Comparative studies of six potato harvesting methods in the Beqa'a Plain of Lebanon[1]

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ABSTRACT

A field experiment was conducted at the Agricultural Research and Education Center of the American University of Beirut, Lebanon to compare various prevailing potato harvesting methods with the mechanical harvester. The methods included were: manual without devining, manual after devining, animal-drawn plow after devining, tractor-drawn Zahle plow after devining, tractor-drawn furrow-opener after devining and the mechanical potato harvester without devining.

The field capacity of the mechanical potato harvester was 8 to 14 times more than the other methods. Its labor requirement as to man-hours per hectare and cost per ton of potato harvesting was also relatively very small. These advantages were completely overshadowed by its much higher tuber-damage, post-harvest leavings in the field and trash collection. The tractor drawn furrow opener appeared to be the best. Its harvesting effeciency was greater but labor and cost requirements smaller than the other conventional methods without increasing tuber damage, field leavings and trash collection. The manual methods proved to be the poorest. The desirable features of mechanical harvesters for various soils and varietal conditions have been discussed.

INTRODUCTION

The potato (*Solanum tuberosum* L.) is an important crop of the Arab world. Its area in Libya and Lebanon increased from 3,000 and 6,000 hectares in 1965 to 17,000 and 9,000 hectares in 1974, respectively. The respective increases in the production of tubers were from 12,000 and 60,000 tons to 80,000 and 120,000 tons (F.A.O. 1974a).

Most of the Arab countries face an acute shortage of labor in the agriculture sector. The transition to agricultural mechanization is, therefore, being followed to reduce dependance on seasonal farm labor and to increase production. For example, Libya and Lebanon had respectively, 11,474 and 4,025 tractor units in 1973 against 3,400 and 2,250 units in 1968 (F.A.O. 1974b).

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Rennie (9) from his intensive experiments indicated mechanization of potato harvesting to be the most efficient and economical method for labor scarcity areas. Larsen (8), however, showed that in spite of several advantages of mechanical harvesting, it causes many problems such as increased tuber damage, post-harvest leavings and trash picked up with the tubers. The tuber injury was more serious, being up to 30 percent of the total production. Tavernetti and Baghott (10), Cashmore (1) and Cox (2) obtained similar results. The proportion of tuber injury, however, depended largely on the soil conditions, the harvester design and the cultivar of potatoes used. Hawkins (7) concluded that the separating mechanism of the harvester should have neither an exposed metal part moving fast enough to give a damaging blow, nor a tuber fall of more than 15.0 centimeters without the provision of a cushion. He also observed a revolving drum separator to be unsuitable, since its tumbling action increased the tuber damage. The damage was especially marked on stony or cloddy soils. Several designs and operational characteristics of harvesters have however been proposed for identical soil conditions by Tavernetti and Baghott (10), Cashmore (1), Rennie (9), French and Blake (6) and Cox (2) to keep the tuber damage, post-harvest leavings and trash collection to a minimum.

The present experiments have been conducted to compare a newly evolved mechanical harvester with the conventional tractor-drawn, animal-drawn and manual methods. Their suitability has been judged on the basis of new concept comparing field capacity, labour consumption and cost of harvesting in relation to tuber damage, post-harvest leavings and trash collection.

MATERIALS AND METHODS

The experiments were conducted in 1973 at the Agricultural Research and Education Center of the American University of Beirut, in the Beqa'a Plain, Lebanon. The

Fig. 1. Potato lifting hand tool.

soil of the test site was calcareous clay containing a considerable amount of pebbles. The experiment was laid out in randomized complete block design with 6 replications. The most common variety of potatoes called 'Up-to-Date' was planted with a single row, mounted, P.T.O. driven and semi-automatic potato planter. The distance between the seed tubers was kept 30 centimeters and the ridges were 75 centimeters apart. The harvesting methods were:

1. manual digging with a fork-type hand tool without devining the ridges, followed by hand picking of the tubers.
2. manual digging with a fork-type hand tool after devining the ridges and then hand picking the tubers (Fig. 1).
3. digging with an animal-drawn plow by going twice along each ridge after devining the ridges and hand picking the tubers (Fig. 2).
4. digging with a tractor-drawn Zahle plow by going twice along the ridge after devining the ridges and hand picking the tubers. This plow is a locally made general purpose implement with 5-bottomed steel structure and is commonly used for potato digging with only 2 bottoms spaced according to the ridge spacing (Fig. 3).
5. digging by tractor-drawn furrow opener by going once along each ridge after devining the ridges and hand picking the tubers. It is a 5-bottomed tractor-mounted implement and is occasionally used for potato digging with only 2 bottoms spaced according to the ridge spacing (Fig. 4).
6. harvesting by a Massey Ferguson 711 mechanical potato harvester without devining the ridges (Fig. 5). It is a trailed, P.T.O. driven and single-row harvester with a disk digger. It has a vertically-revolving cushionless drum separater and 2 horizontally-revolving platforms. The dug material (tubers and trash) passes through the drum separator for preliminary separation and comes to the first platform. Three persons pick the tubers and transfer these to the second platform which passes them into the attached sack. The material left on the first platform goes on falling on the ground.

