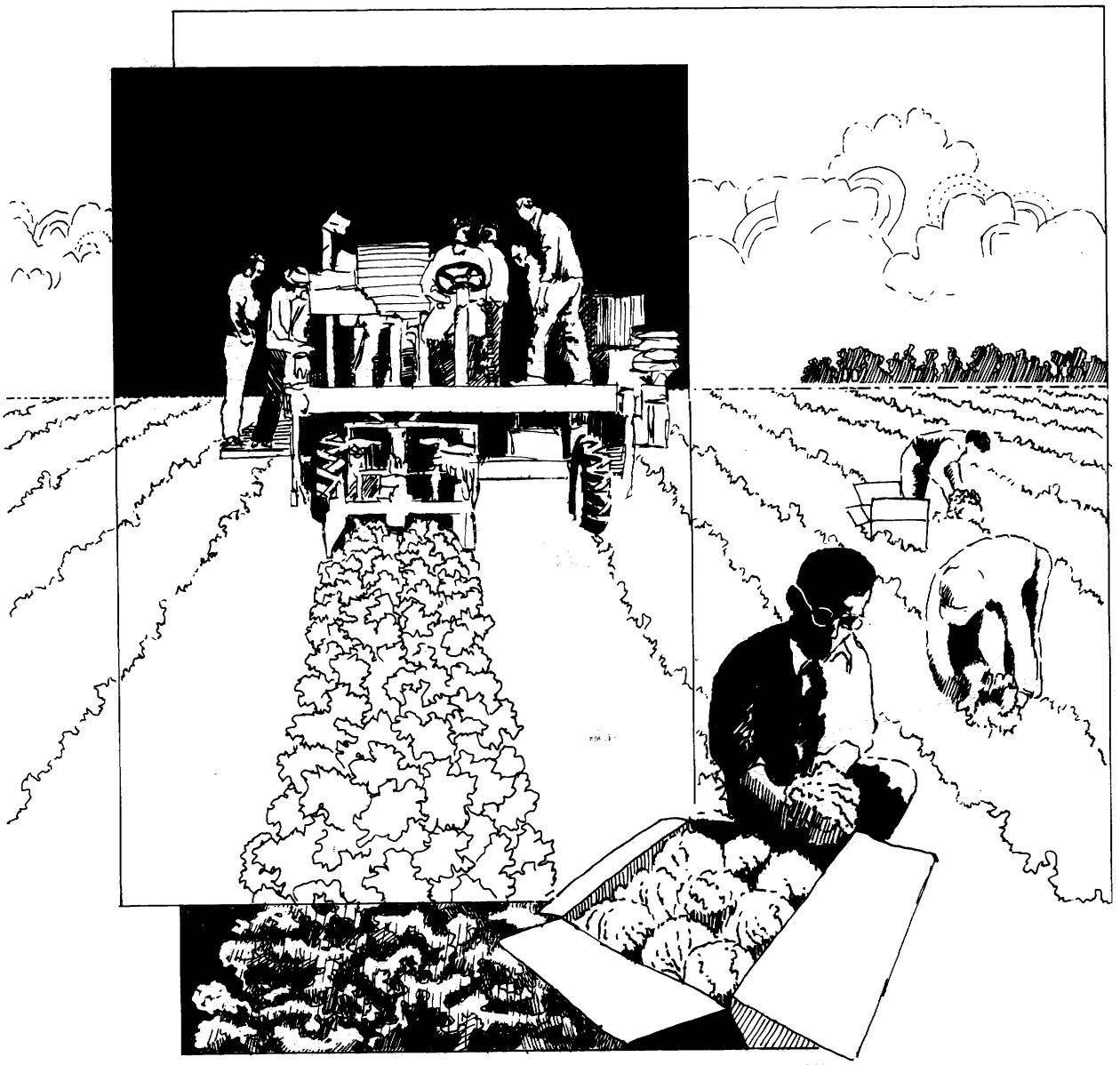
Mechanical Harvesting and Packing of Iceberg Lettuce



U.S. Department of Agriculture/Economic Research Service/Agricultural Economic Report No. 357

MECHANICAL HARVESTING AND PACKING OF ICEBERG LETTUCE. By Stanley S. Johnson and Mike Zahara, Commodity Economics Division, Economic Research Service, U.S. Department of Agriculture. Agricultural Economic Report No. 357.

ABSTRACT

This report describes the operations and costs of existing and alternative mechanized lettuce harvesting systems. For mechanization, the immediate prospect is to substitute a harvest machine for the workers who select, cut, and trim the lettuce. Mechanizing the packing and wrapping operations is also possible.

Analysis of the cost data indicates that the existing hand-cut, pack-in-the-field system is efficient compared with previous hand-cut methods and is slightly higher in cost compared with machine-cut systems. A ranking of harvest costs places the hand-cut system highest, followed by machine systems involving packing either on the machine or at a shed. Output per worker was increased from nearly 15 to 20 cartons per man-hour by replacing hand selecting and cutting with packing on the machine.

Keywords: Harvesting, iceberg lettuce, labor, mechanization.

CONTENTS

	Page
SUMMARY	iii
INTRODUCTION	1
Objectives and Procedures	2
Related Studies	2
Assumptions	3
ALTERNATIVE LETTUCE HARVESTING SYSTEMS	4
COSTS OF ALTERNATIVE HARVESTING SYSTEMS	8
Variable Costs of Operation	8
Fixed Costs of Operation	11
COMPARISON OF THE ALTERNATIVE HARVESTING SYSTEMS	11
Productivity Comparisons	12
Comparison of Costs for All Systems	15
IMPLICATIONS OF ADOPTING THE HARVEST MACHINE	21
Rate of Machine Adoption	21
Capital Investment	22
Effect on Labor	22
Summary of Mechanization Potential	25
BIBLIOGRAPHY	26
APPENDIX TABLES	28

SUMMARY

Costs of harvesting iceberg lettuce under existing hand-cut systems are not greatly higher than preliminary, estimated costs for mechanical-harvesting systems.

Presently, there are two hand-cut systems of harvesting and packing lettuce. One is the regular, or "naked pack," system, in which the lettuce is not wrapped (it is also termed the hand-cut, ground-pack--or "regular pack"--system). The other system, which uses a mechanical aid, is called the hand-cut, film-wrap system.

This report compares the costs and productivity of these systems with the costs and productivity of existing and alternative mechanical-harvesting systems. The mechanical-harvesting systems are (1) a machine system involving packing on the machine; (2) machine systems for harvesting the lettuce but with packing being done at fieldside or central sheds for both regular and film-wrap packs; and (3) other machine systems using new methods.

Analysis of 1975 cost data indicates that the hand-cut, ground-pack system is efficient compared with previous hand-cut systems, and only slightly higher in cost than the machine-cut systems. Output per worker increased from about 15 cartons per hour under the hand-cut, ground-pack system to 20 cartons under the machine-cut, pack-on-machine system.

A ranking of harvesting costs places the hand-cut, ground-pack system first at $1.40 per carton. Machine-harvesting systems involving packing ranged from $1.20 per carton for the pack-on-machine system to $1.25 per carton for the central-shed packing system. The machine-cut, bulk-load system had harvesting costs estimated at $1.20 per carton.

Under all of the hand-cut and mechanical-harvesting systems, harvesting costs for wrapping lettuce with film were greater than those for the regular pack because of higher costs and added wages and equipment. Film-wrap harvesting costs are roughly similar for hand cutting ($2.05 per carton) and the two shed wrapping systems ($2.01 for the fieldside shed and $2.07 for the central shed). However, productivity was about 50 percent greater under the machine-cut systems.

An alternative to conventional wrapping is use of machine systems for "tube-and-cube" packaging. Although this system is still experimental, estimated harvesting costs of $1.65 per carton are considerably lower than costs for the other wrapping methods.

Capital requirements of new systems can be high, especially if new permanent sheds are to be constructed. Per carton investment costs for systems that wrap lettuce already are high, so a change from the hand-cut, film-wrap system to a machine-cut system will not greatly increase initial investment requirements.

The analysis indicates that a 25-percent adoption rate of the specified machine-cut systems would result in a 7.8-percent decrease in full-time jobs. The rate of job displacement in mechanizing the film-wrap harvesting system is estimated to be twice the rate for mechanizing naked-pack systems. Job skill requirements would still be high under the mechanized systems, and the work amelioration should open up jobs to women and older men. Wages are relatively high for most existing job positions in lettuce harvesting because of piece rate incentives; no estimate can be made of future worker incomes.

