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Observations of

Potato Harvesting Cost

BY HAND AND BY MACHINE

in the

Red River Valley

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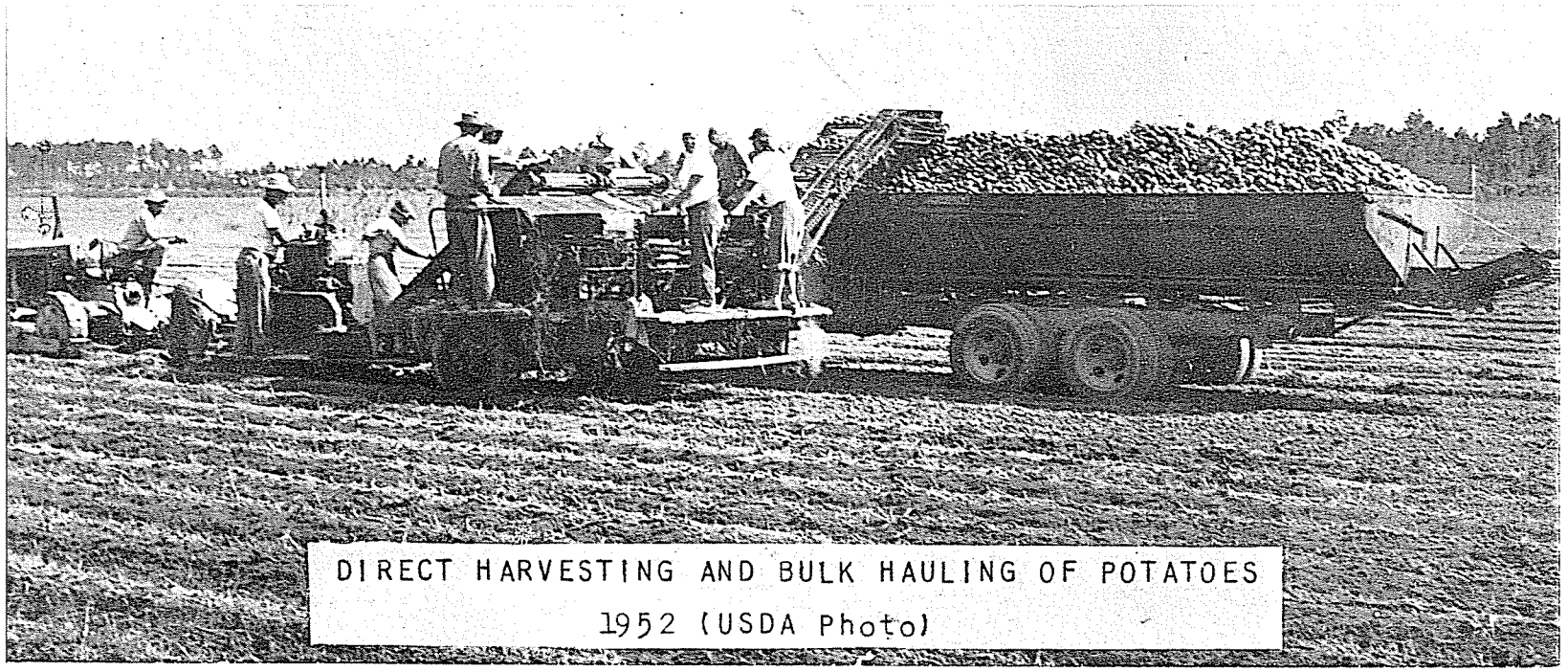

DIRECT HARVESTING AND BULK HAULING OF POTATOES
1952 (USDA Photo)

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OBSERVATIONS OF POTATO HARVESTING COST BY HAND AND BY MACHINE

By Lewis J. Downing,[1] Perry V. Hemphill[2] and Rainer Schickele[3]

INTRODUCTION

The machine method of harvesting potatoes has become prominent in the Red River Valley in recent years. Yet no published information has been available on the experience of farmers in the use of mechanical harvesters, especially with respect to costs. In order to bring together such information, the U. S. Department of Agriculture[4] with the cooperation of the North Dakota Agricultural College[5] made this study, to secure approximate costs of different potato-harvesting methods over a wide area of the Valley, during the 1952 harvesting season.

1/ Graduate student, University of Minnesota, was temporarily employed by the Bureau of Plant Industry, Soils, and Agricultural Engineering, USDA, while making this survey.

2/ Associate Agricultural Economist, NDAC.

3/ Principal Agricultural Economist, NDAC.

4/ Alfred D. Edgar, Senior Agricultural Engineer, located at the Red River Valley Potato Research Center, East Grand Forks, Minnesota, initiated the study on behalf of the Bureau of Plant Industry, Soils, and Agricultural Engineering, USDA. Wm. N. Garrott, Agricultural Economist, Bureau of Agricultural Economics, USDA, assisted in obtaining information from growers.

5/ H. W. Herbison, Extension Economist; Roy Gilcreast, BAE; and other members on the staff of the Department of Agricultural Economics, gave assistance in preparing the questionnaire and in the analysis and presentation of the information. Lyle W. Currie, Park River, Randell A. Johnson, Cavalier, William R. Page, Grand Forks, and R. L. Nelson, Hillsboro, County Extension agents, cooperated in the field survey.

It is a preliminary case study of the harvesting costs of a selected number of potato producers, some using the mechanical potato harvester by the "direct" method, where digging and picking are done in one operation, others using the harvester by the "indirect" method, where digging and picking are done in separate operations, and other producers using the hand picking method. It was not intended to be a conclusive and comprehensive study; in comparing costs of the three methods, the small sample did not permit arriving at statistically reliable figures of average costs for all Red River Valley potato growers. Instead, emphasis has been placed upon showing the range of the data. Even though the mechanical harvesting of potatoes is still in the experimental stage, this report should be useful to those who need to make decisions about potato harvesting. This preliminary survey has helped to ascertain the types of data needed to conduct a more intensive study of harvesting costs in the future.

