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Title AN ANALYSIS OF COSTS AND EFFICIENCIES IN MECHANICAL CANEBERRY HARVESTING

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The purpose of this study, initiated early in the development of mechanical caneberry harvesting, was to provide timely information for early management decisions concerning mechanical harvesting. This was accomplished through an economic comparison of mechanical and hand harvesting of selected types and varieties of caneberries. Consideration was given to the economic effects of mechanical caneberry harvesting upon both growers and processors.

Hand harvesting costs of red raspberries, black raspberries, Thornless Evergreen and Marion blackberries were estimated by use of grower group interviews in a number of counties in Oregon.

Five types of mechanical harvesters were being operated in Oregon in 1963. Two of these were operated on a commercial basis while the other three were experimental. The two commercial machines were very similar with regard to their appearance, performance, and operating requirements. Because of a difference in

shaking mechanisms, one was used most successfully on black raspberries and the other on Marion and Thornless Evergreen blackberries.

Detailed economic engineering studies were conducted on all operations involving the one type of machine used on black raspberries. These studies involved the collection of data on speed and capacity of the machine, crew requirements, recovered yield per acre by picking, field loss, physical damage to berries and canes, turn-around times, loading and unloading times, and other pertinent factors. The study was designed so that relationships developed for this particular machine on black raspberries would have application to other machines and other berries. It is believed that a multi-berry shaking mechanism or interchangeable shaking mechanism will be developed which will not alter the operating requirements of the machine.

Field studies were made during the 1963 harvest season for both hand and machine picking operations to determine the relative picking efficiency of each method. Samples were taken in various rows throughout machine and hand harvested fields, and the berries dropped after each picking and those remaining on the canes after harvest were estimated.

If picking costs only are considered, costs of mechanically harvesting black raspberries are $85.63 per acre less than hand picking costs. When field loss or difference in recovered yield also is taken into account, this net economic advantage is reduced to only $25 per acre in favor of mechanical harvesting. It was estimated that from a total yield of 3, 000 pounds per acre, 2, 445 pounds would be recovered by the hand picking method and 2, 231 pounds by machine harvesting.

Because the mechanical harvesters are in the early stages of development, synthetic costs for improved levels of performance were also analyzed and compared with hand harvesting. It was found that mechanical harvesting costs could be further reduced by: increasing acreage harvested during a season, increasing recovered yield per acre, reducing harvester replacement cost, and lengthening expected harvester life.

Interviews with processors, although inconclusive, revealed both advantages and disadvantages of mechanically harvested cane-berries for processing. Processors generally agreed that the principal advantage of machine picked berries over those that are hand picked is their somewhat higher soluble solids content.

Although not quantitatively measurable, it appeared that there were increased processing costs resulting from the additional cleaning and sorting necessary because of the cull fruit and foreign material intermixed with the mechanically harvested berries when they arrived at the plant. In most cases mechanically harvested berries were utilized in products such as jam, jelly, puree, flavoring, and dye. For black raspberries these uses were not limiting, because this particular type of berry is not utilized to any extent in products requiring the whole berry form. For other berries used to a larger extent in whole berry form, this limitation would be more restrictive.

AN ANALYSIS OF COSTS AND EFFICIENCIES IN MECHANICAL CANEBERRY HARVESTING

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CHAPTER I

INTRODUCTION

Mechanization of agricultural harvesting is not new. Cyrus McCormick, who invented the reaper in 1831, is generally considered to be the man who began the development toward machine harvesting of agricultural crops. Numerous strides have been made in harvest mechanization since that time.

Mechanical harvesting may range from complete mechanization, where the crop is never touched by man, to hand harvesting aids. Hand harvesting aids are devices used to help hand pickers increase their harvesting efficiency. Both mechanical pickers and harvesting aids are the result of man's creative imagination and his persistence in trying to achieve the peak of efficiency.

Two of the most important economic factors encouraging mechanization have been a continuing increase in labor costs, and the low productivity of harvest labor. Grower interest in mechanized harvesting has been quickened in recent years by the unpredictability of the supply of farm labor.

Thousands of supplementary workers are needed for hand harvesting many agricultural crops in the United States. It is estimated that 425,000 migratory farm workers, 460,000 foreign nationals, and about 3, 000, 000 local people who live in the area of employment help harvest the fruit and vegetable crops in the United States each year. Migratory workers are mostly from the southern states, working in cotton and vegetable crops in the fall and winter and moving north to help harvest the fruit and vegetable crops in the spring and summer (30, p. 337) (42, p. 100-104).

The South in recent years is becoming increasingly more industrialized, more year-around employment is available in that area, and this has reduced the number of agricultural harvest migrants each year. Foreign nationals have been vital to the harvest of many agricultural crops. The continuation of this program seems doomed, however, as many groups strongly object to this source of help.

Beginning with the 1960 harvest, another factor greatly increased the interest in, and change-over to mechanization. Labor unions began to organize harvesting crews in the fruit belt of California. In some cases strikes were called, and growers were unable to recruit help to pick their crops. As a result, they sustained financial losses (30, p. 339). While union efforts to organize harvesting crews have not thus far been overly successful, it seems certain they will carry on their drive for some form or degree of organization of harvest labor.

For the above reasons, growers are interested in the development of mechanization that will lower costs through a reduction in the amount of labor required. Mechanical harvesting is feasible only if the savings in labor costs offset the cost of the machine and perhaps a lower quality and lower recovered yield which seems to be inherent in some mechanization.

Mechanical Harvesting Developments

During the past 15 years, there has been a rapid expansion in harvest mechanization. Harvest operations have been mechanized in varying degrees for numerous row crops, including potatoes, sugar beets, cotton, carrots, tomatoes, snap beans, peas, peanuts, and tobacco. Other row crops for which harvesting innovations are presently being developed are lettuce, cucumbers, asparagus, cantaloupes, and grapes. An "all mechanical" harvesting operation is possible for such tree crops as walnuts, filberts, almonds, pecans, prunes, and tart cherries (6). Power-driven harvesting equipment is also being developed and used to a limited extent for olives, figs, peaches, apples, sweet cherries, pears, and apricots.

Mechanization of Tomato Harvesting

The mechanical tomato harvester, for example, is moving into an operation that requires tremendous amounts of labor. In 1962, at least 25 tomato harvesters were being used by commercial growers in California. Although there are several different types of machines, they are similar in their operation (10)(24)(25).

One of the self-propelled mechanical tomato harvesters uses a pickup mechanism, consisting of two counter-rotating discs in combination with convoluted belts. The discs, which travel slightly below the surface of the ground, not only gather in the entire vine, but also loose fruit that may be lying on the surface. Essentially all the fruit is recovered from the bed (10).

This tomato harvesting machine has an average speed of 0.9 miles per hour, and can handle up to nine tons per hour. The machine accommodates a total of 12 sorters and 1 operator. Five sorters are on each side belt and two are on a conveyor that receives loose fruit directly from the pickup conveyor (10).

The harvester separates the tomatoes from the vines and dirt, and the workers at the sorting belts remove any green or defective tomatoes which may be present. The remaining fruit is elevated from the harvester to either bins or boxes on a flat bed trailer beside the harvester.

Because the harvesters are being used for a one-time operation, a major problem faced by tomato growers is obtaining uniform maturity. Varieties have been and are being developed for uniform ripening (24).