Washington, D. C. 20250 January 1977

MECHANICAL HARVESTING AND PACKING OF ICEBERG LETTUCE

by

Stanley S. Johnson and Mike Zahara 1/

INTRODUCTION

Agriculture is faced with rising costs of production and marketing. Means are being sought to counteract these cost increases in the iceberg lettuce industry by increasing efficiency. One possible way of improving efficiency is in capital-labor substitution, principally by mechanization of the harvesting operation.

An interdisciplinary study is underway involving the U.S. Department of Agriculture and the University of California to assess the feasibility of mechanizing the lettuce harvest. A prototype machine has been built which can select, cut, and trim the lettuce head. Beyond this stage, further development alternatives still exist. The objective of the interdisciplinary research team is to develop and analyze these alternative handling systems. Stages in handling lettuce from harvesting to retail, and some possible alternatives, are shown below:

Harvesting method	Packing method	Packing containers
Hand select - cut - trim Machine select - cut - trim	Pack with wrapper leaves Pack with film wrap No pack: random fill containers	Various sizes of containers possible

Packing location	Prepare for transport	Transport
Pack in field on ground Pack in field on machine Pack away from field at fieldside or central shed	Vacuum cool, using fixed or portable tubes	Rail or truck

Wholesale market	Retail market
Build or not build handling facilities to repack bulk lettuce	Prepackaged lettuce, or trim wrapper leaves

1/ The authors are agricultural economists with the Commodity Economics Division, Economic Research Service, University of California at Davis.

Objectives and Procedures

Before new handling procedures are devised, the costs of present systems need to be compared. This report describes existing lettuce harvesting practices and contrasts them with possible alternative practices using the mechanical harvester. Two of the alternatives are currently in use: the hand-cut, ground-pack method, and the hand-cut, film-wrapped method using a mechanical aid. These are the only hand-cut alternatives examined. For an older practice, packing lettuce in a shed away from the field, operating costs have been calculated using 1975 costs, but assuming mechanical harvesting. New operations for which procedures and costs are estimated involve mechanical harvesting with options to pack on the machine in either conventional cartons or bulk containers. The alternatives considered are outlined below:

REGULAR (NAKED) PACK

Present system:
(1) hand-cut, ground-pack

Machine cut:
(2) packed on machine
(3) packed off the machine at fieldside shed
(4) packed off the machine at central shed
(5) not packed (bulk loaded)

FILM-WRAPPED PACK

Present system:
(1) hand-cut, packed and wrapped with machine aid

Machine cut:
(2) packed off the machine at fieldside shed
(3) packed off the machine at central shed
(4) bulk-packed on the machine (tube-and-cube)

For each alternative practice considered, the system is described and output and costs are estimated. Total costs per carton or per container are presented. Finally, comparisons are made between practices; and the effects of changes on wages, machinery costs, and other factors are calculated and discussed.

Machine performance data and machine harvest labor requirements used in this study are based on field observations made during the 1973 lettuce harvesting season. Only minor changes in machine design have been made since 1973, and these data are equally applicable today (1976).

Related Studies

Benchmark studies on lettuce harvesting and packing methods were done in the fifties, when the industry was changing from icepacking to vacuum cooling of lettuce (2, 9). 2/ The vacuum cooling alternative permitted packing lettuce in the fields, which was more efficient than shed packing. Costs of field and shed packing were updated in 1965, when the Bracero

2/ Underscored numbers in parentheses refer to the bibliography listed at the end of this report.

Program ended. 3/ At roughly the same time, research began on the mechanical harvester (2). Lettuce harvesting costs have also been estimated in separate studies (such as 15 and 16).

Research on the mechanical lettuce harvester proceeded through the sixties; development, however, is still not in the commercial stage (6). A major constraint is a lack of unanimity on a desired handling system.

Assumptions

Certain assumptions are made in this study concerning lettuce yields, worker productivity rates, machine performance, and other factors influencing lettuce handling. For hand-harvest methods, the assumptions are based on personal observations, discussions with industry representatives, and published information. Assumptions for machine-harvest methods are based on published information, on applying existing practices to the alternative methods, and on discussions with industry personnel. General assumptions are discussed here, but specifics are discussed under each alternative practice.

Operating Season

A common practice for large grower-shippers is to move from one area to another over the year. The two major lettuce growing areas are the Salinas Valley, which has a 6-month season, and the Imperial Valley, which has a 4-month season. For purposes of this study, and based on earlier studies, an operating season of 2,240 hours was assumed over the 12 months (9).

Wages

Wages for all alternatives were based on piece and hourly rates paid to field and shed workers specified in agreements and union contracts for the period July 1, 1974 to June 30, 1975 (17, 18, 19). All hourly wages were converted to piece rates to make the analysis consistent. The hand-cut, ground-pack workers and truck drivers are paid on a piece rate. Hand-cut, machine-aid workers are paid on an hourly rate; their wage was calculated on an average output basis as an equivalent piece rate. Shed workers are paid hourly, but piece rates apply above a minimum output; these piece rates were used. Wage rates for new positions were estimated at an average of the ground-pack and shed rates.

Equipment Costs

All equipment other than the mechanical harvester is listed at 1975 costs. The harvester price is estimated to be $40,000, except for the model with additional positions for packing on the machine, which is estimated at $44,000.

3/ From 1953 through 1964, the domestic farm labor supply was augmented with foreign contract workers under Public Law 78. The workers, mostly from Mexico, were commonly known as braceros.

Yield

Observations on yield during the 1973 season at Salinas indicated average yields of 450 and 350 cartons per acre for first and second cuttings, respectively. Taking a mean of these yields, an average of 400 cartons per acre per cutting is used in this study.

Output

Hand-harvest crew output forms the basis for all packing and wrapping operations. Productivity was estimated for this study for both hand-harvested and wrapped lettuce. Output for each operation is listed for each job position in the following pages.

Output of the machine is determined by the speed of the machine (2 mph), number of rows harvested, field efficiency (75 percent), and lettuce yield per cutting. At an average yield per cut of 400 cartons per acre, the machine can harvest 480 cartons per hour (16). In contrast, the hand crew of 38 men can harvest 560 cartons per hour.

ALTERNATIVE LETTUCE HARVESTING SYSTEMS

A summary of the lettuce harvesting operations and job descriptions are shown on pages 5, 6, and 7. All operations described on page 5 are for the regular pack method. Two methods which can be either wrap or nonwrap--the fieldside or central shed--are described on pages 6 and 7. Other operations for harvesting and packing lettuce are also included.

The hand-cut, ground-pack method of harvesting lettuce, a hand-labor operation performed in the field, has been the most common method used in California since the fifties. In the machine-cut, pack-on-machine method, selecting, cutting, and trimming are performed by the machine. Most of the experimental mechanical harvesting work has been done by substituting machine selecting, cutting, and trimming for hand harvesting (16). Although other operations are performed by hand, they are performed on the machine rather than on the ground.

The film wrapping method began commercially in 1960 and has continued to increase in volume, representing about 15 percent of the total volume shipped in 1975. The machine-cut, fieldside-packing-shed method uses the machine to cut the lettuce. Packing of either regular or wrapped lettuce is performed in a fieldside packing shed. In the machine-cut, central-packing-shed method, the mechanical harvester also selects, cuts, trims, and conveys the lettuce heads into trailers pulled through the field by tractors alongside the harvester. When loaded, the trailers are attached to trucks at the side of the field and transported to a central packing shed, where the lettuce can be either regular or wrap packed.

Job description and crew organization for regular pack method of harvesting and packing lettuce: hand and machine methods

Crew	Hand-cut		Machine-cut			
	Ground-pack job description	Number of men	Pack-on-machine job description	Number of men	Bulk-pack job description	Number of men
Select-cut-trim crew	Mature heads are selected, hand-cut, and trimmed at 2 beds (4 rows) per man. Trimmed heads are placed butt up on the harvest bed. Distribute assembled cartons to packers when necessary.	18	A driver operates the mechanical harvester spanning 2 beds (4 rows) which selects lettuce heads according to firmness and cuts them. The machine mechanically trims away the coarse outside leaves.	1	A driver operates the mechanical harvester spanning 2 beds (4 rows) which selects lettuce heads according to firmness and cuts them. The machine mechanically trims away the coarse outside leaves.	1
Carton assembly crew	Cartons are assembled and stitched on trucks moving behind the cutting crew. Assembled cartons are distributed over harvest strip.	2	Carton makers fold, stitch, and place the cartons on the conveyor belt which transports the cartons to the packers.	2		
Quality-control crew			The quality-control workers select out the damaged or undesirable lettuce heads and toss them back into the furrows.	4	The quality-control workers pick out the damaged or undesirable lettuce heads and toss them back into the furrows.	4
Packers	Trimmed lettuce heads are placed in cartons (24 heads per carton. Packed cartons are windrowed in furrows.	9	Trimmed lettuce heads are placed in cartons (24 heads per carton). Packed cartons are windrowed in furrows.	8		
Sprayers (wash butt)	Top layer of lettuce heads is washed with water from pressurized tanks.	1				
Closers	Packed cartons are closed and stapled shut.	2	Packed cartons are closed and stapled shut.	4		
Utility workers					The utility workers supervise the packing of the bulk containers and work as closers or loaders.	4
Loaders	Windrowed cartons are loaded on highway trucks by hand.	4	Windrowed cartons are loaded on highway trucks by hand.	4	The trailers (truck) are pulled alongside the harvester to receive containers.	2
Haulers	Cartons are transported to the vacuum cooler.	2	Cartons are transported to the vacuum cooler.	1	The trailers are hooked to trucks and the lettuce is transported to the vacuum cooler.	2
Total crew		38		24		13