The study was mainly concerned with differences in the costs of digging, picking, loading, and the labor costs of unloading. It did not measure the efficiency of the potato picking operations as related to the degree of bruising or percentage of usable potatoes that may have been left in the fields. The cost of special truck boxes used with mechanical harvesters was taken into account. All costs prior to the actual digging operation were excluded from the analysis. Truck hauling costs were not included, because they are approximately the same with the different harvesting methods. Supervisory costs were not included, because they were usually a non-cash item since the operator did most of the supervising.

METHOD OF SURVEY

A questionnaire was prepared relating to information needed to calculate comparative costs between hand picking, indirect mechanical harvesting, and direct mechanical harvesting. The information included the potato acreage harvested, soil type, yield per acre, method of harvesting, equipment cost (including depreciation and repairs) and labor costs (including wages and labor required to put potatoes into storage). In addition, other information was obtained, such as reasons for using each method, harvesting difficulties, rate of harvesting, and anything else that seemed relevant.

Information was obtained from 23 growers, selected with the help of Extension workers and others.[1] The growers were selected on the basis of their willingness and ability to give information, their experience with the different methods of harvesting, and their location. For each of the different methods of harvesting, growers with light, medium, and heavy soils were included. The 23 growers had potato acreages ranging from 60 to 730 acres (see Table 1). The total acreages of cropland ranged from 240 to 4,000 acres. The average acreage of potatoes was 287 and of cropland 1,236 acres. These growers are located on varying types of soil between the Canadian border and about 225 miles south, and from near the Red River to about 35 miles away from it, mostly on the North Dakota side. Seven of these growers hand picked all their

1/ Mr. Herbison, R. L. Nelson, Wm. Page, Lyle Currie, and Randell Johnson helped to select and interview growers.

"WINDROWING" POTATOES, PREPARATORY TO "INDIRECT" OR "PICKUP" HARVESTING,
Wm. Baldwin farm, St. Thomas, N. Dak.
1951 (USDA Photo)

INDIRECT, OR "PICKUP" HARVESTING, FROM WINDROW
1951 (USDA Photo)

acreage; 6 used the indirect harvesting method, and 10 used the direct harvesting method. Of the 16 who used mechanical harvesters, 8 hand picked part of their acreage. Table 1 gives the potato acreages and yields of the growers using each method.

Table 1. Potato Acreage and Yield, by Harvest Method

Method of Harvesting	Acres Harvested			Bushels per Acre			Number of Farms
	Average	High	Low	Average	High	Low	
Hand picking	246	730	100	232	260	150	7
Indirect machine	154	280	60	283	390	200	6
Direct machine	336	650	160	212	325	86	10

Growers were interviewed as they were completing their 1952 harvest or shortly after they had completed it. In most cases, between one and two hours was spent with each grower discussing his harvesting problems and getting specific information on his potato operations. Most of the information was based on estimates and memory. The interviewers did not examine the growers' records or accounts.

The average production of the growers who hand picked all their acreage is 50,500 bushels, as compared to an average of 42,800 bushels for the indirect machine-harvested crops and an average of 68,570 bushels for the direct harvested crops. So, the size of operations is comparable. See Table 2.

Table 2. Rates of Harvesting

Method of Harvesting	Average Production Bushels	Average Acres of Potatoes	Days to Complete Harvest	Bushels Harvested Daily		Acres Har. Daily	
				Per Farm	Per Machine	Per Farm	Per Machine
Hand Picking	50,500	246	12	4,200	--	18	--
Indirect Machine	42,800	154	18-1/2	2,700	2,300	10[1]	9
Direct machine	68,570	336	20	3,600	2,400	17[2]	12

The growers who hand picked completed their harvesting in 12 days on the average; the indirect machine method took 18.5 days, and the direct method 20 days. The machines used for direct harvesting were generally larger and more expensive.

1/ One operator used 2 machines.

2/ One operator used 3 machines and three operators used 2 machines.

COMPARATIVE COSTS OF HARVESTING

The total cost of harvesting each grower's crop was calculated by adding his labor and equipment costs (see Tables 10, 11, and 12 in the Appendix). The cost per bushel and per acre was obtained by dividing that total cost by the total number of bushels or acres harvested. See Tables 3 and 4.

Average costs per bushel were 15.1¢ for hand picking, 13.2¢ for indirect machine harvesting, and 10¢ for direct machine harvesting. Hence, the average cost per bushel of indirect harvesting was 80% of the cost of hand picking; with direct machine harvesting it was 66% of the cost of hand picking. The average cost of direct machine harvesting was 76% of the average cost of indirect machine harvesting.

There is considerable variation in the costs of growers using each of these methods. The costs of hand picking are more consistent and uniform than those of mechanical harvesting. As indicated by the "low" and "high" figures in Table 3, the costs per bushel vary, with hand picking from 13¢ to 18.1¢; with indirect harvesting, from 7.2¢ to 19¢, and with direct harvesting, from 6.7¢ to 16¢. Three growers who hand picked had lower costs per bushel than three who harvested indirect by machine, and lower than two others who harvested direct by machine.