Mechanization of Cantaloupe Harvesting

Another mechanical harvester, this one in the experimental stage, is being developed by agricultural engineers at the University of California to harvest cantaloupe. The self-propelled harvester proceeds down a row of cantaloupe and gently lifts the vines, and the melons at the half to full-slip stage of ripeness fall from the vines onto a conveyor belt. Another machine is used well before harvest to "side-rake" and train the vines in one direction across the field. About 75 percent of a cantaloupe crop comes off during a short period of time, and it has been estimated that a harvesting machine used at the proper time could pick an economic portion of the crop in a few trips (5).

Mechanization of Prune Harvesting

Various methods of mechanically harvesting prunes are used, depending upon size of the orchard, yield, size of tree, age of tree, and climatic conditions. The method most commonly used, however, is the powered catching frames which come together under a tree and receive the prunes when they are shaken loose by either an inertia shaker or trunk shaker. The fruit rolls down the catching frames to a conveyor on each frame where it is then delivered to bulk bins. Only four men are needed to operate a two-frame set which can do the work of from 30 to 40 hand pickers (13).

Some Oregon growers have used and experimented with mechanized prune harvesting. The use of boom shakers in combination with hand pickup is the most common method of mechanization. Two completely mechanized harvesting operations have also been used, but on a limited experimental basis. One of these is a boom shaker in combination with a powered catching frame. The other is a boom shaker in combination with a ground pickup machine.

Not all of the prune harvesting problems are solved by turning to mechanical harvesting. Tree injury by the various shaking mechanisms appears to have some undesirable results (8).[1/] Lack of uniform maturity in many areas has created difficulties for both the growers and processors. Improvements are being made in machine design and pruning practices, and plant breeders continue in their search for varieties with uniform maturity.

Mechanization of Cherry Harvesting

The mechanization of the tart cherry harvest is similar to that in prune harvesting. Indeed, a number of Michigan growers are harvesting both crops with the same equipment (11). Either

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1/ Ceratocystis canker, a tree disease resulting from bruised bark tissue, spreads into healthy tissue around the bruised area, eventually girdling scaffold limbs or tree trunks.

hand moved or powered catching frames are used in conjunction with either a boom or inertia shaker to free the cherries. It has been found that tart cherry quality comparable to or better than that obtained with hand harvesting may be secured. This has been accomplished by transferring the harvested fruit into tanks containing cold water, which are then hauled to the processing plant (23).

Experience in Michigan during the 1962 tart cherry harvest season indicated that quality packs of machine-harvested tart cherries can be made with only minor changes in existing processing methods. If the additional packing costs of $3 to $6 per ton are viewed in the light of the $30 to $40 per ton decreases in harvesting costs brought about by mechanical harvesters, substantial over-all savings to the industry are apparent (41, p. 18).

Mechanically harvesting tart and sweet cherries has also been done in Oregon on a more limited basis. Boom shakers and hand moved catching frames are typically used.

Mechanization of Strawberry Harvesting

The mechanization of the berry harvest is also developing rapidly. In strawberries, the emphasis has been toward harvesting aids which attempt to increase picker productivity, while maintaining berry quality. These aids have ranged from single-row picking aids to multi-row personnel carriers, covering from 8 to

14 rows (15)(16).

One machine which has been tried is operated by the strawberry picker himself as he leans forward on his chest. Pressure on the chest support can be used to move the machine down the rows, leaving both hands free for harvesting (3, p. 135).

The multi-row personnel carriers for strawberries often have lights which serve both for illumination and to keep the pickers' hands warm. Such an arrangement allows for harvesting on a 24 hour basis. It has been found that the berries harvested at night are of a better quality than those harvested during the heat of the day. In addition, the damage to plants and green berries is reduced (28).

Mechanization of Blueberry Harvesting

More complete harvest mechanization is available for blueberries than is the case for strawberries and a number of other fruits. In 1958, United States Department of Agriculture engineers working at Michigan State University developed hand-held vibrators and portable collecting units which reduced the cost of harvesting 4.5 cents per pound below the 10-year average of 8 cents per pound (31, p. 1). About 35 percent of the Michigan crop and 20 percent of the New Jersey crop (these two states produce approximately 70 percent of the United States cultivated blueberries) were harvested mechanically with these units in 1963 (31, p. 1-2). Washington state blueberry growers are also making considerable use of this harvesting method (31, attached sheet).

The United States Department of Agriculture engineers at Michigan State University are presently developing a continuous blueberry harvester in cooperation with two equipment manufacturing companies.[1/] Although still experimental, the continuous harvester is expected to detach ripe berries only from the bushes, collect the berries, and transfer them into containers. It has been estimated that 3 men using the experimental machine are able to do the work of 120 men harvesting by hand, resulting in a harvest cost of 0.5 cents a pound (31).

Extent of Mechanical Caneberry Harvesting

In mechanical harvesting of caneberries more elaborate machines are presently being used than for most other berries. The early mechanical caneberry harvesters were developed by growers. In addition to the growers' machines, others are being developed by equipment companies, processors, and state universities. Much of the development has been directed toward continuous automatic harvesting machines.

1/ By continuous harvester, it is meant that the machine proceeds down a row, removing fruit ready for harvest without pausing at each plant or group of plants.

All of the harvesters operate on the principle that a mature berry may be detached from the fruit spur more easily than an immature berry. Detachment of the mature fruit is accomplished by imparting a shaking motion to the fruit-bearing canes. The harvesters differ primarily in the mechanism used to achieve the shaking action. The fact that the shaking action imparted to the canes removes the mature berries first is the characteristic of caneberries which allows multiple pickings during a harvest season.

Most of the work in the development of mechanical harvesting equipment for caneberries has been done in the Pacific Coast states where production is concentrated. The Pacific Coast states comprised about 50 percent of the United States caneberry acreage and 74 percent of the production in 1959 (38).[1/] Caneberries are an important commercial crop to many growers in this area. For the 1963 harvest, growers in the three Pacific Coast states received a gross income of $13,170,000 (35)(36)(37). Caneberry production for the area increased during the years 1950 through 1957 but has since declined below the 1957 figure (Figure 1).

1/ A more recent comparison of the importance of the Pacific Coast states in the production of caneberries in terms of acreage and production is not possible because of the lack of data. The United States Agricultural Census is the only published source of the total caneberry acreage and production. Therefore, comparison of the importance of various areas with United States production may not be done, except for United States Agricultural Census years.