Continued

Job description and crew organization for the film-wrapped pack method of harvesting and packing lettuce: hand and machine methods--continued

Crew	Hand-cut, machine-aid		Machine-cut			
	Machine-aid job description	Number of men	Fieldside or Central-shed job description 1/	Number of men	Tube-and-cube job description	Number of men
Select-cut-trim crew	Mature heads are selected, hand-cut, and trimmed and placed on the mobile wrapping.	14	An operator drives the mechanical harvester spanning 2 beds (4 rows) which selects and trims lettuce heads.	2	An operator drives the mechanical harvester spanning 2 beds (4 rows) which selects and trims lettuce heads.	1
Quality-control crew			The quality-control men pick out the damaged or undesirable lettuce heads.	8	The quality-control workers pick out the damaged or undesirable lettuce heads.	4
Tractor drivers			Tractors pull trailers alongside mechanical harvester. Filled trailers are driven to dump at fieldside.	6		
Spotters			Spotter drives bug, picks up the loaded trailers to dump, and takes unloaded trailers to tractor drivers.	2		
Unloaders			Trailers are unloaded and trimmed heads are put on the conveyor belt.	3		
Carton assembly crew	Cartons are assembled and stitched on the mobile wrapping machine and conveyed to packers.	1	Carton assembly crew folds and stitches cartons and places them on conveyors which run alongside the packing line.	2		
Wrappers	Lettuce heads are wrapped with a film.	9	Lettuce heads are wrapped with a film.	40		
Packers	Wrapped heads are put in cartons.	4	Wrapped heads are put in cartons.	14	The heads are packed in containers using the tube-and-cube (bulk) packing method.	4
Utility workers					These workers act as closers if the containers are to be closed, help load containers, and perform other miscellaneous tasks.	4
Closers	Packed cartons are closed and stapled and dropped in the furrows.	2	Carton closers fold and staple or glue the full cartons shut.	2		

Continued

Job description and crew organization for the film-wrapped pack method of harvesting and packing lettuce: hand and machine methods--continued

Crew	Hand-cut, machine-aid		Machine-cut			
	Machine-aid job description	Number of men	Fieldside or Central-shed job description 1/	Number of men	Tube-and-cube job description	Number of men
Loaders	Cartons are loaded manually on highway trucks.	3	The full closed cartons are loaded onto trucks. One person operates forklift.	3	The two tractor drivers pull trailers (truck) down the furrows beside the harvester. The containers are loaded on the trailers.	2
Haulers	Cartons are hauled on highway trucks to the vacuum cooler.	2	Fieldside shed: Cartons are hauled on highway trucks to the vacuum cooler.	2	The trailers are hooked to highway trucks and transported to the vacuum cooler.	2
			Central shed: Lettuce is hauled to central shed in trailers.	5		
			Packed cartons are hauled to cooler.	1		
Total crew		35	Fieldside shed Central shed	84 88		17

1/ Data on the sheds were updated from information contained in (9) and (10).

The number of jobs and the job descriptions in the central-packing-shed method are the same as for the fieldside-packing-shed method, except for transportation. It is assumed that for the central shed system, the truck can haul 2 trailers containing an equivalent of 400 cartons, and that 6 trucks and drivers are needed, with 5 hauling from the field and 1 hauling from the shed to the cooler.

With machine handling, there is no longer a constraint on container size and weight to facilitate easy handling, and any size of container is possible. Possible advantages of nonconventional containers are lower costs and increased efficiency through economies achieved in packing and in handling materials during cooling and shipping. Factors to consider include a possible quality deterioration, the cost of changing handling systems, a decrease in efficiency, and an increase in costs if bulk density in transit is not maintained or improved.

There are no bulk container systems used commercially; those discussed here are experimental. Two systems are examined: a bulk container and a wrapped lettuce package, both being roughly of pallet size. 4/ The bulk container is loosely filled, closed, cooled, and transported. No additional handling is required at the shipping point. Should the retailer desire a smaller amount of lettuce than that in the container, there must be some wholesale handling.

The other nonconventional container system is the "tube-and-cube" method. Several heads of lettuce are contained in mesh or plastic, with several packages making up the load in the container called tubes and cubes (1). The advantage of this method is to provide a product which is ready to market and which can be easily broken down into smaller packages on demand.

COSTS OF ALTERNATIVE HARVESTING SYSTEMS

Harvesting and packing costs are divided into direct and fixed costs. Included in these costs are labor and equipment, packing and wrapping materials, supervision, and office, sales, and other expenses (tables 1 and 2).

Variable Costs of Operation

Labor

Labor costs are divided into harvesting, transportation, and packinghouse categories. Data on wages are derived from 1975 wage rates matched to job positions (16, 17, 18). Transportation costs refer to transporting lettuce from the field to either the shed or the cooler.

Labor costs accounted for 42 percent of total costs in the hand-cut, regular-pack system, compared with 19 to 32 percent in the machine-cut, regular-pack system (table 1). In film wrapping, labor costs were similar for all the conventional packing systems, accounting for 29 to 31 percent of total costs. Only the tube-and-cube system, where labor costs were down to 16 percent, achieves labor economies (table 2).

Table 1--Cost summary for lettuce harvesting systems, regular pack, 1975

Item	Hand-cut, ground-pack	Machine-cut			
		Pack-on-machine	Fieldside shed	Central shed	Bulk-load
	Dollars per carton				
Labor:					
Field labor	0.556	0.347	0.114	0.114	0.163
Packinghouse labor	--	--	.186	.186	--
Transportation	.035	.035	.035	.044	.035
Total	.591	.382	.335	.344	.198
Equipment:					
Operating costs	.017	.022	.041	.062	.024
Other costs:					
Office and selling expenses	.257	.257	.257	.257	.257
Supervision	.026	.005	.008	.008	.004
Packing material	.500	.500	.500	.500	.500
Total direct and miscellaneous costs	1.391	1.166	1.141	1.171	.983
Equipment:					
Fixed costs	.013	.041	.045	.077	.038
Total cost per carton	1.404	1.207	1.186	1.248	1.021
	Percent				
Labor cost as a percentage of total cost	42	32	28	28	19

Table 2--Cost summary for lettuce harvesting systems, film-wrap pack, 1975

Item	Hand-cut, machine-shed	Machine-cut		
		Fieldside shed	Central shed	Tube-and-cube
	Dollars per carton			
Labor:				
Field labor	0.600	0.114	0.114	0.223
Packinghouse labor	--	.446	.446	--
Transportation	.035	.035	.045	.035
Total	.635	.595	.605	.258
Equipment:				
Operating costs	.042	.041	.062	.024
Other costs:				
Office and selling expenses	.257	.257	.257	.257
Supervision	.009	.008	.008	.004
Packing material	.500	.500	.500	.500
Wrapping material	.566	.566	.566	.566
Total direct costs	2.009	1.967	1.997	1.609
Equipment:				
Fixed costs	.036	.045	.078	.038
Total cost per carton	2.045	2.012	2.075	1.647
	Percent			
Labor cost as a percent of total cost	31	30	29	16

In comparing the alternative wrap-pack systems, a difficulty arose because of two widely differing wage scales. One scale for the hand-cut system used an hourly rate set above the minimum wage, and another scale for the shed system had a provision for piece rates. At the output assumed for the systems, the actual wage computed for the shed systems was double that of the hand-cut system. Care should be exercised in comparing these systems.

Equipment Operating Costs

These costs are summarized in tables 1 and 2 from more detailed data in appendix tables 1-3. Equipment was specified for each harvesting system from observation, industry sources, updated earlier studies (2, 9, 10, 15), experimental systems estimates, and standard sources on equipment use (7).

Equipment costs are relatively constant among systems. The effect on unit costs of a long operating season is discussed later.

Packing and Wrapping Material

These costs were computed using 1975 prices. The plastic wrap cost represented the cost of one of several materials in current use. Since the cost of nonconventional materials is not known, the cost of conventional materials was used for the bulk-load and tube-and-cube systems.