The forward speed of the mechanical harvester was 2.75 kilometers per hour (kph), the tractor-drawm implements 3.00 kph and the animal-drawn plow about 1.75 kph. The capacity of the methods and labour requirements were determined from the time taken to complete the processes of devining, digging and picking of tubers from a 20-meter long ridge. The cost of operation was computed on the basis of prevailing rental rates

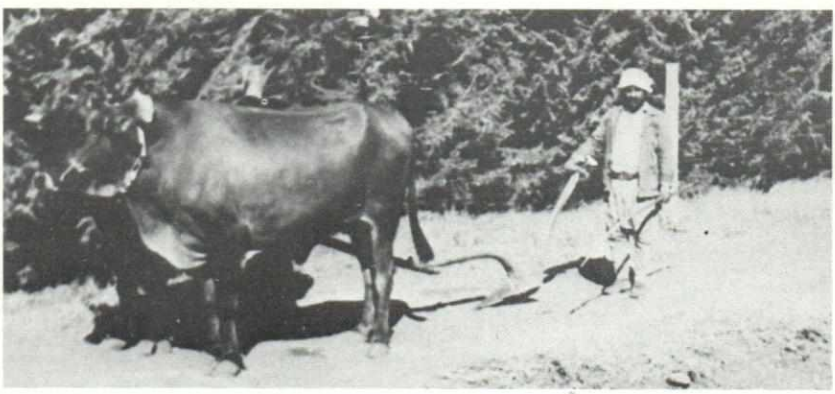

Fig. 2. Animal-drawn plow.

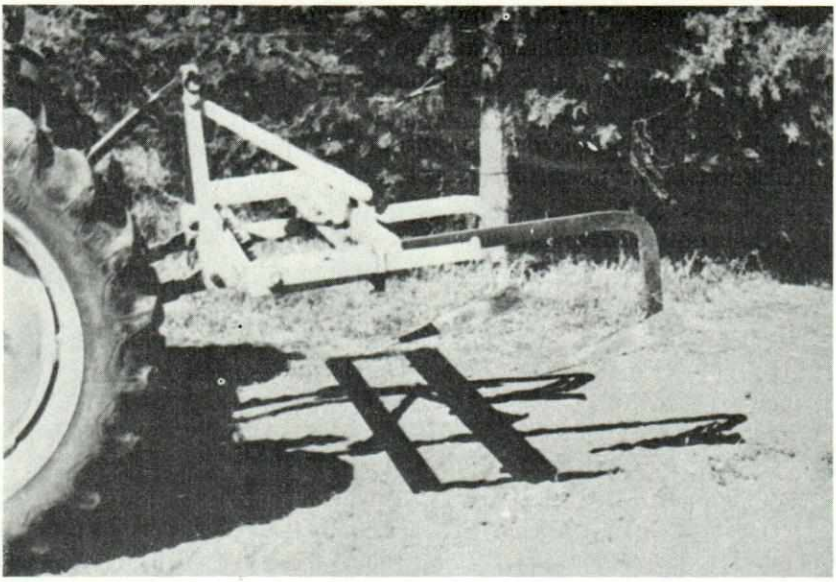

Fig. 3. Tractor-drawn Zahle plow.

of labour and equipment. The tuber damage was divided into: (a) skinning: one stroke of peeler, removing a 1.5 millimeter slice, removed the whole damage (b) slight: three strokes of the peeler removed the whole damage and (c) serious: three or more strokes were required to remove the whole damage. It also included the splits.