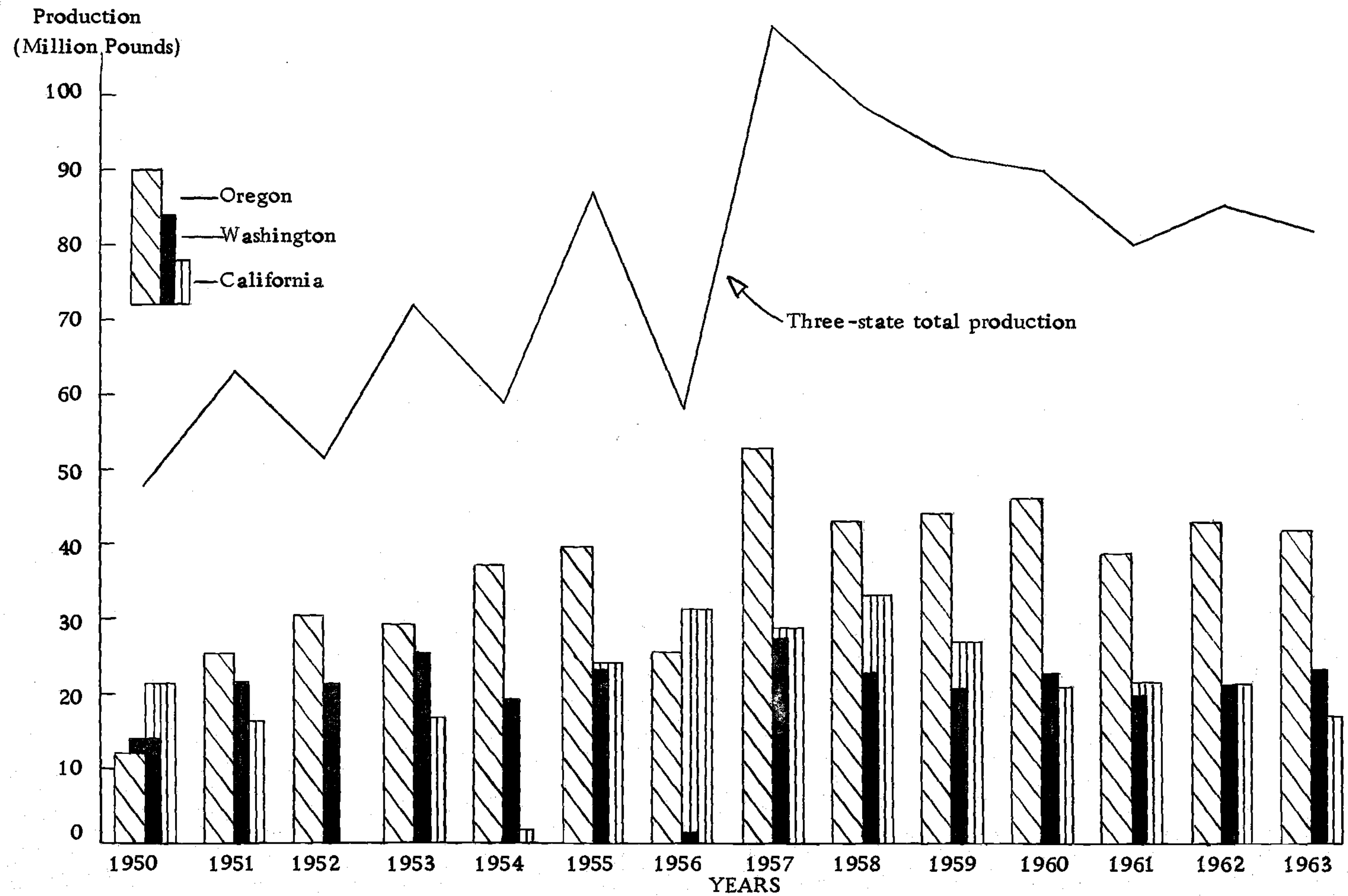

Figure 1. Production of caneberries in the Pacific Coast states, 1950 - 1963 /1

/1 Includes black raspberries, red raspberries, and blackberries with the following exceptions: Washington data do not include Boysenberry, Youngberry and Loganberry production; California data are not available for 1952 and in 1954 include only Loganberry production. Source: (35), (36), (37).

There has been a similar pattern during this period in Oregon. Over 51 percent of the caneberry production in the Pacific Coast states for 1963 was produced in Oregon (35)(36)(37).[1/] Caneberry growers in Oregon received \$6.3 million for their 1963 crop. Raspberries accounted for \$3.6 million and blackberries for \$2.7 million of the total cash value (36). If one could measure all of the dollars which caneberries generate through processing, storage, transportation, pickers, taxes, and other factors, a much larger impact on the Oregon economy would be evident.

Mechanical caneberry harvesters have been used with varying degrees of success on the various types and varieties of caneberries.

The term "caneberries" usually refers to those plants having a hollow or pithy jointed stem, usually slender and more or less flexible, and/or the fruit thereof. But because of this wide classification and the greater economic importance of certain groups, caneberries will be used here to refer to two groups -- blackberries and raspberries.

The blackberry group may be broken into two types -- erect and trailing -- differing primarily in the character of their canes.

1/ Appendix Table 1 shows production of caneberries for the three Pacific Coast states. Appendix Tables 2 through 4 show production of caneberries by type for the three Pacific Coast states.

Trailing blackberries, also called dewberries, ground berries, or running blackberries, have canes that are not self-supporting; the canes must be tied to poles or wire trellises in rows to facilitate cultivation and harvesting. Varieties of trailing blackberries frequently grown in the Pacific Coast states are Aurora, Boysen, Cascade, Chehalem, Logan, Marion, Olallie, Pacific, and Young. Erect blackberries have arched, self-supporting canes. However, the two erect blackberry varieties most frequently grown in the Pacific Coast states, Thornless Evergreen and Himalaya, are generally trained to wire trellises as are the trailing types (34, p. 3, 10-12).

The two blackberry types also differ in their fruit characteristics. The fruit clusters of the trailing blackberry varieties are smaller and more open than those of the erect blackberry varieties.

Raspberries, the second group into which caneberries have been divided, may be broken further into three types -- red, black, and purple. Purple raspberries are hybrids of red and black raspberries and are grown commercially only in Western New York. Red raspberries have erect canes, but because of their height, 4 to 8 feet, they are usually trained to, or between, a wire trellis in rows. Black raspberries, commonly referred to as blackcaps, have arched canes and are not trained to a trellis system.

At least 16 mechanical caneberry harvesters consisting of five different types were used or experimented with during the 1963 harvest season in Oregon. Two of these machines are being built on a commercial basis. As a result of the mechanism used by each to achieve the shaking action, one of the harvesters performs most satisfactorily on black raspberries and the other on select blackberry varieties.

Mechanical Harvesting, An Interdisciplinary Problem

The combined efforts of many disciplines have been involved in meeting the challenge of mechanical harvesting. Many of the crops now being harvested mechanically were once considered impossible to harvest in this way. To mechanically harvest certain crops successfully has required the development of varieties particularly suited to harvest mechanization. Other crops have required new planting, pruning, and training systems, while still others have necessitated new concepts in mechanical harvesting and machine design to facilitate successful harvesting.

Mechanization of harvesting points up the need for improved methods of handling the harvested product. Increased use of bulk handling methods is generally involved, along with prepackaging and precooling for some crops. Harvest mechanization and new handling methods in many instances result in changes at the processor level. These changes resulting from the type of harvest and method of handling may mean either increased or decreased costs for the processor.

Mechanical harvesting not only affects grower costs but may also have an impact on processors, other marketing firms, and perhaps even on the consumer. For this reason cooperation among growers, horticulturalists, agricultural engineers and economists, food technologists, and processors is needed in order to properly evaluate mechanical harvesting. The over-all attempt is toward increased efficiency in the harvest operation, in the processing industry, and in the marketing events which follow. The overriding criterion governing these developments is an economic one; that is, are the developments profitable?

In determining the feasibility of mechanically harvesting caneberries, possible cost reductions through harvest mechanization need to be estimated and evaluated. Consideration also should be given to the impact on acreage requirements, yields, product quality, training systems and other cultural practices, marketing functions, and many other factors before machine harvesting is adopted. In many previous studies relating to mechanical harvesting, only harvesting costs have been considered. This is important but only one aspect of the problem.

An economic evaluation of a new method is too often made after it has been commercially adopted. It is the intent of this research, initiated early in the development of mechanical caneberry harvesters, to provide timely information upon which growers and processors may base early management decisions.

Objectives of the Study

The over-all objective of this study is to quantify and analyze the costs and efficiencies of mechanically harvesting caneberries. Consideration is given to the economic effects of mechanical caneberry harvesting upon both the grower and the processor. The specific objectives of this study are as follows:

1. To estimate direct and indirect costs of hand harvesting selected types and varieties of caneberries.
2. To estimate requirements and costs of mechanically harvesting selected types and varieties of caneberries.
3. To make an economic comparison of mechanical versus hand harvesting of selected types and varieties of caneberries, considering such factors as cost to the grower and processor, effects on yield, quality of harvested product, and cultural implications.