Supervision

Field and shed supervision was estimated based on observations of the hand-cut systems and on likely requirements of the machine-cut systems. More supervision was considered necessary for the labor-intensive systems.

Office and Sales Expenses

These costs, based on (11), were considered as direct costs, although some categories were semifixed. Cost categories included are insurance, telephone, office salaries, sales salaries, brokerage fees, business taxes, and other indirect costs.

Fixed Costs of Operation

The source of these data is discussed under equipment operating costs. Tables 1 and 2 summarize the fixed costs of each harvesting system. The cost detail on the items of equipment is contained in appendix tables 4-6.

Fixed-cost variation is the second largest difference among the systems. Size economies are discussed later.

COMPARISON OF THE ALTERNATIVE HARVESTING SYSTEMS

Comparisons are made on the basis of both productivity and cost. Productivity of the hand-cut, ground-pack system in 1973 is contrasted with 1963 to provide a perspective. Output per man-hour comparisons are made to provide indications of any relative efficiency of machine systems. Cost

comparisons illustrate economic advantages. Then, since the study incorporates assumptions on many factors, certain of these assumptions are relaxed to indicate likely cost effects.

Productivity Comparisons

Comparison of Job and Crew Output

A comparison of the job and crew output per hour for both regular and wrap packs is presented in tables 3 and 4. Hand-cut crew outputs were 560 cartons per hour for the ground pack and 178 cartons for the machine aid. All machine-cut systems are based on machine output of 480 cartons per hour. The 2 shed systems each utilize 2 machines with a total hourly output of 960 cartons.

Keys to productivity are the major labor-using jobs. The hand-cut, ground-pack system relies on a trio of workers as the basis of crew organization--two selector-cutter-trimmers (SCT's) and a packer. To achieve an output of 560 cartons per hour, 27 of the 38 men in the crew are part of this trio (71 percent). The hand-cut, machine-aid system uses 14 SCT's out of a crew of 26 (69 percent), plus 9 wrappers to cut and pack.

An average packing rate of 62 cartons per man-hour for the hand-cut, ground-pack system was observed in 1973. This rate was used as the basis for estimating packing rates on the machine and in the sheds. The machine packing rate was estimated at 60 cartons per man-hour, the shed rate was estimated at 70 cartons per man-hour, and the machine-aid rate was observed to be 45 cartons per man hour. Output rates equivalent to carton packing rates were calculated for the bulk systems at 120 cartons per man-hour each for the bulk-pack and the tube-and-cube systems.

Another major labor-using position is wrapping. A rate of 20 cartons per man-hour was estimated for the machine-aid system. Based on this rate, a rate of 25 cartons was estimated for the sheds.

Efficiency of the Hand-Cut, Ground-Pack

Efficiency of an operation is commonly assessed through such measures as output per unit of input and in terms of cost per unit of final product. The efficiency of the ground-pack operation can be judged in two ways: first, by comparison with previous estimates of efficiency criteria, and second, by comparison with efficiency estimates for alternative methods. An initial efficiency comparison is made below with a study of harvest labor cost and productivity performed in 1963 (15, 16):

	1963	1973
Crew size	72	38
Method of payment	Hourly	Piece rate
Number of cuttings per acre	3 to 4	2
Output per man-hour	5 to 6	14.7

Table 3--Crew productivity per job for regular-pack harvesting systems, 1975

Job	Hand-cut, ground-pack		Machine-cut							
			Pack-on-machine		Fieldside shed		Central shed		Bulk-pack	
	Output per man-hour	Size crew	Output per man-hour	Size crew	Output per man-hour	Size crew	Output per man-hour	Size crew	Output per man-hour	Size crew
	Cartons	Number	Cartons	Number	Cartons	Number	Cartons	Number	Cartons	Number
Select-cut-trim	31	18	480	1	480	2	480	2	480	1
Carton assembly			240	2	480	2	480	2		
Quality-control			120	4	120	8	120	8	120	4
Packer	62	9	60	8	70	14	70	14		
Forklift operator					960	1	960	1		
Tractor driver					160	6	160	6	240	2
Spotter (bug driver)					480	2	480	2		
Unloader					320	3	320	3		
Utility worker									120	4
Closer	187	3	120	4	480	2	480	2		
Loader	140	4	120	4	320	3	320	3		
Stitcher	560	1								
Stitcher-truck driver	560	1								
Total field crew		36		23		43		43		11
Hauler	280	2	480	1	480	2		5	240	2
Total crew plus haul		38		24		45		48		13
Crew output per hour	560		480		960		960		480	
Crew output per man-hour	14.7		20.0		21.3		18.8		36.9	

Table 4--Crew productivity per job for wrap-pack harvesting systems, 1975

Job	Hand-cut machine-aid		Machine-cut					
			Fieldside shed		Central shed		Tube-and-cube	
	Output per man-hour	Crew size	Output per man-hour	Crew size	Output per man-hour	Crew size	Output per man-hour	Crew size
	Cartons	Number	Cartons	Number	Cartons	Number	Cartons	Number
Select-cut-trim	13	14	480	2	480	2	480	1
Carton assembly	178	1	480	2	480	2		
Quality-control			120	8	120	8	120	4
Wrapper	20	9	24	40	24	40		
Packer	45	4	70	14	70	14	120	4
Forklift operator			960	1	960	1		
Tractor driver			160	6	160	6	240	2
Spotter (bug driver)			480	2	480	2		
Unloader			320	3	320	3		
Utility worker							120	4
Closer	89	2	480	2	480	2		
Loader	69	3	320	3	320	3		
Total field crew		33		83		83		15
Hauler	89	2	480	2	160	6	240	2
Total crew plus haul		35		85		89		17
Crew output per hour	178		960		960		480	
Crew output per man-hour	5.1		11.3		10.5		28.2	

Crew size in 1963 was double the 1973 crew size of around 72 field workers. Workers were paid by the hour rather than by piece rate. Harvesting of fields was done three to four times instead of twice. Output of the crew was considerably less per man-hour; in 10 years, productivity doubled for the hand-cut, ground-pack system.

Labor Productivity: Output Per Unit Comparisons

The common estimate of productivity is to estimate output per hour of labor use. Such estimates for hand-cut and machine-cut alternatives are listed in table 5. For the regular pack, the lowest productivity in 1973 was for the hand-cut method--14.7 cartons per man-hour. The 3 alternative machine-cut methods involving hand packing were roughly a third more productive at 20.0 cartons per man-hour for packing on the machine, and 18.8 and 21.3 cartons, respectively, for the central and portable sheds. High productivity was estimated for the bulk-pack method--36.9 cartons per man-hour, or twice the output of the others. A gain in productivity of roughly one-third over the hand-cut method was achieved by mechanizing the cutting operation. The bulk method is estimated to achieve an additional 100-percent increase in productivity over these methods by replacing the packing activity.

The potential productivity increase is greater for the film-wrapped pack, with increases of 106 to 122 percent for the sheds, and 450 percent for the experimental tube-and-cube system. In each of these mechanizing steps, productivity per man-hour increased, but at a cost equal to the capital required to provide the mechanization. This capital cost is not indicated in the man-hour requirements, but is estimated separately and included in the total cost.

Comparison of Costs for All Systems

A summary of harvesting and packing costs per carton for the systems considered is presented in table 5. The basis of comparison is the hand-cut system. Among regular-pack methods, harvesting costs in 1975 were highest for the hand-cut, ground-pack system--$1.40 per carton. The machine-cut, hand-packing alternatives are estimated to be slightly lower in cost. Packing costs in a fieldside or central shed are calculated at $1.19 and $1.25 per carton, respectively.

Compared with the cost of hand cutting, these costs represent decreases of 11 to 16 percent. Costs for packing on the machine--the other alternative involving hand packing--are estimated at $1.21 per carton, or 14 percent less than hand cutting costs. Estimated costs for the bulk-pack system are $1.02 per carton--27 percent less than the hand-cut system. In brief, estimated cost reductions in harvesting from hand cutting ranged from 7 to 15 percent for the systems still requiring hand packing, and a savings of 27 percent for no packing. The savings represent reductions of ½ to 1½ cents per head. Given a retail price of 39 cents per head, there is a 2-percent savings.