Table 3. Comparative Harvesting Costs per Bushel

	Hand Picking	Indirect Machine	Direct Machine
Average, cents	15.1	13.2	9.9
Low, cents	13.0	7.2	6.7
High, cents	18.1	19.0	16.0
Average number of acres harvested	246	154	336
Average yield, bushels per acre	232	282	216

Frequency Distribution,

Costs per Bushel	Number of Farms		
6 to 8 cents	-	1	3
8 to 10 cents	-	1	3
10 to 12 cents	-	1	1
12 to 14 cents	2	-	1
14 to 16 cents	3	1	1
16 to 18 cents	1	1	1
18 to 20 cents	1	1	-
Total	7	6	10

Table 4. Comparative Harvesting Costs per Acre

	Hand Picking	Indirect Machine	Direct Machine
Average	$34.67	$36.08	$19.30
Low	24.81	17.98	14.95
High	45.32	48.70	23.58
Average number of acres harvested	246	154	336
Average yield, bushels per acre	232	282	216
Frequency Distribution,			
Costs per Acre	Number of Farms		
$13 to $17	-	-	3
$17 to $21	-	1	5
$21 to $25	1	-	1
$25 to $29	-	1	1
$29 to $33	1	-	-
$33 to $37	3	-	-
$37 to $41	1	2	-
$41 to $45	-	-	-
$45 to $49	1	2	-
Total	7	6	10

One grower who hand picked had a lower cost per acre than five of the six who used the indirect machine method; his cost per acre was lower than one of the ten growers who used the direct machine method. Six of the seven who hand picked had higher costs per acre than all the growers who used the direct method. Four of the six who used the indirect method had higher costs per acre than four of the seven who hand picked all their acreage.

It will be noted that the cost per acre with the indirect machine method is somewhat higher than with hand picking, as shown in Table 4. But those who hand picked had an average yield of 50 bushels per acre less than those who harvested by the indirect method. So, if those who hand picked had obtained a yield equal to those who used the indirect method, the cost of hand picking per acre would have been higher.

The variations in cost shown in Tables 3 and 4 indicate that various conditions determine when each method may be the most economical; the problem is to find out what those conditions are. Let us see how each grower's costs were built up. We can then make comparisons of the amount of labor and equipment cost that each grower had, per bushel and per acre, and the effect of acreage, yield, and soil type on per bushel costs. This information should be helpful to growers in deciding which method to employ.

Method of Calculating Grower's Costs

The elements of costs used in the calculation were labor, interest on harvesting equipment, depreciation and repair costs.

Labor was charged at the rates each farmer paid and according to his estimate of the amounts of labor hired.

Interest was calculated at 5% on half the original cost of the equipment (its average value). Some growers, for their own calculations, might have to use a higher rate of interest if they had to pay more than 5%.

Depreciation on mechanical harvesters is difficult to estimate. The machines are continually being improved in design. Obsolescence is a factor which could make the present machines worth very little in a short time. Most growers thought depreciation on these machines should be calculated at 20%; some thought 33-1/3%. To arrive at costs for this study, 20% of the original cost was charged as the annual depreciation.

Most growers considered that the conveyor-bottom truck boxes should be depreciated at a much lower rate. Average opinion on the length of life (including obsolescence) of these truck boxes was 12 years, making for an annual depreciation rate of 8-1/2% of original cost. This figure was used in these calculations. All growers using mechanical harvesters, except two, used conveyor-bottom truck boxes.

The grower's estimate of actual repair costs was used.

Costs of Hand Picking

The price paid for picking was the biggest factor causing variation in costs of hand harvesting. (See Table 3.) The three growers with the lowest cost paid 10¢ per picker bag; the others paid 12¢. Loading costs varied between 1¢ and 2.2¢ per bushel, averaging 1.7¢ per bushel. Unloading costs varied between 1¢ and 2¢, averaging 1.3¢ per bushel. The cost of picker bags and baskets varied between 0.3¢ and 2.2¢, averaging 0.8¢ per bushel.

When labor is available, hand picking seems to have an advantage, in that it is easier to add small units of cost (hand pickers) than a large unit of cost (an expensive machine). In addition, the cost of additional hand pickers applies only in the current year, when yields and prices are fairly well known. The cost of the machine must be spread over future years in which the need for the machine and the advantage of it are more uncertain. Eight of the 16 growers using mechanical harvesters hand picked part of their acreage, mainly because of soil difficulties.

Costs of Indirect Machine Harvesting

The grower with the lowest cost per bushel (7.3¢) had a low-priced machine and the largest total production of potatoes (see Table 7). His cost of machine pickers was low compared to the bushels handled; his soil is probably somewhat lighter (coarser in texture) than the average of the other growers who used the indirect method. The grower with the highest cost per bushel (19¢) had fixed costs (depreciation, interest and repairs) somewhat higher than the others, and a much smaller crop, resulting in a high cost per bushel. The grower with the next highest cost per bushel had high fixed costs as a result of using two machines. His soil is heavy and he had a lot of difficulty with clods. His labor cost for workers on the machine was the highest in the group. The growers with the second and third highest costs had heavy soil and a lot of trouble with clods. Their labor costs were more than 4¢ per bushel higher than the average (see Table 7).

The costs of indirect machine harvesting were higher than those of direct machine harvesting in this study, partly due to the additional cost of the separate digging operation with indirect method. In addition, however, it may be that some of those who used the indirect method did so because of clods. Those who used the indirect method hand picked 18% of their acreage. Those who used machine harvesters gave "too many clods" as the main reason for hand picking part of their acreage.

Cost of Direct Machine Harvesting

The grower with the lowest costs had the largest total production (see Table 7). He used low-priced machines. The growers with the second and third lowest costs per bushel each harvested a fairly large crop with a single machine. In each case their machine cost per bushel was slightly below the average, and their labor cost per bushel was almost 3¢ below average. Their soils were medium in texture. Their yields were 54 bushels per acre larger than the average yield of the other growers who harvested by the direct method.