The selected groups of caneberries which will be considered are blackberries, red raspberries, and black raspberries. For blackberries, however, only two varieties, Thornless Evergreen and Marion, will be dealt with. These groups have been selected because they compose the bulk of caneberry production in the United States and the Pacific Coast states, and also because of the status of mechanical harvesting for these and other berries. The two blackberry varieties were selected because considerable mechanical harvesting work has been done on them in Oregon.

The data upon which this study is based were obtained during the 1963 caneberry harvest season and the following fall months. The study was carried out as an Oregon State Agricultural Experiment Station project with the cooperation of caneberry growers, processors, and equipment manufacturers in Oregon. The methods used in obtaining the data will be presented in the ensuing chapters.

CHAPTER II

ESTIMATED COSTS OF HAND HARVESTING SELECTED TYPES AND VARIETIES OF CANEBERRIES

Hand picking is the long established method of harvesting caneberries. In order to properly determine the economic advantage or disadvantage of a new method of harvesting these berries, the current physical requirements and related costs of the conventional method should be known. For this reason, estimated costs of hand harvesting black raspberries, red raspberries, Thornless Evergreen blackberries, and Marion blackberries were obtained to provide a norm for comparison with mechanical harvesting in Chapter IV.

Procedures Used in Estimating Costs

The grower group interview technique was followed to obtain estimates of physical requirements and costs of hand harvesting. Group interviews were conducted in several Oregon counties having large acreages of the selected caneberries. Each group consisted of from four to seven representative commercial growers and the county agricultural extension agent.

The general procedure for conducting the group interview was to develop with each group what was considered to be the typical harvest operation for a commercial producer of the particular type or variety of caneberry being considered. After determining the typical producing acreage, the interview proceeded to a determination of the physical requirements and costs of hand harvesting, based upon a full-production year. Using this method, the typical costs and factors involved in hand harvesting each of the selected caneberries were obtained, and this information was used in estimating costs of hand harvesting with varying yields and acreages.

Hand harvesting costs have been divided into direct and indirect costs. Direct costs include only the rate per pound which the picker receives. All other costs are included as indirect costs. Hand harvesting costs have been classified in this manner as opposed to classifying them as fixed and variable costs. Reasons for doing this are that fixed costs would be a small part of total harvesting costs if so classified, and caneberry growers themselves classify their hand harvesting costs as direct and indirect.

In addition to the group interviews to estimate costs of hand harvesting, detailed field studies were conducted during the 1963 harvest season to estimate field loss in the hand picking operation. Studies to determine the amount of berries dropped or knocked off on the ground were made after each picking for black raspberries and Thornless Evergreen berries. Grower fields were selected and samples taken after each picking to determine the amount of berry loss. A similar procedure was followed after all pickings had been completed to determine the pounds of berries remaining on the canes after harvest. These berries are an economic cost of this hand harvest operation and are so considered in Chapter IV.

Analysis of Hand Harvesting Costs

Black Raspberries

The typical black raspberry operation utilizing the hand pick method of harvesting consists of approximately 20 acres. Total recovered yield per acre is estimated to average about 2,250 pounds. This yield is obtained through three pickings with the yield per picking estimated to be 900, 1,125, and 225 pounds respectively.

The picking season in the normal year occurs between July 1 and July 30 and lasts for about 15 days. An average of 36 hand pickers working approximately seven hours per day are required for all three pickings in the 20-acre operation. Each picker harvests approximately 83 pounds per day. An estimated 75 percent of all black raspberry hand pickers work for the same grower for all three pickings and, therefore, become eligible for receipt of a bonus over and above the base rate paid.

In addition to picker labor, a limited amount of supervisory or nonpicker labor is required. This includes a manager, field boss, loader-checker, and record keeper. Each of these supervisory workers works every day during the harvest season, but each works a different number of hours per day: the manager works an estimated average of 12 hours per day (50 percent as direct supervision), the field boss eight hours, the loader-checker seven hours, and the record keeper one hour per day. A total of 420 hours of supervisory labor is required during the harvest season for the 20 acre black raspberry operation. The total direct and supervisory labor is estimated to be 210 man-hours per acre for all pickings.

Equipment used in connection with the black raspberry hand harvest is limited but includes the following for the typical grower: 90 10-quart pails, a 1-1/2 ton truck, a school bus, 2 water barrels, 6 outdoor toilets, and miscellaneous equipment such as paper cups and punches. The 10-quart pails are estimated to have a 5-year life. The 1-1/2 ton truck's depreciation period is estimated to be 15 years. It is driven approximately 4,000 miles per year, 200 of which are in conjunction with the black raspberry harvest. Gasoline consumption for the truck is estimated to be 7 miles per gallon.

The school bus has an assumed life of ten years. It is driven approximately 2,000 miles per year, with 1,000 miles being in connection with the black raspberry harvest. Gasoline consumption for the bus is about the same as that of the truck.

The water barrels and outdoor toilets are each estimated to have a 10-year life. Fifty percent of the use of these facilities is allotted to the black raspberry harvest. The miscellaneous items in general are assumed to be depleted during the harvest season.

Both direct and indirect costs for the typical 20-acre black raspberry harvest operation are shown in Table 1. The black raspberry direct harvest costs are 5.75 cents per pound, while indirect harvest costs are estimated to be 2.33 cents per pound. The resulting total harvest cost is 8.08 cents per pound or $181.80 per acre.

Red Raspberries

The typical red raspberry grower has harvest requirements similar to the black raspberry grower, with the differences resulting principally from the greater yield of red raspberries. Typically, according to the growers interviewed, 20 producing acres are harvested, with a total recovered yield per acre of 9,000 pounds. Because of the higher total recovered yield, five pickings are normally required. Recovered yields per acre by picking are estimated to be as follows: first picking, 1,000 pounds; second picking, 1,500 pounds; third picking, 2,750 pounds; fourth picking, 2,750 pounds; and the fifth and final picking, 1,000 pounds.

A total of 20 picking days normally is required to complete the red raspberry harvest, with 120 pickers working an estimated 6 hours each day for a total picker labor time of 14,400 hours for

Table 1. Estimated costs of hand harvesting black raspberries for a typical Willamette Valley grower in 1963. /1

Item	Costs Per 20 Acres	Percentage of Harvest Costs
Direct:		
Picker Labor /2	$2,587.50	71.1
Total Direct Cost	$2,587.50	71.1
Indirect:		
Supervisory Labor /3	$ 667.50	18.3
Social Security /4	24.21	0.7
State Industrial Accident Insurance /5	93.03	2.6
Equipment /6	265.40	7.3
Total Indirect Cost	$1,050.14	28.9
Total Harvest Cost	$3,637.64	100.0

Total harvest cost per pound is 8.08 cents.

/1 Based upon 20 producing acres having an average recovered yield of 2,250 pounds per acre.

/2 Based upon a piece rate of 5 cents per pound, plus a 1 cent bonus paid to the estimated 75 percent of the pickers who pick the entire season.

/3 Wage rates computed on an hourly basis as follows: manager, $1.50; field boss, $2.25; loader-checker, $1.00; and record keeper, $1.50.

/4 Computed as 3.625 percent of wages paid supervisory labor only.