The potato sample was taken from 3 random lengths of 1-meter each from the ridge, for observing the tuber damage and trash percentage on weight basis. The sample yield

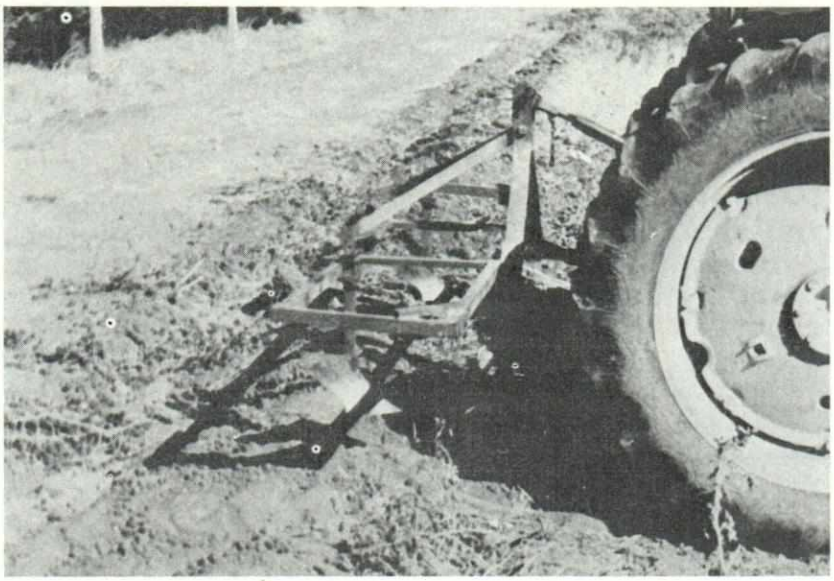

Fig. 4. Tractor-drawn furrow opener.

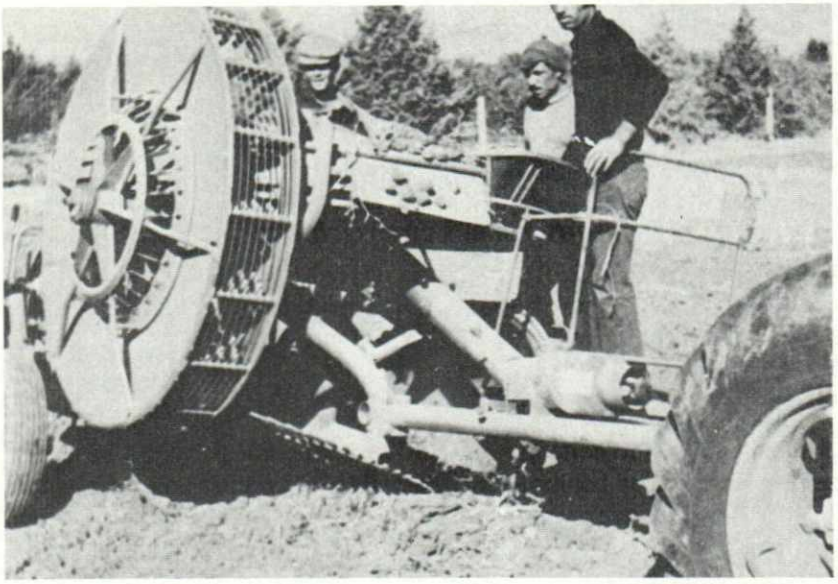

Fig. 5. Mechanical potato harvester.

was added to the weight of tubers of the remaining 17-meter ridge to obtain the plot yield. Field leavings were determined by digging 3 random lengths of 1-meter each. Their percentage on weight basis was then computed from the plot yields. The tubers passing through a 2.5 centimeter riddle were discarded for all observations.

RESULTS AND DISCUSSION

The mechanical harvester exhibited highest field capacity for potato harvesting. It was 8 to 14 times higher than the other methods (Table 1). Similarly the mechanical harvester also required less labour and was less expensive compared with all the other

Table 1 Theoretical field capacities, labour requirements and cost of harvesting potatoes by different harvesting methods.

Serial number	Harvesting method	T.F.C. hectares per hour	Man-hours per hectare	Cost per hectare (U.S.$)	Yield per hectare (Metric tons)	Man-hours ton	Cost per ton (U.S.$)
1	Manual, without devining	0.014	268.89	1000.51	20.25	13.28	49.41
2	Manual, after devining	0.013	302.22	1124.54	22.77	13.27	49.39
3	Animal-drawn plow, after devining	0.019	204.22	740.76	16.03	12.74	46.21
4	Tractor-drawn Zahle plow, after devining	0.022	176.00	618.32	14.56	12.09	42.47
5	Tractor-drawn furrow opener, after devining	0.024	170.44	589.74	15.87	10.74	37.16
6	Mechanical potato harvester, without devining	0.196	20.40	184.87	14.77	1.38	12.51

methods. Its labour requirement in man-hours per hectare was only 0.12 to 0.07 and cost per ton of tuber 0.34 to 0.25 of other tractor-drawn, animal-drawn and manual methods. The tractor-drawn furrow opener and Zahle plow followed the mechanical harvester with their labour requirement and cost per ton of tubers much lower than the animal-drawn and the manual methods. The furrow opener appeared slightly better than the Zahle plow. Several investigators have enumerated similar advantages of mechanical harvesters. For example, when Rennie (9) compared it with a hand picking team, it had 4 times more field capacity, consumed 0.50 the labour and was 0.33 of the cost of harvesting.