Table 5--Productivity and cost comparisons for various harvesting systems, 1975 1/

System	Cartons per man-hour	Costs per carton				
		Labor	Equipment		Other 2/	Total
			Operating	Fixed		
	Number	Dollars				
Regular pack:						
Hand-cut, ground-pack	14.7	0.591	0.017	0.013	0.782	1.404
Machine-cut, pack on machine	20.0	.382	.022	.041	.761	1.207
Machine-cut, fieldside shed pack	21.3	.335	.041	.045	.765	1.186
Machine-cut, central shed pack	18.8	.344	.062	.077	.765	1.248
Machine-cut, bulk-pack	36.9	.198	.024	.038	.761	1.021
Film wrap pack:						
Hand-cut, machine-aid	5.1	.635	.042	.036	1.332	2.045
Machine-cut, fieldside shed pack	11.3	.595	.041	.045	1.331	2.012
Machine-cut, central shed pack	10.5	.605	.062	.077	1.331	2.075
Machine-cut, tube-and-cube	28.2	.258	.024	.038	1.327	1.647

1/ Labor rates include 17 percent fringe benefits. The operating season is 2,240 hours. Crew output per hour is 560 cartons for the hand-cut, ground-pack crew; 480 cartons for all other regular-pack, machine-cut, and tube-and-cube crews; 178 cartons for hand-cut, machine-aid crews; and 960 cartons for both shed pack crews.

2/ Other costs include: packing material ($0.50 per carton), office and selling expenses ($0.275) per carton), field and shed supervision (varying costs), and the wrap-pack wrapping material ($0.566 per carton).

Source: (8).

Referring again to table 5, the cost of film wrapping lettuce using a hand-cut, mechanical-aid system was $2.05 per carton, or about 55 cents higher than the hand-cut, ground-pack system. Among cost items, the greatest difference is in the price of the film-wrap material, which cost an estimated 57 cents per carton. There was little difference between costs for the machine aid and the shed systems. The cost for the machine-cut, central shed, at $2.08 per carton, was slightly higher than that for the hand-cut method, but the cost for the fieldside-shed system was slightly less than $2.01 per carton. The cost for the tube-and-cube system, using a wrap enclosing several heads at a time, was estimated from rough experimental data to be $1.65 per carton, or 19 percent less than the mechanical aid. Briefly, only the new technology tube-and-cube system offered cost savings--1½ cents per head.

Given the savings per head, the savings to the California-Arizona lettuce industry can be estimated by assuming complete mechanization, a division of regular and wrapped lettuce at a ratio of 90 percent:10 percent, and an output of lettuce from the 2 States of 93 million cartons annually. The regular pack savings of ½ to 1½ cents per head would total $10.0 million to $32.1 million, and the wrap-pack savings would range from none to $3.7 million. The total savings to the industry would range from $10.0 million to $33.8 million. Although the savings per unit are low, the aggregate savings to the industry are significant.

Effect of Wage Increases on Widened Cost Differences

Table 6 presents three estimates of total harvesting costs: at 1975 wage rates, at rates 20 percent higher than the 1975 rates, and at rates 40 percent higher.

For the regular pack, wage costs for the hand-cut systems would rise sharply, compared with those for the machine-cut systems. Since the labor cost is high relative to total cost for the hand-cut system, the total cost rises at a more rapid rate when wages increase.

However, the slope of increase for the hand-cut, wrap-pack method is the same as for the shed systems. The cost of labor in both cases is roughly the same. As examined previously, the machine-cut, shed systems had higher productivity but also higher wage rates. The tube-and-cube system indicated a lower total increase in response to wage raises. Wage increases will provide greater economic incentive to mechanize for those systems with relatively less labor input.

Effect of Changes in Materials Cost

Prices have increased rapidly since 1974 for containers and film wrap. The impact of those price changes is significant since the share of materials in total lettuce harvesting costs is large. Carton costs comprised 35 to 50 percent of total regular pack harvesting costs. The carton, plus wrapping costs for the film-wrap pack, accounted for 65 percent. A 1-percent increase in price for cartons can raise total harvesting costs 0.36 to 0.49 percent for the regular pack, and 0.24 to 0.31 percent for the film-wrap pack. The

wrapping material price increases will have a similar effect on total costs for the film-wrap pack.

Table 6--Cost comparisons of 1975 wage rates and assumed wage increases for regular pack and wrap-pack systems

System	Total cost per carton		
	Present wage rate	Increased wage rates of--	
		20 percent	40 percent
	Dollars per carton		
Regular pack:			
Hand-cut, ground-pack	1.404	1.522	1.640
Machine-cut, pack-on-machine	1.207	1.283	1.360
Machine-cut, fieldside shed	1.186	1.253	1.320
Machine-cut, central shed	1.248	1.317	1.386
Machine-cut, bulk loaded	1.021	1.061	1.100
Wrap-pack:			
Hand-cut, machine-aid	2.045	2.172	2.299
Machine-cut, fieldside shed	2.012	2.131	2.250
Machine-cut, central shed	2.075	2.196	2.317
Machine-cut, tube-and-cube	1.647	1.699	1.750

Effect of Firm Size on Fixed Costs of Equipment Per Unit

Lettuce producers in the Southwest provide a year-round supply of lettuce by switching from one producing area to another as climatic conditions dictate. A large percentage of grower-shippers have expanded to an integrated lettuce operation in two or more areas. As a consequence, harvest labor crews have become specialists, moving with the crop. The lettuce firm is made up of individual operations producing sequentially throughout the year.

Firm size is characterized by the number of operating hours. Estimates of 1975 fixed costs per carton at various operating hours are presented in appendix table 7. Total costs of selected harvest systems at various operating hours are presented graphically in figure 1. Total costs per carton are affected little by changes above 1,120 hours in the operating scale of the enterprise. As the number of operating hours decreases, a point is reached where the costs of the hand and machine systems coincide. These points of equal cost are reached at about 560 operating hours, and are indicative of the hours of operation below which it is more favorable to use hand labor.

The effect of changes in harvest machine costs on total cost per carton are not significant because of the long operating season. The fixed cost of equipment per carton at 2,240 hours of operation is small--$0.041 in 1975;

TOTAL COSTS OF SELECTED HARVEST SYSTEMS AT VARIOUS OPERATION HOURS, 1975

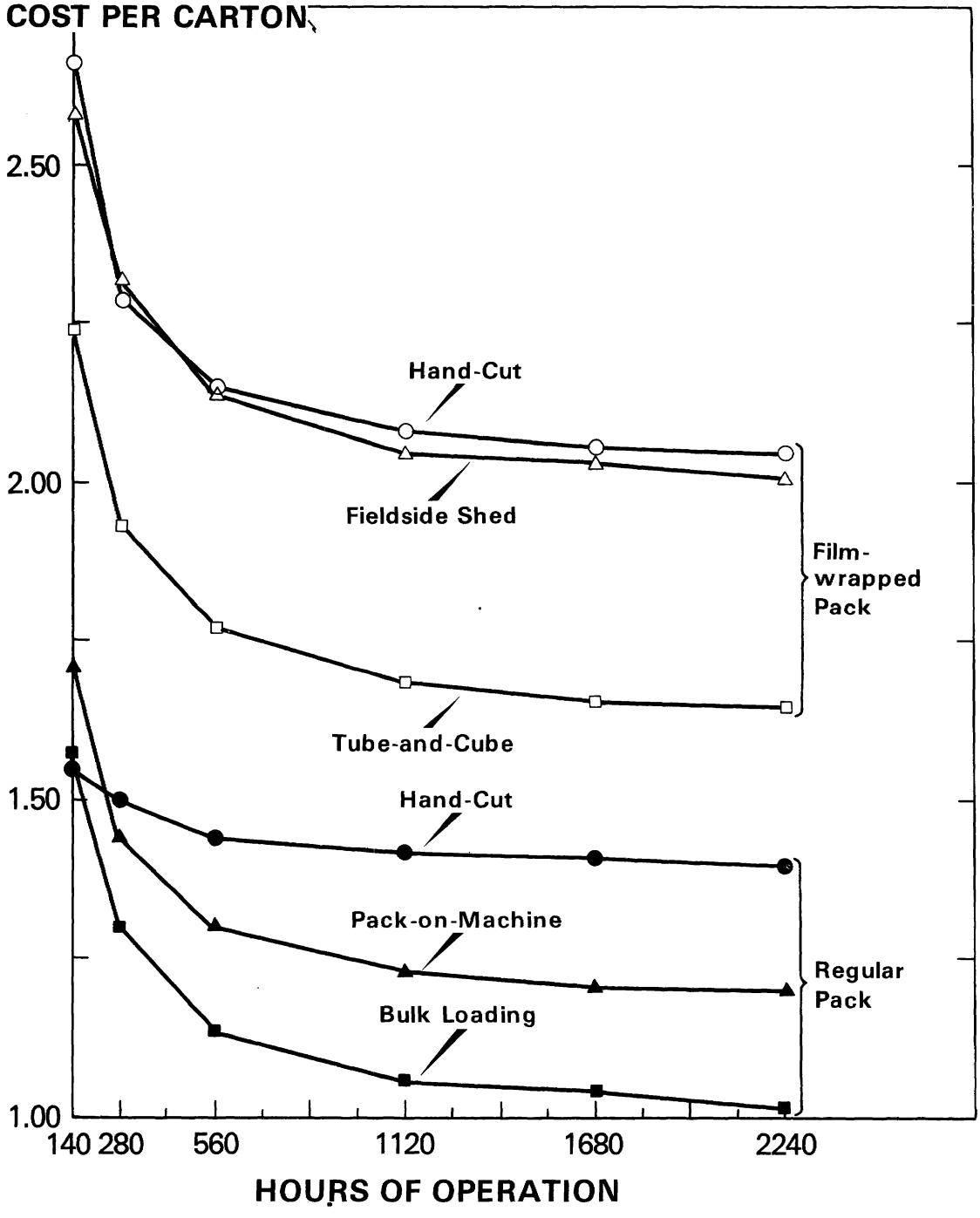


Figure 1

USDA

NEG. ERS 2605-76 (11)

a doubling of machine cost would double this figure to $0.082, an increase of only 4 cents per carton (app. table 7).