/5 Fifty percent of an annual registration fee of $7.50 is prorated to black raspberry harvest. The rate for pickers is $1.95 per $100 of payroll, plus $.02 per picker per day. Direct supervisors take the same rate as the pickers. For all other labor, the rate is $12.40 per $100 of payroll, plus $.02 per employee per day. All of these State Industrial Accident Insurance costs are paid by the operator.

/6 Includes the following annual costs chargeable to black raspberry harvest:

Pails	$16.15	2 water barrels	$ 1.30
1-1/2 ton truck	34.00	6 outdoor toilets	7.80
School bus	180.00	Miscellaneous equipment	26.15

the 20 acres. The average picker will harvest approximately 75 pounds per day over the length of the harvest season.

Supervisory labor required for the red raspberry harvest includes the following jobs: manager, checker, 2 supervisors, 2 bus drivers, truck driver, and record keeper. Time worked per day in each job is estimated to be about as follows: manager -- 12 hours (about 75 percent as direct supervision), checker -- 8 hours, supervisors -- 7 hours each, bus drivers -- 4 hours each, truck driver-- 5 hours, and record keeper -- 1.25 hours. A total of 963 hours of supervisory labor is typically used for the 20-acre operation during the harvest season. Total harvest labor, including picker and supervisory labor, during the typical red raspberry harvest season is estimated to be 15,363 hours for all pickings on the 20-acre field. The resulting man-hours of labor per acre are approximately 768 hours.

Equipment used in connection with the red raspberry hand harvest includes the following for the typical grower: 300 picker pails, a 1-1/2 ton truck, 3 school busses, a car, 2 water barrels, 8 outdoor toilets, and miscellaneous items. The depreciation periods for the pails, truck, and school busses are the same as those presented for the black raspberry harvest. The truck is used a total of 4,000 miles per year, 1,500 miles being in conjunction with the red raspberry harvest. Gasoline consumption for the truck is estimated at 7 miles per gallon.

The three school busses are used a total of 5,000 miles, 80 percent of which is assignable to the red raspberry harvest. Gasoline consumption for the school busses is assumed to be the same as for the truck.

The car, used 2,500 miles in conjunction with the red raspberry harvest, is estimated to have a total yearly use of 12,000 miles. The length of useful automobile life is assumed to be 10 years.

As with the black raspberry harvest, the water barrels and outdoor toilets are each assumed to last 10 years. Fifty percent of the use of these facilities is allotted to the red raspberry harvest. Miscellaneous items and equipment used in the harvest operation include, among other minor items, four tables and a cash box.

Direct and indirect costs for the typical 20-acre red raspberry harvest operation are shown in Table 2. Red raspberry direct harvest costs are 5.42 cents per pound, while the indirect costs are estimated to be 1.67 cents per pound. The resulting total harvest cost per pound is 7.09 cents. Total harvest cost per acre is $638.10.

Thornless Evergreen Blackberries

The typical Thornless Evergreen blackberry producing acreage was estimated to be five acres. Five pickings are normally required to obtain an expected total recovered yield per acre of 10,000 pounds.

Table 2. Estimated costs of hand harvesting red raspberries for a typical Willamette Valley grower in 1963. /1

Item	Costs Per 20 Acres	Percentage of Harvest Costs
Direct:		
Picker Labor /2	$ 9,756.00	76.5
Total Direct Cost	$ 9,756.00	76.5
Indirect:		
Supervisory Labor /3	$ 1,294.50	10.1
Social Security /4	46.93	0.4
State Industrial Accident Insurance /5	304.31	2.4
Equipment /6	$ 1,355.77	10.6
Total Indirect Cost	$ 3,001.51	23.5
Total Harvest Cost	$12,757.51	100.0

Total harvest cost per pound is 7.09 cents.

/1 Based upon 20 producing acres having an average recovered yield of 9,000 pounds per acre.

/2 Based upon a piece rate of 5 cents per pound for first three pickings and 6 cents per pound for last three pickings, or a season rate per pound of 5.42 cents.

/3 Wage rates computed on an hourly basis as follows: manager, $1.50; checker, $1.00; supervisors, $1.43 each; bus drivers, $1.50 each; truck driver, $1.00, and record keeper, $1.50.

/4 Computed as 3.625 percent of wages paid supervisory labor only.

/5 Eighty percent of an annual registration fee of $7.50 is prorated to red raspberry harvest. The rate for pickers is $1.95 per $100 of payroll, plus $.02 per picker per day. Direct supervisors take the same rate as the pickers. For all other labor the rate is $12.40 per $100 of payroll, plus $.02 per employee per day. All of these State Industrial Accident Insurance costs are paid by the operator.

/6 Includes the following annual costs chargeable to red raspberry harvest:

Pails ---------	$53.82	2 water barrels ---	$ 1.30
1-1/2 ton truck--	255.00	8 outdoor toilets ---	13.04
3 school busses -	800.00	miscellaneous equipment ------	56.65
Car -----------	175.00		

The recovered yields per acre by pickings one through five respectively are estimated by the growers to be as follows: 1,500 pounds, 2,500 pounds, 3,000 pounds, 2,000 pounds, and 1,000 pounds.

The Thornless Evergreen blackberry harvest season typically lasts about 24 picking days. The first 3 pickings occur during the first 13 days, with an average of 20 people picking about 6 hours each day. The fourth picking lasts about 6 days and the fifth about 5 days. Twelve people pick 6 hours per day each during the fourth picking, and 10 people pick 6 hours per day each during the fifth picking. Smaller picker crew sizes are typically used during the latter 2 pickings due to a lack of available harvest labor. A total of 2,292 hours of picker labor are used to complete the harvest. The pickers harvest approximately 131 pounds per day each over the length of the harvest season.

Supervisory labor required for the Thornless Evergreen blackberry harvest consists of a manager and record keeper. The manager works about 9 hours each harvest day, with approximately 75 percent of his time spent in direct supervision. The record keeper works an estimated 10 hours during the harvest season. A total of 226 hours of supervisory labor are used. The total hours of harvest labor, including picker and supervisory labor, during the season, are estimated to be 2,518 hours for all pickings on the 5 acre field. The harvest time, or man-hours of labor, per acre is approximately

504 hours.

Equipment used in the harvest of Thornless Evergreens, like the other berries, is limited but includes the following for the typical grower: 50 10-quart pails, a 1-1/2 ton truck, a car, 1 water barrel, 2 outdoor toilets, and miscellaneous items. Depreciation periods for all equipment are the same as those presented for the other caneberries. The truck has a total estimated use of 5,000 miles per year, 600 miles being in connection with the Thornless Evergreen harvest. The gasoline consumption rate for the truck is identical to that assumed for the other harvest operations above. The car use is assumed to be 750 miles for the harvest, having an estimated total use of 12,000 miles per year. Twenty-five percent of the use of the water barrel and outdoor toilets is prorated to the Thornless Evergreen blackberry harvest.

Both direct and indirect costs for the typical 5-acre Thornless Evergreen blackberry harvest are shown in Table 3. Direct harvest costs are 4.17 cents per pound, with indirect harvest costs estimated to be 1.21 cents per pound. The resulting total harvest cost per pound is 5.38 cents. Total harvest cost per acre is $538.

Marion Blackberries

The typical producing acreage for Marion blackberry growers in Oregon is estimated to be 4 acres. Four pickings are required

Table 3. Estimated costs of hand harvesting Thornless Evergreen blackberries for a typical Willamette Valley grower in 1963. /1

Item	Costs Per 5 Acres	Percentage of Harvest Costs
Direct:		
Picker Labor /2	$2,085.00	77.5
Total Direct Cost	$2,085.00	77.5
Indirect:		
Supervisory Labor /3	339.00	12.6
Social Security /4	12.29	0.5
State Industrial Accident Insurance /5	67.58	2.5
Equipment /6	184.85	6.9
Total Indirect Cost	$ 603.72	22.5
Total Harvest Cost	$2,688.72	100.0

Total harvest cost per pound is 5.38 cents.

