean swath of tubers.

Cost of Harvesting

The cost of potato harvesting per hectare with the digger was 31.6 to 46.2% of the manual method. This range was 31.7 to 42.7% for the cost per ton of tubers. The cost per hectare was slightly higher by harvesting without elevator agitation. This was due to slow picking of tubers from an uncleaned swath. The speed ratio of 0.57:1 was the least expensive.

The mechanical potato digger had more field capacity, and required less labor and cost than the manual harvesting as also shown by (2,12); although these qualities were adversely affected by the cushionless elevator chain and poor manoeuvrability (5).

Tuber Losses

The differences among means of tuber damages in various categories for all treatments except the slight tuber damage (Table 2) were significant. The skinning was significantly less with the manual harvesting (4.48%) as compared to other treatments. The speed ratio of 1.55:1 resulted in the maximum (16.38 and 11.68%) skinning. It also gave significantly more (7.65 and 5.05%) serious tuber damage than the manual method (2.10%). The other ratios (1.04:1, 0.85:1 and 0.57:1) were comparable to the manual digging. All speed ratios, except 0.85:1 and 0.57:1 without agitation, gave significantly higher total tuber damage as compared to the manual harvesting (8.95%). The highest total damage (31.68 and 20.90%) was noted for speed ratio of 1.55:1 with and without agitation. The total tuber damage was increased by agitation in all speed ratios. The total tuber damage excluding skinning was significantly more than the manual method (4.48%) with all the speed ratios except 0.57:1, and 1.04:1 and 0.85:1 without agitation of elevator chain. The speed ratio 1.55:1 resulted in the maximum damage (15.3 and 9.23%). Similar observations are also reported in literature (1,2,4, 7,11). The cushionless elevator chain was one of the causes for the increased damage with the digger as reported by Hawkins (5). Our results, however, did not agree with him as he found significantly more slight tuber damage with either higher elevator speeds or agitations.

The field leavings (harrowings) were also significantly less with the manual harvesting (2.06%) as against the speed ratios of 1.55:1 (8.57 and 7.72%), 1.04:1 without agitation (5.61%) and 0.57:1 with agitation (6.43%). The other speed ratios were comparable to manual method as also shown previously (11,12).

The effect of elevator agitation on the skinning of tubers was significant (Table 2). The agitation results in 12.57% skinning as against 9.41% without agitation. The speed ratios did not significantly affect skinning percentage. There was no significant interaction between the speed ratios and the agitations. The data in Table 2 shows that speed ratios and agitations, and their interaction did not have any significant effect on the proportion of slight tuber damage as also shown by other workers (4,5,7,10). The observations of Hopkins (6) were different regarding the effect of either elevator speed or agitation on the slight tuber damage.

Table 2 Effect of elevator speed to forward speed ratios with or without elevator agitation, and the manual potato harvesting on tuber losses.

Elevator speed to forward speed ratios	Elevator agitations	Skinning % 1	Slight damage % 2	Serious damage % 3	Total damage % 4	Total damage excluding skinning % 5	Field leavings % 6
1.55:1	With agitation	16.38	7.65	7.65	31.68	15.30	8.57
	Without agitation	11.68	4.18	5.05	20.90	9.23	7.72
1.04:1	With agitation	10.85	4.18	4.88	19.90	9.05	5.15
	Without agitation	9.48	3.35	3.60	16.43	6.95	5.61
0.85:1	With agitation	11.40	3.70	4.08	19.18	7.78	5.39
	Without agitation	8.55	3.03	3.70	15.28	6.73	4.76
0.57:1	With agitation	11.63	3.75	2.98	18.35	6.73	6.43
	Without agitation	7.93	3.00	3.33	14.25	6.33	5.44
Manual harvesting		4.48	2.38	2.10	8.95	4.48	2.06
LSD (0.05)		3.44	N.S.	2.92	7.40	3.31	3.46

LSD (0.05) for elevator speed to forward speed ratios with or without agitation were:
Column 1. due to agitation 2.71%
3. due to ratios 2.18%
4. due to ratios 5.40% and due to agitations 3.82%
5. due to ratios 2.45% and due to agitations 1.73%

The speed ratios gave significant differences among the mean values of serious tuber damage (Table 2). The values for speed ratios of 1.04:1, 0.85:1 and 0.57:1 (4.24, 3.89 and 3.16%, respectively) were comparable, but 1.55:1 resulted in a significantly higher value (6.35%) as compared to other speed ratios. The effect of agitations and the interaction between the treatments was non-significant. Cashmore (1) and Peterson *et al.* (11) have reported corroborating results. Magee (10) made dissimilar observations and found significantly higher tuber damage due to agitation of the elevator chain.