The two growers with the highest costs per bushel had the lowest yields. Their soil was heavy and, with the low yields, their costs per bushel for labor were 2.7¢ and 3.4¢ above average. The low yield made the machine cost per bushel above average. Their costs per acre were lower than most of the others.

Four of the 10 direct-harvesting growers hand picked part of their acreage. Two growers hand picked 35 and 80 acres respectively, in order to finish sooner and avoid frost risk. One grower hand picked 60 acres because of a very light yield (30 bushels per acre) and he reported that it would have cost more to harvest mechanically. Another grower hand picked 250 acres because he believed the soil was too cloddy to harvest economically by machine.

Effect of Acreage and Yield on Per-Bushel Costs of Harvesting

Hand Harvesting

The growers with below-average costs had yields only slightly higher than the growers with above-average costs; i.e., 249 bushels per acre as compared with 221 bushels per acre. So, within this range of 150 and 260 bushels per acre, yield does not appear to have any significant effect on the cost of hand picking on these farms (see Table 5).

Growers with below-average costs had much smaller acreages: an average of 146 acres compared to 322 acres for those with above-average costs. The two growers with the highest costs per bushel had the biggest acreages.

Indirect and Direct Mechanical Harvesting

High yields are an important factor in reducing the per-bushel cost of mechanical harvesting. With direct machine harvesting, growers having yields of 200 bushels or more had harvesting costs ranging from 6.6¢ to 9.3¢ per bushel; growers with yields of less than 200 bushels had costs ranging from 10.9¢ to 16¢. With indirect machine harvesting, growers having above-average yields(305 bushels per acre) had harvesting costs ranging from 7.3¢ to 10.1¢ per bushel; growers having below-average yields (259 bushels per acre) had costs ranging from 15.5¢ to 19¢ per bushel. The effect of high yields on reducing the cost is not so evident with the growers using indirect harvesting. Growers with higher yields seemed to have heavier soils, which had more clods and therefore a higher labor cost per bushel (see Table 5).

Table 5. Effect of Acreage and Yield on Per-Bushel Costs of Harvesting

Grower No. and Method of Harvesting	Total Cost Per Bushel	Acres Harvested	Yield, Bushels Per Acre
	Cents		
Hand Picking			
2	13.0	100	257
3	13.2	152	230
4	14.0	185	260
7	15.5	200	250
6	15.7	100	225
5	16.6	730	150
1	18.0	260	250
Average	15.1		
Indirect Machine			
8	7.3	280	250
13	9.6	76	390
10	10.1	110	275
11	15.5	160	300
12	17.5	240	278
9	19.0	60	200
Average	13.2		
Direct Machine			
15	6.6	650	225
20	6.7	200	270
23	6.7	200	270
14	8.0	300	250
24	8.4	275	325
16	9.3	500	250
17	10.9	160	185
18	12.1	190	190
21	14.6	640	106
22	16.0	250	86
Average	9.9		

Analysis of Machine Cost Alone

Direct Machine Harvesting

The machine cost per bushel (including depreciation, interest and repairs on truck boxes and harvesters) with direct harvesting ranged from 1.6¢ to 6.4¢ (see Table 6). The average was 3.4¢. The growers with machine costs below average had an average production of 90,800 bushels in 1952; the growers with machine costs above average had an average production of 39,175 bushels.

Indirect Machine Harvesting

The growers who harvested by indirect mechanical harvester had an average machine cost per bushel of 3.9¢ (not including the digger); this is a half cent higher than the average machine cost with direct machine harvesting, because the growers who used the direct method harvested more bushels per machine. Growers with machine costs below average had an average production of 44,472 bushels; growers with machine costs above average had an average production of 39,250 bushels (see Table 6). The effect of the number of bushels harvested by the indirect method is not as pronounced as with those using the direct method, because of factors other than production.

Table 6. Effect of Number of Bushels Harvested on Machine Cost per Bushel

Grower No. and Harvesting Method	Original Machine Cost 1/	Annual Fixed Machine Cost per Bushel	Total Number of Bushels Harvested
		Cents	
Indirect Machine			
8	$1,300	1.2	70,000
11	1,900	1.9	48,000
13	2,100	2.5	29,640
10	2,500	3.6	30,250
12	3,900	4.3	66,700
9	2,800	10.0	12,000
Average		3.9	
Direct Machine			
16	$2,000	1.6	110,000
15	2,500	1.8	146,000
24	5,000	2.6	90,000
23	4,830	3.0	54,000
20	5,000	3.2	54,000
14	3,600	3.4	75,000
18	4,000	3.8	37,000
21	4,500	4.1	68,200
17	3,300	4.2	30,000
22	4,200	6.4	21,500
Average		3.4	

1/ In those cases where more than one machine was used the average cost is given.

A BRIEF REVIEW OF SOME OF THE EXPERIENCES AND OPINIONS

Hand-Picking Growers

All the growers in this study who hand picked their crop consider using a mechanical harvester in the future. One grower started with a mechanical harvester but went back to hand picking because the machine could not harvest fast enough in his heavy soil with a lot of clods. Four growers thought that the machines were not developed enough yet and that depreciation on the machines would be too heavy in the next year or two because of obsolescence. They felt this was particularly true with growers having 100 acres or less. One grower thought that with a particularly valuable crop it was safer to harvest by hand picking than to take a chance with the relatively unproved machine harvesting method. Another grower used a machine in previous years but, because of many clods and weeds, did not use it this year. He planned on redesigning his homemade machine for use next year.