/1 Based upon 5 producing acres having an average recovered yield of 10,000 pounds per acre.

/2 Based upon a piece rate of 4.17 cents per pound.

/3 Wage rates computed on an hourly basis as follows: manager - $1.50; and record keeper - $1.50.

/4 Computed as 3.625 percent of wages paid supervisory labor only.

/5 Fifty percent of an annual registration fee of $7.50 is prorated to Thornless Evergreen blackberry harvest. The rate for pickers is $1.95 per $100 of payroll, plus $.02 per picker per day. Direct supervisors take the same rate as the pickers. For all other labor, the rate is $12.40 per $100 of payroll, plus $.02 per employee per day. All of these State Industrial Accident Insurance costs are paid by the operator.

/6 Includes the following annual costs chargeable to Thornless Evergreen blackberry harvest:

Pails	$ 7.80
1-1/2 Ton Truck	96.00
Car	52.88
Water Barrel	.55
2 Outdoor Toilets	1.30
Miscellaneous Equipment	26.32

to harvest an estimated total recovered yield per acre of 8,000 pounds. Recovered yields per picking are estimated to be as follows: first picking - 1,500 pounds, second picking - 2,500 pounds, third picking - 2,500 pounds, and fourth picking - 1,500 pounds.

The Marion blackberry harvest season typically continues for approximately 20 picking days with an average of 8 hand pickers working 8 hours per harvest day. This results in an estimated total picker labor time of 1,280 hours for the 4 acres. The average picker harvests approximately 200 pounds per day over the length of the harvest season.

Supervisory labor required for the Marion blackberry harvest includes a manager and record keeper. The manager works approximately 11 hours each harvest day, with about 75 percent of his time spent in direct supervision. The record keeper works a total of 10 hours during the harvest season. A total of 1,510 hours of harvest labor, including picker and supervisory labor, are typically required during the harvest season for the 4-acre operation. The resulting man-hours of labor per acre would be 378 hours.

The following equipment is used in the Marion blackberry hand harvest: 60 carriers, a 1-ton pickup, 1 water barrel, 2 outdoor toilets, and miscellaneous items. It was the concensus of opinion among the growers interviewed that either a labor camp or transportation are normally provided. The useful life of the carriers is estimated to be 4 years. The depreciation period for the pickup is assumed to be 10 years. The pickup is estimated to have an annual use of 5,000 miles, 200 miles being for this particular berry harvest. The water barrel and outdoor toilets are depreciated over a 10-year period.

The direct and indirect costs for the typical 4-acre Marion blackberry harvest operation are shown in Table 4. The direct harvest costs are 3.50 cents per pound, with indirect harvest costs amounting to 1.94 cents per pound, making a total harvest cost per pound of 5.44 cents or $435.20 per acre.

Other Hand Harvesting Considerations

Another consideration affecting caneberry hand picking operations in Oregon, not quantified above but which should be mentioned, is the availability of picker labor. This is particularly important for the late maturing berries because of the starting of school in the fall and competition from other crops at that time of year. The impact of the available labor supply toward the end of the harvest season may influence the grower to reduce the number of pickings or at least not to consider additional pickings even when the amount of berries remaining on the canes might justify an additional pick if labor were available.

Table 4. Estimated costs of hand harvesting Marion blackberries for a typical Willamette Valley grower in 1963. /1

Item	Costs Per 4 Acres	Percentage of Harvest Costs
Direct:		
Picker Labor /2	$1,120.00	64.4
Total Direct Cost	$1,120.00	64.4
Indirect:		
Supervisory Labor /3	348.00	20.0
Social Security /4	12.62	0.7
State Industrial Accident Insurance /5	42.73	2.5
Equipment /6	216.03	12.4
Total Indirect Cost	$ 619.38	35.6
Total Harvest Cost	$1,739.38	100.0

Total harvest cost per pound is 5.44 cents.

/1 Based upon 4 producing acres having an average recovered yield of 8,000 pounds per acre.

/2 Based upon a piece rate of 3.5 cents per pound.

/3 Wage rates computed on an hourly basis as follows: manager - $1.50; and record keeper - $1.50.

/4 Computed as 3.625 percent of wages paid supervisory labor only.

/5 Twenty-five percent of an annual registration fee of $7.50 is prorated to Marion blackberry harvest. The rate for pickers is $1.95 per $100 of payroll, plus $.02 per picker per day. Direct supervisors take the same rate as the pickers. For all other labor the rate is $12.40 per $100 of payroll plus $.02 per employee per day. All of these State Industrial Accident Insurance costs are paid by the operator.

/6 Includes the following annual costs chargeable to Marion blackberry harvest:

Carriers	$ 10.08
1-Ton Pickup	24.00
Water Barrel	1.30
2 Outdoor Toilets	5.20
Labor Camp (housing) or Transportation	160.00
Miscellaneous Equipment	15.45

Effects of Yield Variation on Harvest Costs

Total recovered yield per acre may vary because of weather, cultural practices, variations in field loss, and other factors. As total recovered yield per acre increases, the indirect harvest requirements and costs do not increase in direct proportion. Additional pickers are required to harvest increased per-acre yields, but the required supervision and other indirect costs change little for a given size of operation. Direct harvest costs per unit remain constant with increased yields for the typical grower while indirect costs per unit decline. As a result the total cost per pound harvested decreases with increased recovered yields per acre as shown in Figure 2 for black raspberries. The same relationship exists for the other selected caneberries.[1/]

Results of the field loss studies for black raspberries and Thornless Evergreens indicated a loss through drops of approximately 5 percent of total recovered yield per acre for all pickings. Based upon this percentage relationship, the absolute berry drop for black raspberries per acre by order of picking is estimated to be: first picking - 64 pounds; second picking - 45 pounds; and third picking - 7 pounds. Total drop for all pickings is estimated to be 116

1/ For a further quantification of the effect for the other caneberries, see Appendix Tables 6 through 8.

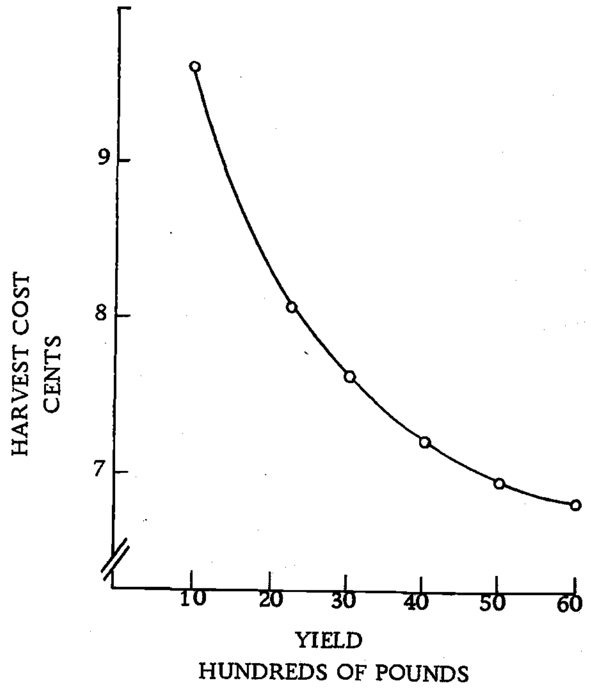

Figure 2. Estimated hand harvesting costs per pound for black raspberries with varying levels of recovered yield per acre. /1

/1 For a more detailed breakdown of costs see Appendix Table 5

pounds. An estimated 392 pounds per acre were left on the canes after completion of harvesting in 1963. For more specific information concerning results of the field loss studies for black raspberries and Thornless Evergreens, see Appendix Tables 9, 10, and 11. As was mentioned earlier, the economics of this field loss is considered in Chapter IV.