Effect of Machine Systems on Quality

Under mechanization, a crop undergoes a different type of handling which can change the rate of crop loss. As mentioned earlier, no estimate of potential crop damage or loss has been made for the machine systems. However, the relative cost of crop damage can be calculated over a range of possible loss so as to indicate the level of loss than can offset the benefits of a machine system.

Conventional lettuce handling systems result in a certain amount of physical damage by the time the lettuce reaches the retailer. One source estimated this loss to be 4.2 percent for the 1966-69 period (14). Any new handling system will incur a loss that can be contrasted to the existing system, either favorably or unfavorably (table 7). If the loss from the machine system were the same as for the hand-cut system, the benefit from using the machine system would be $1.80 - $1.56 = $0.24 per carton. If the average loss under the machine system were 13 percent greater than that under the present system, there would be no benefit from using the machine. Conversely, if the loss from the machine system were less than for the present one, additional economic benefits could accrue.

Table 7--Effect on returns of increased or decreased damage from mechanical harvesting

Anticipated loss from machine harvest	Net returns above production costs 1/	
	To machine system	To hand-cut system
	Dollars per carton	
Decreased damage of--		
5 percent	1.88	
0 percent	2/ 1.79	
Increased damage of--		
-5 percent	1.70	
-10 percent	1.61	
0 percent		3/ 1.60
-15 percent		1.50
-20 percent		1.41
-25 percent		1.32

1/ F.o.b. price of $3.00 per carton less the cost of harvesting.
2/ Pack-on-the-machine return is $3.00 - $1.21 = $1.79.
3/ Hand-cut return is $3.00 - $1.40 = $1.60.

IMPLICATIONS OF ADOPTING THE HARVEST MACHINE

The foregoing comparison of productivity and costs of alternative systems of lettuce harvesting and packing suggests at least three implications. If the assumptions of the study hold, the introduction of machine systems would increase labor productivity significantly, indicating that cost economies can be gained. However, labor cost reduction is offset somewhat by capital costs of equipment and by the level of other overhead costs, thereby reducing the net cost economies. Further, a number of factors held constant for purposes of analysis can vary considerably in actual practice and can change the cost estimates presented. The framework of costs here can serve as a basis of comparison with actual events as they take place. Other implications apply to the effect on labor and capital inputs and are discussed below.

Rate of Machine Adoption

Since a machine is not commercially available, there is little basis for estimating a rate of adoption. To gain insight on technology adoption, reference was made to the experience of mechanization in other crops and to conditions favorable and unfavorable to adopting a lettuce harvester.

Conditions favorable and unfavorable to acceptance of a lettuce harvesting machine are listed below. The coverage is not exhaustive, but is indicative of the types of factors to be considered in assessing machine adoption.

Factors to consider machine vs. hand	Favorable aspects of machine system	Unfavorable aspects of machine system
Availability of labor		Labor is currently available.
Difficulty of work	Machine will lighten work, eliminate stoop labor, and lengthen job longevity.	
Effect of weather		Machine may have difficulty operating in mud.
Supervision/communication	Machine has fewer crew members; easier to supervise; communication will be improved.	
Work stoppage		Machine can break down, stopping flow of lettuce.

The factors discussed above assist in estimating adoption after the machine has been introduced commercially, but there is no real basis for prediction. A cautious approach was used to assess the impact of the machine at different rates of adoption, initially estimating a low rate of adoption but expanding the rate in order to assess a range of possibilities.

Capital Investment

Before discussing the impact of a machine purchase, it is necessary to provide some initial estimate of the future number of machines. At an average annual lettuce harvest of 93 million cartons for California and Arizona, one method of machine estimation was to divide this output by a machine output during 2,240 hours of operation (2,240 hours times 480 cartons per hour): 93 million divided by 1.075 million equals 86.5 machines. Thus, the market for lettuce harvesting machines is a small one. However, these estimates do not allow for excess capacity.

The capital requirements of the different harvesting systems are listed in table 8. The smallest capital needs are for the present hand-cut, ground-pack system of $72,000. The regular pack, machine-cut systems require additional capital per unit of output of:

pack-on-the-machine:	49 percent
bulk-load:	75 percent
fieldside shed:	143 percent
central shed:	362 percent

The additional capital needs of machine systems for wrapped lettuce differ from the above, because capital needs per carton are relatively high for the hand-cut, machine-aid system. The fieldside shed wrap system requires 16 percent less investment than the hand-cut system, but the central shed system needs 64 percent more investment.

Additional capital requirements are not the total cost of new investment, but reflect the relative size of capital needs for the different systems. Since the ground-pack is a relatively low capital user per carton, the additional capital needs appear high; the high capital needs of the machine-aid wrap systems reflect a modest capital increase need.

Effect on Labor

The impact on labor will depend on the harvesting systems adopted and the rapidity of machine adoption. Changes in jobs and numbers of workers when changing from hand to machine harvesting are indicated in table 9. To simplify comparisons, assume that a hand-cut, ground-pack crew is replaced by a machine-cut, pack-on-the-machine crew. The 18 selector-cutter-trimmer jobs are replaced, and 2 job categories for 5 crewmen are created--1 machine operator and 4 quality-control people. If the hand-cut, machine-aid system were replaced by the fieldside wrap machine, 14 SCT's would be replaced and 5 jobs would be created--1 machine operator and 4 quality-control people. These comparisons are difficult to interpret because these systems operate at different harvesting rates. Based on output per man-hour (table 5), the reduction in manpower for the hand-cut, ground-pack replacement is 26 percent, or 9 men from the 36-man crew. For the hand-cut wrapped lettuce, the reduction is 55 percent, or 18 men from a 33-man crew. In brief, there is an indicated drop of one-fourth of the ground-pack crew and one-half of the machine-aid crew for those crews transferred to the machines specified.

Table 8--Capital requirements of alternative harvesting systems

Machines adopted	Machine-cut				Output of lettuce per hour	Equivalent number of hand crews		Equivalent investment in hand systems	
	Pack-on-machine	Fieldside shed	Central shed	Bulk-load 1/		Ground-pack	Machine-pack	Ground-pack	Machine-aid
	1,000 dollars				Cartons	Number		1,000 dollars	
0									
1	92			108	480	0.9	2.7	62	174
2	184	300	717	216	960	1.7	5.4	122	349
4	368	600	2/ 1,140	432	1,920	3.4	10.8	245	697
12	1,104	1,800	2/ 3,420	1,296	5,760	10.3	32.4	741	2,092
48	4,416	7,200	2/13,680	5,184	23,040	41.1	129.4	2,958	8,355

1/ Also the cost for tube-and-cube.
2/ The central shed system should be able to extend the fixed facilities to accommodate the output of several machines in one shed. Cost reductions occur through no duplication of permanent shed facilities and cull disposal systems in moving from two to four machines.

Source: Appendix tables 4, 5, 6, and 7.

One criticism of mechanization is that skilled, heavy-labor jobs, at better paid piece rates, are frequently replaced by less arduous, but hourly paid jobs. The new machine operator position should be for a skilled driver, mechanically inclined, and probably needing crew boss skill. The quality-control positions require new but less demanding skills, probably equivalent to those of the SCT's.

Additionally, there are tractor drivers and other similar positions for most machine systems, all mechanical jobs requiring skills. A majority of the jobs on the machine are the same as before, although requirements for job skills may be higher than before. The question of wages is still open.

Stoop labor positions are the first jobs replaced, since they are usually the most labor-intensive. Thus, many of the old and all of the new jobs are on the machine, in the shed, or on a tractor. There is an aemlioration of the hardships of the job. This factor may allow certain of the previously all-male, young adult jobs to be performed by older men and women, providing more labor flexibility. Further, job security would be increased since workers could continue in positions much longer than before.