One grower used the pallet (boxes holding 38 bushels each) system of handling potatoes. Each pallet cost $11.50 including labor, and the fork-lift truck to handle the pallets cost $5,100. But he reported that this system of handling has resulted in substantial advantages because of improved potato quality, as compared to potatoes stored in large bulk bins. He thinks this system is definitely the best for preserving potato quality. And it requires less labor at the warehouse at harvest time. Last year the pallets were mounted on trailers and filled directly from the harvester in the field; the trailers were pulled to the warehouse. This year the pallets were filled at the warehouse by emptying the bags into them.[1]

Indirect and Direct Machine Harvesters

These growers gave three main reasons for using mechanical harvesters:

(1) The cost of harvesting is lower unless the soil is very cloddy, the yield is very low, or the acreage is small.

(2) Labor for hand picking is sometimes hard to get and unreliable.

(3) The quality of the potatoes can be protected better with the mechanical harvester.

One grower said that a good stand of clover, which he plowed down, did not seem to help with the clodding problem. Another grower thought that plowing down clover helps to prevent clods. He could see no difference in cloddiness between land that was summerfallowed the previous year and land that was in crop the previous year, but he thought the summerfallow land would average one-third more in yield.

1/ Mr. A. D. Edgar of the East Grand Forks Potato Research Center reports that time and operation cost studies were made of the operations of one large grower who had had several years' experience in harvesting and storing potatoes and onions in 40-bushel palletized boxes. This study was made in Iowa as an addition to the Red River Valley study for the purpose of getting some idea, although not exactly comparable information upon this harvesting, handling and storage method. Including the cost of the warehouse handling equipment on the same basis as the field machinery and the palletized handling and storage boxes depreciated 10 percent a year, the overall harvesting and handling costs were 13¢ per bushel.

One grower did part of the clod removal at the warehouse. When workers were not busy picking clods they were put at other work.

This grower used grain-type truck boxes with a hoist. A conveyor was hooked across the back of the truck for unloading. This method was considered quite satisfactory. It was cheaper and made the trucks more easily available for other uses.

Another grower harvested 60 acres by hand picking because the yield on it was very light and spotty -- only 30 bushels per acre, due to flooding. It cost 30¢ per picker bag for the picking (not including loading, etc.), but it was considered cheaper than using a machine for such a light yield.

A number of growers expressed the opinion that potato harvesting should be completed by October 15th. One grower thought that not more than 125 acres should be planned for one machine. Several believed that 175 to 200 acres was the maximum acreage that should be planned for one machine. In lighter soils a larger acreage could be harvested. The average acreage harvested with one machine was 132 acres with indirect machine harvesting and 212 acres with direct harvesting. The machines that were used direct were larger and cost more. (See Tables 11 and 12).

HOW MUCH CROP WILL JUSTIFY PURCHASE OF A MACHINE?

A mechanical harvester has a high original cost. There is a considerable annual fixed cost to be borne no matter how large or small the crop, due to depreciation (including obsolescence), interest and repairs.

According to grower estimates, the annual fixed cost of a mechanical harvester is seldom less than 30% of the original cost and could easily be higher. This means an annual fixed cost of $600 to $1500 or more. If potatoes can be hand picked, loaded and unloaded, for 13¢ to 18¢ per bushel, it is obvious that the fixed cost of a mechanical harvester must be spread over a considerable number of bushels, otherwise hand picking would be cheaper.

The minimum amount of crop, in bushels, which is necessary to justify the purchase of a machine is not easy to determine. It will vary, depending on different circumstances, with individual farms; for instance: (1) availability and cost of labor for hand picking in the local area, (2) cost of machine and equipment, (3) amount of cloddiness expected, (4) number and cost of machine pickers and other operating costs, and (5) estimated loss or gain in quality of potatoes when hand picked as compared to machine harvesting.

A formula may be useful in estimating the minimum crop which will justify purchasing a machine: the minimum number of bushels per year necessary (X) equals .3(times original cost of machine (M) divided by the cost of hand picking per bushel (H) minus probable operating cost per bushel for labor, tractor, etc. (O) of machine method. This simple thumb rule looks like this:

Bushels necessary to justify machine harvesting

$$(X) = \frac{\text{30\% of original machine cost } (0.3M)}{(H) - (O)}$$

(H) Hand picking cost per bushel

(O) Operating cost per bushel with machine

This means that, when the bushels to be harvested are more than the number of times the labor savings per bushel (H-D) go into the annual fixed cost of the machine (M) the machine use is cheaper than hand picking. The reasoning is: if the annual fixed cost of the machinery investment is less than the difference in operating cost between hand picking and machine harvesting, the latter is more profitable. Since the operating costs vary in proportion to the size of crop harvested while the fixed machinery cost does not, there must be some volume of potatoes below which hand picking is cheaper and above which machine harvesting is cheaper. The above formula might help in roughly estimating where that point is likely to be.

Some growers would use a higher figure for the annual fixed cost of a machine than the 30% used in the above formula. If depreciation were figured at 33% instead of 20% the annual fixed cost including interest and repairs would amount to about 40%, or .4 times original cost of machine. Since each grower may have different operating costs per bushel, depending on soil type, kind of machine used, and so on, he would have to estimate the operating cost per bushel under his conditions for hand picking and machine harvesting before he could use the formula. The tables in the Appendix may help him in estimating these figures. By adding the per-bushel figures for labor and tractor costs on Appendix Table 7, operating costs per bushel can be obtained for each grower. The average cost per bushel is 6.4¢ for labor and 0.6¢ for the tractor, a total average operating cost of 7¢ per bushel for all the growers who used mechanical harvesters. The average cost of hand picking was 15.1¢ per bushel.