The occurrence of total tuber damage presented in Table 2 shows that the effect of speed ratios and agitations was significant. The speed ratios of 1.04:1, 0.85:1 and 0.57:1 with 18.17, 17.23 and 16.30% damage respectively were statistically similar. The speed ratio of 1.55:1 gave significantly higher total tuber damage (26.35%) than other speed ratios. The agitation of elevator chain also had a significant effect on total tuber damage. The agitation produced 22.31% damaged tubers as against 16.72% without agitation. There was no interaction between the speed ratios and agitations. These results agreed with those reported by (1,4,7,10,11).

The effect of the speed ratios and the agitations on the total tuber damage excluding skinning (Table 2) was significant but their interaction was non-significant. The speed ratios of 1.04:1, 0.85:1 and 0.57:1 gave similar effects. The respective damage was 8.00, 7.26 and 6.53%. A significantly higher tuber damage (12.27%) was found with 1.55:1 speed ratio. The percentage of field leavings (Table 2) was not significantly affected by speed ratios and agitations, and their interaction. The workers like (1,10, 11,12) have made similar observations.

The digger under study has poor manoeuvrability, cushionless elevator chain and instability of different components during the operation. This adversely affected its superiority over the manual harvesting.

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تاثير نسب سرعات الغربال المتحرك المهتز على كفاءة وتكاليف الحصاد وفقد الدرنـــات

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مستخلـــص البحـــث

أجريت التجربة فى مزرعة كلية الزراعة بجامعة الفاتح بالجماهيرية العربية الليبية الشعبية الاشتراكية خلال خريف ١٩٧٦ م · وكان الهدف منها دراسة السعة الحقلية ، اليد العاملة المستعملة وتكاليف الحصـاد لجنى البطاطس آليا باستعمال آلة مزودة بغربال ذو أربعة سرعات ·

وتمتاز آلة جنى البطاطس بسعة حقلية نظرية عالية مقدارها ٧ر٩ ، وتحتاج الى ٨ر١٢ ٪ من العمالة و ٤ر٣٨ ٪ من التكاليف اذا ما جنى المحصول يدويا · والغربال المتحرك الهزاز يزيد من السعة ويقلل مـن العمالة والتكاليف مقارنة عندما يكون الغربال المتحرك بدون اهتزاز ـ ونسب السرعات ٥٧ر٠ : ١ و ٨٥ر٠ : ١ تبدو أكثر فعالية لزيادة السعة وتقليل العمالة والتكاليف واصابة الدرنات بخدوش مع نسبة السرعـــة ٥٥ر١ : ١ أعلى من التقليع بالطريقة اليدوية · وبالنسبة للسرعات ٠٤ر١ : ١ و ٨٥ر٠ : ١ بدون اهتزاز و ٥٧ر٠ : ١ لا تعطى أية دلالة مختلفة عن التقليع اليدوى · واصابة الدرنات بخدوش عالية عندما يكـون الغربال المتحرك المهتز لو قورنت بالدرنات عندما يكون الغربال المتحرك بدونه ·

الخدوش وتجريح القشرة والضرر الكلى ، الضرر الكلى بدون تجريح القشرة يعطى دلالة معنوية عند زيادة سرعات الغربال المتحرك · ونسبة السرعات تعطى دلالة معنوية على الأضرار البليغة والضرر الكـل بدون تجريح القشرة وذلك يرجع الى تكرار مرات التصادم بين الدرنات والغربال المتحرك · ولا يوجـــد أية دلالة معنوية بين نسب السعات واهتزاز الغربال المتحرك على الخدوش البسيطة للدرنات فى حالة نـزع المجموع الخضرى قبل القلع أو بعده ·

والآلة التى تحت الدراسة ظهرت بها بعض العيوب منها صعوبة المناورة داخل الحقل والغربال المتحـرك بنقصه كادم للصدمات على السلسلة المتحركة · وعدم توازن بعض القطع للاهتزازات الناتجة عند السرعـات العاليـــة ·

ان الآلة بوضعها الحالى تحتاج الى اعادة التصميم لتلائم طبيعة العمل بالجماهيرية العربية الليبيـــة الشعبية الاشتراكية ·