Given the job descriptions of the alternative systems, an estimate can be made of the number of jobs lost and gained if mechanization occurs. To simplify the analysis, one regular pack and one film-wrap pack machine system will be contrasted with hand-cut systems. An original mix of hand-cut crews is calculated at 100 regular-pack and 30 wrap-pack crews. 3/

If the machine systems adopted were the pack-on-the-machine (regular pack) and the fieldside shed (wrap-pack) system, the number of workers would drop (table 9) as follows:

Table 9--Effect of machine adoption on number of jobs

Jobs affected	Number affected when the assumed rate of machine adoption is--			
	5 percent	25 percent	50 percent	100 percent
For ground-pack systems of--				
9 workers per crew	45	225	450	900
100 crews	5	25	50	100
For wrap-pack systems of--				
18 workers per crew	27	135	270	540
30 crews	1.5	7.5	15	30
Total jobs lost	72	360	720	1,440

3/ Estimated from data from various California agricultural commissioners' offices.

These numbers appear rather small, but account for full-time, 12-month equivalents of workers. The total number of workers in lettuce harvesting is calculated at an equivalent of 4,590 full-time workers. 4/ Thus, the decrease in workers is estimated at 1.57 percent of the work force at a 5-percent adoption rate, and at 7.84 percent at a 25-percent adoption rate. For 50- and 100-percent adoption rates, jobs lost are estimated at 15.7 and 31.4 percent, respectively, of the 1973 work force.

The value of wages lost then can be estimated. At an estimated hourly equivalent wage of $6.50 per hour (fringes included) for the full-time pack worker, wage loss is $13,520 per year (15). The wrap-pack worker equivalent wage is $3.25 per hour or $6,760 per year. Annual net wage loss is then a weighted average of the two: at a 5-percent adoption rate, wage loss is $790,000; at a 25-percent rate, wage loss is $3.95 million.

Summary of Mechanization Potential

The incentive for mechanization is the provision of a workable, dependable harvest machine that can achieve economies through substitution of capital for labor. In the innovation process in agriculture, research produces a prototype model which commercial firms use to adapt to commercial uses. Such a model exists today for lettuce, though only for the harvesting and not for the packing function. The industry needs to decide on the type of packing and subsequent handling system to be used before a finished model can be built.

As the decisions on the handling system are made, and as the mechanical problems are overcome, there will be no foreseeable technical impediments to at least partial adoption of the machine. The constraints are more likely to come from economic and social considerations. Social considerations are important in terms of potential jobs lost and in labor union bargaining. There is a high degree of risk associated with being an early innovator, but the benefits to be gained from mechanizing should offset this risk.

Further research and development of the machines is continuing. Pressures to substitute capital for labor will probably remain high for those activities with large numbers of workers preforming the same duties. The immediate substitution possibility is to replace the hand selector-cutter-trimmers with the machine. A second area of pressure for substitution is to mechanize or delete the packing operation. Finally, for wrapped lettuce, the low output rate of the wrapper position calls for improved productivity.

Since the lettuce industry is small in terms of numbers of harvest machines that can be used, perhaps 100 to 200 machines, farm machinery companies are reluctant to spend significant amounts for research and development. This is money that will have to be regained through the sales price. A start in development will more likely come through efforts of individual growers who build prototype harvesters of their own. Commercial companies could take over the machines if they proved successful.

4/ Calculated at 100 regular crews times 36 plus 30 wrap crews times 33 equals 4,590, not including highway truck drivers whose numbers would not be affected.

BIBLIOGRAPHY

(1) Cargill, B.F., and R.E. Garrett, "The Big Picture of Lettuce Handling," Transactions of American Society of Agricultural Engineers, Vol. 18, No. 1, pp. 7-9.

(2) Enochian, R.V., F.J. Smith, and L.L. Sammet, Cost and Efficiency in House Packing Western Head Lettuce, California Agr. Expt. Sta. Giannini Found. Mimeo, Rept. No. 199, 1957.

(3) Grise, V., and S. Johnson, An Economic Analysis of Cling Peach Production With Emphasis on Harvest Mechanization, U.S. Dept. of Agriculture, Economic Research Service, Agric. Econ. Rept. No. 240, 1973.

(4) Johnson, S.S., An Economic Analysis of Wine Grape Production With Emphasis on Harvest Mechanization, U.S. Dept. of Agriculture, Economic Research Service Report (forthcoming).

(5) Johnson, S.S., and M. Zahara, "Prospective Lettuce Harvest Mechanization, Impact on Labor," Jour. Amer. Soc. Hort. Sci. (forthcoming).

(6) Lenker, D.H., P.A. Adrian, G.W. French, and M. Zahara, "A Selective Crisphead Lettuce-Harvest System," American Society of Agricultural Engineers, Paper No. 72-146, 1972.

(7) Reed, A.D. Machinery Costs and Performance, University of California Agricultural Extension Service, AXT-336, Rev. 1972.

(8) Sammet, L.L., "Transferability of Microeconomic Data Over Time: An Illustration," American Journal of Agricultural Economics, 56:3, Aug. 1974, pp. 614-621.

(9) Smith, Frank J., L.L. Sammet, and R.V. Enochian, Cost and Efficiency of Packing Western Head Lettuce, California Agr. Expt. Sta. Giannini Found. Mimeo. Rept. No. 183, Berkeley, 1955.

(10) Thor, Eric, A.A.M. Goueli, and A. Hutchens, Costs of Alternative Methods of Harvesting and Packing Lettuce, University of California, Agricultural Extension Service Info. Series No. 65-1, Berkeley, 1965.

(11) U.S. Dept. of Agriculture, Economic Research Service, Development in Marketing Spreads for Agricultural Products in 1973, ERS-14, 1974.

(12) _____, Economic Research Service, The Farm Index, June 1970.

(13) _____, "Harvesting Lettuce Electronically," Agricultural Research, Jan. 1974, pp. 8-11.

(14) Wright, W.R., and B.A. Billeter, Marketing Losses of Selected Fruits and Vegetables at Wholesale, Retail and Consumer Levels in the Chicago Area, U.S. Dept. of Agriculture, Agricultural Research Service, Marketing Research Rept. No. 1017, 1975.

(15) Zahara, M., and O.D. McCoy, Four Methods of Lettuce Harvest, University of California, Dept. of Vegetable Crops Series 130, 1963; and various cost studies by University of California Agricultural Extension Service in Monterey County.

(16) Zahara, M., S.S. Johnson, R.E. Garrett, "Labor Requirements, Harvest Costs, and the Potential for Mechanical Harvest of Lettuce," Journal of American Society of Horticultural Science, 99(6), 1974, pp. 535-537.

(17) 1973-1975 Western Agricultural Master Agreement, Areas' Negotiating Committee and Western Conference of Teamsters.

(18) 1973-1976 Truck Drivers' Contract, Grower-Shipper Vegetable Association of Central California and General Teamsters Locals.

(19) 1974 Packinghouse Agreement, Grower-Shipper Vegetable Association of Central California and Fresh Fruit and Vegetable Workers Local P-78-A.

Appendix table 1--Operating costs per hour for alternative naked pack lettuce harvesting systems, 1975 1/

Equipment	Hand-cut, ground-pack		Machine-cut							
			Pack-on-machine		Fieldside shed		Central shed		Bulk-pack	
	Used	Operating cost/hour	Used	Operating cost/hour	Used	Operating cost/hour	Used	Operating cost/hour	Used	Operating cost/hour
	Number	Dollars	Number	Dollars	Number	Dollars	Number	Dollars	Number	Dollars
Stitcher	1	0.52	1	0.52	1	0.52	1	0.52		
Stitcher truck	1	3.09								
Highway truck	2	6.14	2	6.14	2	6.14	6	18.42	2	6.14
Closer clamps	5	.02	5	.02						
Staple guns	5	.02	5	.02						
Harvest machine			1	3.81	2	7.32	2	7.32	1	3.81
Tractor (40 hp)					6	7.26	6	7.26	1	1.46
Trailer					20	1.46	20	1.46	2	.15
Bug (small tractor)					2	1.50	2	1.50		
Forklift					1	1.52	1	1.52		
Mobile packing platform					2	.48				
Conveyor belts, packing line, unloading equipment					1	12.97	1	12.97		
Shed							1	5.46		
Cull disposal							1	3.13		
Cost per hour		9.75		10.51		39.17		59.56		11.56
Cost per carton		.0174		.0219		.0408		.0620		.0241

1/ See app. table 3 for cost detail.