Each grower should use whatever figure would be closest to his actual cost of hand picking; it wouod probably differ from the average shown in this survey. Assume that a $4,000 harvester is being considered. If costs of operating and hand picking are estimated at the average in our survey, the calculations would be as follows:

The general formula is

$$X = \frac{0.3M}{H - O}$$

M= original machine cost, $4,000 in our example

H= hand picking cost per bushel, $0.151 in this case

O= operating cost under machine method (labor + tractor cost) per bushel, $0.07 in this case

Under these conditions, the minimum number of bushels justifying machine harvesting would be

$$X = \frac{0.3 \times \$4,000}{\$0.151 - \$0.070}$$

$$X = \frac{1,200}{0.081} = 14,815 \text{ bushels}$$

With an expected yield of 150 bushels, this would require $\frac{14,815}{150}$ = 98 acres.

With an expected yield of 200 bushels, this would require $\frac{14,815}{200}$ = 74 acres.

With an expected yield of 250 bushels this would require $\frac{14,815}{250}$ = 59 acres.

If it is thought that mechanical harvesting would cause less damage to the potatoes to the extent of 10¢ per bushel, for example, that could be included in the formula as follows:

$$X = \frac{0.3 \times 4,000}{0.151 + 0.100 - 0.07}$$

$$X = \frac{1,200}{0.181} = \underline{6,630 \text{ bushels}}$$

With an expected yield of 200 bushels per acre, this would require 33 acres to justify the purchase of the machine.

The following table shows the results when applying this formula using the lowest, average, and highest operating costs as found in our survey. The same hand picking cost and the same annual fixed machine cost are used in each case. The figures shown in the table do not take into account any effect that the machine might have on potato quality, and trucking costs are not included in operating costs.

Minimum Number of Bushels and Acres Necessary to Justify Machine Harvesting, with Low, Average, and High Operating Costs

Estimated Operating Cost (labor & tractor)	Original Cost of Harvester	Estimated Cost of Hand Picking	Minimum Number of Bushels	Minimum Number of Acres at 200 bu. per ac.
Low: 4¢ per bu.	$4,000	15.1¢ per bu.	10,811	54
Average: 7¢ per bu.	$4,000	15.1¢ per bu.	14,815	74
High: 10¢ per bu.	$4,000	15.1¢ per bu.	23,529	118

One grower with high yields thought it would pay to have a mechanical harvester for as little as 35 acres. The above figures suggest that it could pay under some conditions for less than 35 acres, but under other conditions it might require even more than 100 acres.

The average acreage harvested with one machine in our survey was 132 acres with indirect harvesting and 212 acres with direct harvesting. One grower harvested only 76 acres, with a 390-bushel yield, by indirect machine method at a cost of only 9.6¢ per bushel, much lower than the average of 15.1¢ for hand picking. On the other hand, another grower harvested 60 acres with a 200-bushel yield by indirect machine method at the high cost of 19¢ per bushel. Among the growers using the direct machine method, only one had a cost higher than the average hand picking cost, and that is largely accounted for by the low yield of 86 bushels on 250 acres.

The more detailed tables in the following appendix are presented in the hope that Red River Valley potato growers will find many helpful data that will make it possible for any individual grower to orient himself as to the various cost elements and other factors determining whether it is more profitable to harvest potatoes by hand or by machine.

We should keep in mind, however, that technology is changing fast. Potato harvesters are being improved every year. In a few years these data may easily be out of date. Then we shall conduct a similar study. Plans are being made for a more comprehensive survey of harvesting costs in the near future. The present preliminary survey will serve as a guide in developing such a more intensive study.

In the meantime, the authors invite every potato grower to send his comments or criticisms of this report or any observations that might be useful in this field, so that we can benefit from the grower's experience when we get ready for a more comprehensive study a few years hence. Please address your comments to Prof. Perry V. Hemphill, Dept. of Agricultural Economics, State College Station, Fargo, N. Dak.

APPENDIX

Table 7. Harvesting Costs per Bushel (Digging, Machinery, Labor, Bags)

Grower No. and Method of Harvesting	Total Bushels Harvested	Digging Cost per Bushel	Machine Cost per Bushel	Tractor Pulling Harvester per Bushel	Labor Cost per Bushel	Picker Bags & Baskets per Bushel	Total Cost per Bushel
		Cents	Cents	Cents	Cents	Cents	Cents
Hand Picking							
2	25,700	1.6	-	-	10.5	0.9	13.0
3	35,000	1.7	-	-	10.6	0.9	13.2
4	46,000	1.6	-	-	11.8	0.6	14.0
7	50,000	1.6	-	-	13.3	0.6	15.5
6	22,500	1.8	-	-	13.6	0.3	15.7
5	109,500	2.7	-	-	13.6	0.3	16.6
1	65,000	1.6	-	-	14.2	2.2	18.0
Average 1/		1.8	-	-	12.5	0.8	15.1
Range 2/		1.1	-	-	3.7	1.9	5.0
Indirect Machine							
8	70,000	1.6	1.2	0.5	4.0	-	7.3
13	29,640	1.0	2.5	0.5	5.6	-	9.6
10	30,250	1.5	3.6	0.5	4.5	-	10.1
11	48,000	1.3	1.9	0.6	11.7	-	15.5
12	66,700	1.4	4.3	0.6	11.2	-	17.5
9	12,000	2.0	10.0	0.6	6.4	-	19.0
Average 1/		1.5	3.9	0.6	7.2	-	13.2
Range 2/		1.0	8.8	0.1	7.7	-	11.7
Direct Machine							
15	146,000	-	1.8	0.5	4.3	-	6.6
20	54,000	-	3.2	0.3	3.2	-	6.7
23	54,000	-	3.0	0.5	3.2	-	6.7
14	75,000	-	3.4	0.2	4.4	-	8.0
24	90,000	-	2.6	0.5	5.3	-	8.4
16	110,000	-	1.6	0.6	7.1	-	9.3
17	30,000	-	4.2	0.5	6.2	-	10.9
18	37,000	-	3.8	0.6	7.7	-	12.1
21	68,200	-	4.1	1.1	9.4	-	14.6
22	21,500	-	6.4	0.9	8.7	-	16.0
Average 1/			3.4	0.6	6.0	-	9.9
Range 2/			4.8	0.9	6.2	-	9.4

1/ Unweighted averages.