Hand Harvesting Costs Relative to Total Production Costs

Based on the above estimates of hand harvesting costs and recent estimates of nonharvesting costs of producing caneberries made by the Cooperative Extension Service of Oregon State University, it can be concluded that hand harvesting costs are a major component of total costs. Estimated costs of hand harvesting expressed as a percentage of total production costs are as follows: red raspberries -- 59 percent; black raspberries -- 44 percent; Thornless Evergreen blackberries -- 57 percent (7).

With harvesting costs such a large portion of total costs, the great amount of interest in mechanical harvesting of caneberries is not surprising.

CHAPTER III

ESTIMATED COSTS OF MECHANICALLY HARVESTING SELECTED TYPES AND VARIETIES OF CANEBERRIES

Developmental Status of Mechanical Caneberry Harvesters

Several caneberry harvesters are being developed and experimented with in Oregon. As mentioned in Chapter I, at least 16 mechanical caneberry harvesters consisting of five different types were used during the 1963 harvest season in Oregon. Two of these have been commercially adopted while the others were used on an experimental basis. In addition, some experimental work has been conducted with mechanical caneberry harvesting aids. Most of the developmental work, however, has been directed toward a machine which will harvest continuously and automatically.

Harvesters developed to date are primarily self-propelled, one-row machines which straddle the row while shaking the canes. The two commercially adopted machines are similar in appearance, both being built on inverted "U" type frames.

One of these machines is somewhat larger than the other. Its wheel base is 6 feet 6 inches by 9 feet, and the maximum outside dimensions are approximately as follows: 9 feet in width, 25 feet in length, and 12 feet in height. The harvester weighs approximately 6 tons. Power is obtained from a 35 horsepower engine for either a fluid drive, four-wheel chain drive, or a two-wheel chain drive.

This harvester uses a solid oscillating wooden panel on each side of the row as the shaking mechanism. Only those berries ready for harvest are removed by controlling the oscillation rate. Different types of caneberries require different rates of oscillation. Other factors influencing the adjustment of this action include temperature, time of day, picking, and the type of end use for which the berries are being picked.

When the mature berries have been shaken loose by the oscillating panels, they fall onto catching plates which are spring-loaded and ride tightly against the lower part of the canes. These plates are slightly tilted, and their flexing action around the canes moves the berries into conveyors at each side of the machine. The picked fruit is then transported to the top of the machine where it is air-cleaned and conveyed along an inspection belt, with from one to four workers sorting out the cull berries. The fruit then falls off the inspection belt into containers, ready for delivery to a processor.

This berry harvester typically had a crew of four consisting of an operator, a crater, and two sorters. The machine operator was generally in charge of the harvesting operation and supervised the crew in addition to being in charge of most maintenance and repairs. The two sorters, one on each side of the sorting conveyor, removed cull berries and foreign material not previously removed by the air-blower type cleaner. Male workers were most frequently used as sorters, although female sorters appeared to perform much better at this task. The crater did a limited amount of sorting, but his main responsibility was to remove full crates from the end of the sorting belt and replace them with empty crates.

The machine has a harvesting ground speed of from 0.6 to 1.5 miles per hour, although in actual practice the optimum operating speed was about 0.9 miles per hour regardless of yield per acre or picking. The machine operates best on level land but with the four-wheel drive can satisfactorily perform on gently rolling slopes.

This particular type of machine operated best on black raspberries. It was observed operating under a range of conditions. Rain or heavy dew did not appear to impede the harvesting of black raspberries. Some difficulty with leaves sticking to the catch pans and conveyor belts was noticed. However, heavy or continuous rains caused harvesting to be stopped as the harvesters would mire down.

Lights on the caneberry harvester permitted the operator to lengthen the working day. Night operation is no different from that in the daytime, and the appearance of the harvested fruit is generally improved during night operation. Temperature differences, however, require adjustments to be made by the operator in the frequency and degree of shaking being performed.

The other commercially adopted berry harvester, somewhat smaller in size, has outside dimensions of approximately 8 feet by 16 feet. It also is a four-wheel machine -- two being powered -- which straddles the berry row while harvesting. It is hydraulically driven throughout, powered by a 40 horsepower engine.

This harvester performs most satisfactorily on Thornless Evergreen and Marion blackberries and uses as its shaking mechanism metal fingers protruding from vibrating freely turning drums. This shaking may be controlled to select only those berries ready for harvest. Factors influencing this adjustment are similar to those for the other commercial harvester.

After the mature berries are shaken loose, they drop onto fish-plate catch aprons, so sprung as to ride tightly against the lower part of the canes. These spring-loaded plates are tilted, and their action against the lower part of the canes causes the fallen berries to roll onto a conveyor of catch pans. Undesirable berries, and foreign matter not removed by the blower are picked out quickly by at least two workers. The mechanically harvested berries fall off the inspection belt into containers for delivery to a processor (27).

The two commercially operated machines have very similar operating requirements and crew sizes. The other three types of mechanical caneberry harvesters being developed and tested in Oregon were similar in over-all design to the two commercially adopted machines. All three of the experimental machines were self-propelled, one-row harvesters. With minor variations, the catching mechanisms used resembled those used on the commercial machines.

One of these three harvesters used canvas flaps activated by short air blasts as the shaking mechanism. This particular harvester was tested primarily on Thornless Evergreen blackberries during the 1963 harvest season.

A limited amount of harvesting was done with the other two experimental machines. One of the machines, using a shaking mechanism of revolving drums with finger-like prongs protruding into the canes, was used experimentally to harvest red and black raspberries. Work with the remaining harvester was centered around an attempt to harvest red raspberries. These three caneberry harvesters appear to have harvesting requirements and costs similar to the two commercially adopted machines.

Apart from the Oregon developments, considerable mechanical caneberry harvester innovation has taken place among individual growers in California. None of these harvesters have been commercially adopted in California as of this writing, but there is considerable interest among caneberry growers with regard to developments in mechanical harvesting.

One of the harvesters developed by a California caneberry grower is mounted on the right side of a wheel tractor. It consists of an inverted "U" frame that straddles the berry row and a picking mechanism of two revolving canvas paddles -- one on each side of the row. The berries, when shaken loose, fall into "V" shaped catching troughs with conveyor belt floors that carry the berries to cleated conveyors which in turn lift the fruit to the rear of the machine. There the harvested berries are deposited into containers ready for transportation to a processor (18).

Mechanical caneberry harvesting developments in Oregon and California appear to be further advanced than those in other caneberry producing areas. The Departments of Horticulture and Agricultural Engineering at Oklahoma State University have cooperated in developing an experimental model of a mechanical berry shaker. Essentially it is only a shaking mechanism mounted on a small garden tractor, with the vibration being achieved by an oscillating metal bar having attached prongs which protrude into the canes. Work is now under way on methods to recover the berries once they have been vibrated from the canes. The caneberries on which the shaking mechanism has been tested are erect blackberry varieties which are self-supporting (9)(22).

The Department of Horticulture and Forestry at the University of Arkansas has also developed a "prototype" mechanical harvester for blackberries. They plan to limit their caneberry harvesting efforts, for the time being, to self-supporting blackberry varieties (20).