Appendix table 2--Operating costs per hour for alternative wrapped pack lettuce harvesting systems, 1975 1/

Equipment	Hand-cut machine-aid		Machine-cut					
			Fieldside shed		Central shed		Tube-and-cube	
	Used	Operating cost/hour	Used	Operating cost/hour	Used	Operating cost/hour	Used	Operating cost/hour
	Number	Dollars	Number	Dollars	Number	Dollars	Number	Dollars
Stitcher	1	0.52	1	0.52	1	0.52		
Highway truck	1	3.07	2	6.14	6	18.42	2	6.14
Closer clamps	5	.02	5	.02				
Staple guns	5	.02	5	.02	5	.02		
Mobile wrap machine	1	4.32						
Harvest machine			2	7.32	2	7.32	1	3.81
Tractor (40 hp)			6	7.26	6	7.26	1	1.46
Trailer			20	1.46	20	1.46	2	.15
Bug (small tractor)			2	1.48	2	1.48		
Forklift			1	1.52	1	1.52		
Mobile packing platform			2	.46				
Conveyor belts, packing line, unloading equipment with wrap equipment			1	13.09	1	13.09		
Shed					1	5.46		
Cull disposal					1	3.13		
Cost per hour		7.95		39.29		59.68		11.56
Cost per carton		.0447		.0409		.0622		.0241

1/ See app. table 3 for cost detail.

Appendix table 3--Operating costs per hour for lettuce harvesting equipment, 1975

Equipment	Fuel per hour	Repairs and miscellaneous per hour 1/	Total operating costs per hour
	Dollars		
Stitcher	0.49	0.03	0.52
Stitcher truck	2.02	1.05	3.07
Highway truck	2.02	1.05	3.07
Closer clamps (5)	--	.02	.02
Staple guns (5)	--	.02	.02
Mobile wrap machine	2.02	1.79	4.32
Harvest machine	1.87	2/ 1.79	3.66
Tractor (40 hp)	.90	.31	1.21
Trailer	--	.073	.073
Bug (small tractor)	.52	.22	.74
Forklift	1.25	.27	1.52
Mobile packing unit platform (2)	--	.46	.46
Conveyor belts, packing line, and unloading equipment	11.22	1.75	12.97
Wrapping equipment	11.22	1.86	13.09
Shed	--	5.46	5.46
Cull disposal	2.02	1.11	3.13

1/ Repairs and miscellaneous at 10 percent of replacement cost per season.
2/ $1.94 for pack-on-machine.

Appendix table 4--Fixed costs per hour for regular pack, 1975 1/

Equipment	Hand-cut ground-pack		Machine-cut							
			Pack-on-machine		Fieldside shed		Central shed		Bulk-pack	
	Used	Fixed cost/hour	Used	Fixed cost/hour	Used	Fixed cost/hour	Used	Fixed cost/hour	Used	Fixed cost/hour
	Number	Dollars	Number	Dollars	Number	Dollars	Number	Dollars	Number	Dollars
Stitcher	1	0.06	1	0.06	1	0.06	1	0.06		
Stitcher truck	1	2.29								
Highway truck	2	4.58	2	4.58	2	4.58	6	11.65	2	4.58
Closer clamps	5	.06	5	.06						
Staple guns	5	.10	5	.10	5	.10	5	.10		
Harvest machine			1	14.70	2	24.91	2	24.91	1	12.46
Tractor (40 hp)					6	4.08	6	4.08	1	.68
Trailer					20	3.11	20	3.11	2	.62
Bug (small tractor)					2	.97	2	.97		
Forklift					1	.58	1	.58		
Mobile packing platform					2	1.01				
Conveyor belts, packing line, unloading equipment					1	3.63	2	6.91		
Shed							2	17.21		
Cull disposal							2	4.59		
Cost per hour		7.10		19.50		43.03		74.14		18.34
Cost per carton		.013		.041		.045		.077		.038

1/ See app. table 3 for cost detail.

Appendix table 5--Fixed costs per hour for wrap-pack, 1975 1/

Equipment	Hand-cut, machine-aid		Machine-cut					
			Fieldside shed		Central shed		Tube-and-cube	
	Used	Fixed cost/hour	Used	Fixed cost/hour	Used	Fixed cost/hour	Used	Fixed cost/hour
	Number	Dollars	Number	Dollars	Number	Dollars	Number	Dollars
Stitcher	1	0.06	1	0.06	1	0.06		
Highway truck	1	2.29	2	4.58	6	11.65	2	4.58
Closer clamps	3	.03						
Staple guns	3	.06	5	.10	5	.10		
Mobile wrap machine	1	3.88				24.91	1	12.46
Harvest machine			2	24.91	2	4.08	1	.68
Tractor (40 hp)			6	4.08	6	3.11	2	.62
Trailer			20	3.11	20	.97		
Bug (small tractor)			2	.97	2	.58		
Forklift			1	.58	1			
Mobile packing platform			2	1.01				
Conveyor belts, packing line, unloading equipment with wrap equipment			1	3.98	2	7.62		
Shed					2	17.21		
Cull disposal					2	4.59		
Cost per hour		6.33		43.38		74.88		18.34
Cost per carton		.036		.045		.078		.038

1/ See app. table 3 for cost detail.

Appendix table 6--Fixed costs of individual items of equipment used in harvesting and packing lettuce, 1975

Equipment	Replacement cost	Life	Depreciation	Insurance	Tax and license	Interest on investment	Fixed repairs	Total fixed cost/season	Total fixed cost/hour
	Dollars	Years	Dollars						
Stitcher	650	10	65	16	7	28	26	141	0.06
Stitcher truck	23,600	10	2,360	590	236	1,003	944	4,133	2.29
Highway truck	23,600	10	2,360	590	236	1,003	944	5,133	2.29
Closer clamps	80	5	16	2	1	3	3	25	0.01
Staple guns	25	2	38	2	1	3	3	46	0.02
Mobile wrap machine	40,000	10	4,000	1,000	400	1,700	1,600	8,700	3.88
Harvest machine	1/ 20,000	5	4,000	500	200	850	800	6,350	2.84
	20,000	1	20,000	500	200	850	--	21,550	9.62
Tractor (40 hp)	7,000	10	700	175	70	300	280	1,523	0.68
Trailer	3,200	10	320	80	32	136	228	696	0.31
Bug (small tractor)	5,000	10	500	125	50	213	200	1,088	0.49
Forklift	6,000	10	600	150	60	255	240	1,305	0.58
Mobile packing platform (2)	10,400	5	1,040	260	104	442	416	2,262	1.01
Conveyor belts (4) 2/	14,430	10	1,443	361	144	613	577	3,139	1.40
Packing line and unloading equipment 2/	24,806	10	2,481	620	248	1,054	992	4,995	2.23
Wrapping equipment	2,500	5	500	63	25	106	100	794	0.35
Shed 2/	122,400	20	6,120	3,060	1,224	5,202	3,672	19,278	8.61
Cull disposal 2/	24,750	10	2,475	620	248	1,052	990	5,136	2.29

1/ $44,000 for pack-on-the-machine.
2/ Separate facilities maintained at Salinas (1,280 hours) and Imperial (960 hours).

Appendix table 7--Fixed and total costs for alternative lettuce harvesting systems at various operating hours, 1975

Harvesting systems	Fixed costs of equipment				Total costs			
	2,240 hours	1,680 hours	1,120 hours	560 hours	2,240 hours	1,680 hours	1,120 hours	560 hours
	Dollars per carton							
Nonwrap systems:								
Hand-cut, ground-pack	0.013	0.017	0.026	0.052	1.404	1.408	1.417	1.443
Machine-cut, pack-on-machine	.041	.054	.081	.163	1.207	1.220	1.247	1.329
Machine-cut, fieldside shed	.045	.057	.086	.172	1.186	1.198	1.227	1.313
Machine-cut, central shed	.077	.107	1/.155	2/ .309	1.248	1.296	3/ 1.344	4/ 1.498
Machine-cut, bulk-pack	.038	.051	.076	.153	1.021	1.037	1.062	1.141
Wrap systems:								
Hand-cut, machine-aid	.036	.047	.071	.142	2.045	2.056	2.080	2.151
Machine-cut, fieldside shed	.045	.058	.087	.174	2.012	2.025	2.054	2.141
Machine-cut, central shed	.078	.104	5/.156	6/ .312	2.0754	2.120	7/ 2.172	8/ 2.328
Machine-cut, tube-and-cube	.038	.051	.076	.153	1.647	1.663	1.688	1.767

1/ Or 0.125 for Salinas only or Imperial only.
2/ Or 0.249 for Salinas only or Imperial only.
3/ 1.314, one facility.
4/ 1.438, one facility.
5/ Or 0.125 for Salinas only.
6/ Or 0.251 for Salinas only or Imperial only.
7/ 2.141, one facility.
8/ 2.267, one facility.