2/ Absolute difference between the lowest and the highest cost figure.

Table 8. Harvesting Costs per Acre (Digging, Machinery, Labor, Bags)

Grower No. and Method of Harvesting	Total Acres	Digging Cost per Acre	Machine Cost per Acre	Tractor Pulling Harvester per Acre	Labor Cost per Acre	Picker Bags & Baskets per Acre	Total Cost per Acre	Soil Type
Hand Picking								
5	730	$4.00	-	-	$20.36	$0.46	$24.82	Medium
3	152	4.00	-	-	24.34	2.17	30.51	Medium
2	100	4.00	-	-	27.03	2.28	33.31	Light
4	185	4.00	-	-	29.26	1.50	34.76	Medium
6	100	4.00	-	-	30.64	0.74	35.38	Medium
7	200	4.00	-	-	33.16	1.44	38.60	Medium
1	260	4.00	-	-	35.71	5.61	45.32	Heavy
Average 1/		4.00			28.64	2.03	34.67	
Range 2/					15.35	5.15	20.50	
Indirect Machine								
8	280	4.00	$2.89	$1.21	9.89	-	17.99	Light
10	110	4.00	9.85	1.25	12.32	-	27.42	Medium
13	76	4.00	9.80	1.97	21.71	-	37.48	Heavy
9	60	4.00	20.08	1.25	12.75	-	38.08	Heavy
11	160	4.00	5.73	1.95	35.15	-	46.83	Heavy
12	240	4.00	11.88	1.56	31.25	-	48.69	Heavy
Average 1/		4.00	10.04	1.53	20.51		36.08	
Range 2/			17.19	0.76	25.26		30.70	
Direct Machine								
22	250	-	5.54	0.75	7.50	-	13.79	Heavy
15	650	-	4.15	1.15	9.65	-	14.95	Heavy
21	640	-	4.42	1.21	10.05	-	15.68	Heavy
20	200	-	8.57	0.88	8.72	-	18.17	Medium
23	200	-	8.23	1.25	8.75	-	18.23	Medium
14	300	-	8.44	0.63	11.00	-	20.07	Medium
16	500	-	3.46	1.30	15.60	-	20.36	Heavy
17	160	-	7.95	0.94	11.62	-	20.51	Medium
18	190	-	7.33	1.25	15.00	-	23.58	Light
24	275	-	8.54	1.59	17.50	-	27.63	Heavy
Average 1/			6.66	1.10	11.54	-	19.30	
Range 2/			5.11	0.96	10.00		13.84	

1/ Unweighted averages.

2/ Absolute difference between lowest and highest cost figure.

Table 9. Components of Costs, by Harvest Method

Method of Harvesting	LABOR Average Variation*	MACHINE Average Variation	DIGGING Average Variation	TRACTOR PULLING Average Variation	PICKER BAGS Average Variation	TOTAL COST Average Variation
			COST PER BUSHEL			
	Cents	Cents	Cents	Cents	Cents	Cents
Hand Pick	12.5	-	2.6	-	0.8	15.1
Low	-2.0	-	-	-	-0.5	-2.1
High	+1.7	-	-	-	+1.4	+2.9
Ind. Mach.	7.2	3.9	1.5	0.6	-	13.2
Low	-3.2	-2.7	-0.5	-	-	-5.9
High	+4.5	+6.1	+0.5	-	+	+5.8
Dir. Mach.	6.0	3.4	-	0.6	-	9.9
Low	-2.8	-1.8	-	-0.4	-	-3.3
High	+3.4	+3.0	-	+0.5	-	+6.1
			COST PER ACRE			
	Dollars	Dollars	Dollars	Dollars	Dollars	Dollars
Hand Pick	28.64	-	4.00	-	2.03	34.67
Low	-8.28	-	-	-	-1.57	-9.85
High	+7.07	-	-	-	+3.58	+10.65
Ind. Mach.	20.51	10.04	4.00	1.53	-	36.08
Low	-10.62	-7.15	-	-0.32	-	-18.09
High	+14.64	+10.04	-	+0.44	-	+12.61
Dir. Mach.	11.54	6.66	-	1.10	-	19.30
Low	-4.04	-3.20	-	-0.47	-	-5.51
High	+5.96	+191	-	+0.49	-	+8.33

* Above average indicated by +
Below average indicated by -

Table 10. Costs of Harvesting by HAND PICKING Entire Crop

	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	Average
Acres harvested	260	100	152	185	730	100	200	246
Bushels harvested	65,000	25,700	35,000	46,000	109,500	22,500	50,000	50,500
Yield, bushels per acre	250	257	230	260	150	225	250	232
Hours spent harvesting	127	50	140	140	121	90	170	120
Days spent harvesting 1/	13	5	14	14	12	9	17	12
Number of pickers	53	27	14	26	110	20	25	39
Number of unloaders	8	4	2	3	8	2	3	4.3
Costs								
Digging	$1,040	$ 400	$ 608	$ 740	$ 2,920	$ 400	$ 800	-
Picking	6,685	2,203	3,000	3,943	11,262	2,314	5,143	-
Loading	1,300	250	350	840	2,160	500	850	-
Unloading	1,300	250	350	630	1,440	250	638	-
Picker bags & baskets	1,460	228	330	280	335	74	288	-
Total cost, dollars	11,785	3,331	4,638	6,433	18,117	3,538	7,719	-
Cost per acre, dollars	45.32	33.31	30.51	34.76	24.82	35.38	38.60	34.67
Cost per bushel, cents	18.0	13.0	13.2	14.0	16.6	15.7	15.5	15.1

1/ On basis of 10-hour day.