The advantages of more capacity, less labor consumption and cost of harvesting of the mechanical harvester were, however, completely overshadowed by a greater amount of tuber damage (Table 2; $P < 0.01$). Its total damage excluding skinning was 26% compared with 6 to 7% by the tractor-drawn furrow opener and the Zahle plow. These two implements did not cause more tuber damage than the other softer methods of harvesting.

The increased tuber damage with the harvester seemed to occur partly due to the presence of soil clods and pebbles. The design of the harvester, however, also played a significant role. Thus, the tumbling action in the revolving drum separator, longer distance of travel, greater agitation and tuber contact with the cushionless metal parts en route to the sack, all contributed to increased tuber damage. Earlier researchers also compared damage of tubers by various types of harvesters. Hawkins (7) reported harvesters with drum-type separating mechanisms to cause more damage, particularly on stony soils. Tavernetti and Baghott (10) stressed that cushioning of the metal parts of harvesters reduced the tuber damage whereas agitation increased it. Cashmore (1) observed an increased tuber damage with a mechanical digger and recommended a

Table 2 Average damage of tubers, post-harvest leavings and trash picked up with tubers on a weight basis as a percentage of the yield for six treatments and their statistical significance.

Serial number	Treatment	Damage classification[a]						
		Skinning	Slight	Serious	Total	Total excluding skinning	Leavings[b]	Trash[b]
1	Manual, without devining	6.61b	4.82b	7.10b	18.53b	11.92b	9.15b	6.42bc
2	Manual, after devining	9.42b	3.23b	4.27b	16.92b	7.50b	10.52b	5.60c
3	Animal-drawn plow, after devining	6.37b	2.73b	4.12b	13.22b	6.85b	11.52b	6.50b
4	Tractor-drawn Zahle plow, after devining	5.78b	3.27b	3.73b	11.78b	6.00b	12.35ab	7.35b
5	Tractor-drawn furrow opener, after devining	6.15b	3.43b	3.15b	12.73b	6.58b	11.27b	5.15c
6	Mechanical potato harvester, without devining	29.68a	12.41a	13.53a	55.62a	25.94a	14.78a	10.95a

[a]The treatments with the same letter designation are not statistically different at the 1% level by Duncan's new multiple range test.
[b]5% level of significance.

tuber fall of less than 15.0 centimeters. Larsen (8) reduced the tuber damage of 38% by almost half, by using hard-skinned potato cultivar and by cushioning the separating mechanism of the harvester. The modification was especially effective for the stony soils where a combined effect of pebbles and their agitation, alongwith the tubers in the separating mechanism of the harvester, had aggravated the problem.

The mechanical harvester also exhibited significantly higher post-harvest leavings loss (Table 2; $P < 0.05$). It was 15% compared with about 12% left by the tractor-drawn furrow opener and the Zahle plow. An almost similar amount of loss occurred in the animal-drawn plow and the manual methods. Several earlier workers reported higher potato leavings in mechanical harvesting. For example, Rennie (9) observed 5 times more post-harvest leavings with the harvester than hand picking. Cox (2) also reported similar results.

The mechanical harvester picked up much higher trash with the tubers (Table 2; $P < 0.05$), being 11% compared with 5 to 7% by the other methods. The furrow opener collected less trash than the Zahle plow, animal-drawn plow and manual methods. The present results support the earlier findings of Rennie (9) reporting 3-fold higher trash collection by mechanical than other methods. French and Blake (6) also reported similar results and observed difficulties from higher trash during tuber storage.

The present studies indicate that the harvester under investigation was much inferior to the tractor-drawn implements being presently used for potato harvesting. The presence of stones in the Lebanese soils enhanced the tuber damage with the harvester. Since labour is very expensive in Lebanon, other harvesters with desirable modifications for stony soils should be tested. Until such a harvester is developed, the tractor-drawn furrow opener and the Zahle plow seemed to be preferable over the animal-drawn plow and the manual methods.

The production of potatoes per hectare in Libya is about one-third of that in Lebanon and labour costs are nearly 3 times as high. The harvesting of potatoes is still done by manual labor. The soil is generally sandy loam with few pebbles. A potato harvester with design identical to that reported in the studies may be useful especially if the separating mechanism is well cushioned. However, several types of potato harvesters suiting various soils and varietial conditions are now available. Their operational suitability and economic utility under various Libyan tracts should be examined. A project of these lines has recently been initiated at the Alfateh University, Tripoli, Libya.

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