NOTE: A uniform charge of $4 per acre was made for digging. This may be rather conservative. Tractors were charged at a uniform rate of $1.25 per hour. The above figures do NOT include men driving trucks or trucking costs. Excluding trucks and trucking costs, the range in per-acre costs is from $24.82 to $45.32. The range in per-bushel costs is from 13¢ to 18¢.

Table 11. Costs of INDIRECT MACHINE Harvesting

	No. 8	No. 9	No. 10	No. 11	No. 12	No. 13	Average
Acres harvested by machine	280	60	110	160	240	76	154
Acres harvested by hand	-	-	90	70	26	27	-
Bushels harvested by machine	70,000	12,000	30,250	48,000	66,700	29,640	42,800
Yield, bushels per acre	250	200	275	300	278	390	282
Days spent harvesting 1/	27	6	11	25	30	12	18-1/2
Number of machine pickers	7	8	5	9	12	6	8
Number of unloaders	1	1	3	7	4	3	3
Costs							
Digging	$ 1,120	$ 240	$ 440	$ 640	$ 960	$ 304	-
Depreciation on harv. machine at 20% of original cost	260	560	500	380	1,560	420	-
Interest on harv. machine at 5% on half original cost	32	70	125	95	195	58	-
Repairs on harvesting machine	200	350	200	200	700	100	-
Tractor for pulling harvester	338	75	138	312	375	150	-
Truck boxes: depreciation	180	100 *	125	112	208	79	-
interest	38	25 *	38	34	62	24	-
repairs	100	100 *	96	96	128	64	-
Machine pickers	1,890	480	605	2,812	4,500	900	-
Tractor operator	270	75	150	312	750	150	-
Machine operator	338	150	150	312	750	150	-
Unloaders	270	60	450	2,188	1,500	450	-
Total cost, dollars	5,036	2,285	3,017	7,493	11,688	2,849	-
Cost per acre, dollars	17.99	38.08	27.42	46.83	48.69	37.48	36.08
Cost per bushel, cents	7.3	19.0	10.1	15.5	17.5	9.6	13.2

1/ On basis of 10-hour day. * These are estimates.

NOTE: A uniform charge of $4 per acre was made for digging. This may be rather conservative. Tractors were charged at a uniform rate of $1.25 per hour. The above figures do NOT include men driving trucks or trucking costs. Excluding trucks and trucking costs, the range in per-acre costs is from $17.99 to $48.69; the range in per-bushel costs is from 7.3¢ to 19¢.

Table 12. Costs of DIRECT MACHINE Harvesting

	No. 14	No. 15	No. 16	No. 17	No. 18	No. 20	No. 21	No. 22	No. 23	No. 24	Average
Acres harvested by machine	300	650	500	160	190	200*	640*	250*	200*	275	336
Bushels harv. by machine	75,000	146,000	110,000	30,000	37,000	54,000	68,200	21,500	54,000	90,000	68,570
Yield, bushels per acre	250	225	250	185	190	270	106	86	270	325	216
Days spent harvesting 1/	15	20	26	12	19	17	31	15	20	25	20
Number of machine pickers	16	12	14	8	7	3	9	6	3	7	8
Number of unloaders	2	12	6	2	3	3	5	4	2	3	4
Costs											
Depreciation on harvesting machine (at 20% of cost)	$1,440	$1,500	$ 800	$ 660	$ 800	$1,000	$1,550	$ 840	$ 966	$1,380	-
Interest (5% on 1/2 original cost)	180	188	100	82	100	125	194	105	212	190	-
Repairs on harvesting machine	400	732	400	244	300	250	600	150	300	488	-
Tractor for pulling harvester	188	750	650	150	238	175	775	188	250	438	-
Truck boxes: depreciation	250	125	208	146	75	162	250	150	125	150	-
interest	70	30	62	44	22	48	75	45	38	45	-
repairs	192	125	160	96	96	128	160	96	96	96	-
Machine pickers	2,400	2,400	4,550	1,200	1,662	638	3,488	1,125	750	3,062	-
Tractor operator	300	750	650	180	238	212	620	188	250	438	-
Machine operator	300	720	650	180	238	255	775	188	250	438	-
Unloaders	300	2,400	1,950	300	712	638	1,550	375	500	875	-
Total cost, dollars	6,020	9,720	10,180	3,282	4,481	3,631	10,037	3,450	3,646	7,600	
Cost per acre, dollars	20.07	14.75	20.36	20.51	23.58	18.17	15.68	13.79	18.23	27.68	19.30
Cost per bushel, cents	8.0	6.6	9.3	10.9	12.1	6.7	14.6	16.0	6.7	8.4	9.9

1/ Based on a 10-hour day.

* Growers No. 20, 21, 22, and 23 did some hand picking in addition to the acres machine harvested.

NOTE: Tractors were charged at a uniform rate of $1.25 per hour. The above figures do NOT include men driving trucks or trucking costs. Excluding trucks and trucking costs, the range in per-acre costs is from $13.79 to $27.68; the range in per-bushel costs is from 6.6¢ to 16¢.