The continuous mechanical blueberry harvester mentioned in Chapter I has the potential of being a caneberry harvester also. The machine is not being developed for this purpose, although the shaking mechanism,with some modification, is thought to have possibilities for picking caneberries.

The principal difference among mechanical caneberry harvesters is the mechanism through which they achieve the shaking action. Mechanical shaking of caneberries with the self-propelled harvesters has been accomplished by the following methods: controlled air blast (1), oscillating panel on each side of the row (29), metal fingers protruding from vibrating freely turning drums (27), revolving rollers fitted with flexible rubber flaps (2), canvas flaps activated by short air blasts, an oscillating metal bar with attached prongs (9), and a freely turning wheel which bounces rapidly up and down on a wire trellis to which the canes are trained.

The shaking mechanisms described above have not performed equally well in the mechanical harvesting of all caneberries. Some of these shaking methods were better than others for harvesting particular caneberry types and varieties. The shaking mechanism used, however, does not change the shape and size of the machines or greatly affect the speed, crew size or other harvesting requirements. It seems likely that either interchangeable shaking mechanisms will be developed to harvest all caneberries, or one universal shaking mechanism will be developed which is equally effective over a wide range of caneberry types and varieties. This development will undoubtedly be facilitated through the use of pruning and training systems more suited to machine harvesting.

An analysis of the costs and efficiencies of these harvesters is attempted in this study, based upon data gathered in Oregon during 1963. Although the use of these machines is somewhat experimental and developmental, an analysis of their costs and efficiencies at this time seems appropriate and useful since mechanical caneberry harvesting has economic implications to growers and processors. An analysis such as this, coming at the early stage of machine development and adoption, should be helpful to both growers and processors alike in studying the economics of mechanical harvesting and thereby helping to create an orderly development of this harvesting method.

Procedures and Sources of Data

Initially it was the objective of this phase of the study to determine the incidence of mechanical caneberry harvesting in Oregon and then to study each of these operations. An attempt was made to locate and observe all mechanical caneberry harvesters in Oregon through cooperation with county extension agents, processors, caneberry growers, and the Department of Agricultural Engineering at Oregon State University. Mechanical caneberry harvesters were located in the following Oregon counties: Clackamas, Marion, Multnomah, and Washington. Limited use of the three experimental machines did not lend itself to the collection of reliable data. The owner and developer of one of the two commercial harvesters did not wish to have his machine studied in its developmental stage. As a result, it was decided that a number of the other commercially operated machines would be studied.

Because of the apparent similarity of the caneberry harvesters regarding size, harvesting speed, and input-output requirements, the study was designed in such a way that results obtained for the one type of machine could be used in a broader application. Through synthetic analysis estimated costs of mechanical harvesting were developed for not only the present levels of performance, but for improved levels of performance. In this manner the economic relationships developed in this study have significance not only to the one type of machine studied, but to other machines as well. The study may also have broader application in the sense that relationships developed for one berry may have application to other types and varieties of berries.

Detailed economic engineering field studies were conducted on all operations involving the one type of machine during the summer of 1963. These studies involved the collection of physical data on the speed and capacity of the machine, crew requirements, the recovered yield per acre by picking, the berry loss or drop from the machine, physical damage to berries and bushes, turn-around times at the end of the row, loading and unloading times, required maintenance on the machine, and other pertinent data. The bulk of the studies were of the black raspberry harvest because the machine performed most successfully on this particular berry. All known operations of the machine on other caneberries were observed, and similar studies were conducted. The harvester use for red raspberries and Thornless Evergreen blackberries was somewhat more experimental, although the harvesting crew requirements and ground speed were similar for all caneberries. Additional data for the study were obtained from a series of interviews with machine innovators, growers, operators, county agents, processors, and others.

Physical data obtained from the economic engineering studies were converted to costs by applying current prices and wage rates in the area. The costs are shown below for the level of performance as observed during the study. It is recognized that caneberry harvesters are in the developmental stage and that improvements will be made which will favorably affect mechanical harvesting costs. Therefore, selected improved performance levels have been assumed for further synthetic analysis so that their impact may be taken into account. Improved levels of performance are assumed with respect to harvester replacement cost and years of expected life, acreage harvested, and total recovered yield.

Because of the relatively limited amounts of mechanically harvested caneberries being processed, the different means of handling them, and the somewhat limited end use of these berries, it was difficult to make any direct comparisons regarding cost of processing mechanically harvested berries with that of hand picked berries. In an effort to get some idea of the expected influence of harvest mechanization upon the processor, data were obtained through personal interviews with processors regarding the impact of processing caneberries which had been mechanically harvested.

Analysis of Mechanical Harvesting Costs at the Grower Level

Present Performance Level for Black Raspberries

A commercial caneberry harvester in 1963 typically harvested about 40 acres of black raspberries, performing four pickings during the season. Approximately four and one-half days were necessary for each picking. This time lapse generally allowed a sufficient ripening period, depending upon the weather, so that the pickings were continuous. A little more than 18 ten-hour days were required to complete the harvest.

In addition to the harvester crew of four, one truck driver was required for four hours out of the ten-hour operating day. The truck driver, besides delivering full crates to the processor and returning empty crates to be filled, assisted with the loading and unloading of the crates from the harvester. Either one or two harvester crew members assisted with the unloading and loading of the harvester. The other machine crew members cleaned up the harvester and made necessary repairs and maintenance during this time.

A total of 808 man-hours of labor, including one-half hour of record keeping per ten-hour operating day, were required for all pickings on the 40 acres. This is 20.2 man-hours of labor per acre over all pickings.

The machine had a "picking" speed of 0.9 miles per hour and a turning time at the end of each row of 1.15 minutes. At each end of the field, 30 feet was free of plants and was used as a turning space.

The berry harvester had a gasoline consumption of 15 gallons per ten-hour harvesting day. Small quantities of oil and grease were also used. In addition to the harvester, other equipment required for the operation included a 1-1/2 ton truck used to transport both full and empty berry containers. The truck was driven an estimated 25 miles per day of harvest. An outdoor toilet also was required during the harvest season.

When approximately 150 crates of berries had been harvested, they were transferred to the truck and replaced by an equal number of empty crates. The crates were filled to approximately 15 pounds net weight each. Unloading and reloading the harvester required an average of 25 minutes. The total unloading and loading time per acre for all four pickings was approximately 25 minutes.

The total recovered yield per acre from four pickings was typically estimated to be 2, 250 pounds. Recovered yields per acre by picking were estimated to be as follows: first picking - 675 pounds; second picking - 900 pounds; third picking - 450 pounds; and the fourth picking - 225 pounds. Not all of the berries shaken free are recovered by the catch plates; these are called "drops." In addition, some field loss from berries remaining on the canes after completion of the harvest also exists. Dropped berries and berries remaining on the canes after harvest are an economic cost of mechanical harvesting, and their value is taken into account in Chapter IV. The pounds of berries dropped per acre by pickings one through four respectively were estimated to be approximately 273, 256, 102, and 75, for a total loss through drops of 670 pounds per acre, or almost 30 percent of the total recovered yield. After completion of the harvest, an estimated 106 pounds per acre of berries remained on the canes.[1/]

Machine damage to the canes was slight throughout the 1963 harvest season. The catch plates appeared to inflict little abrasion damage where they "rode" against the lower part of the canes. Berries below these catch plates are not recovered by mechanical harvesting. This was one reason for the high incidence of dropped berries. After completion of a picking, the plants appeared ruffled in some cases, but future pickings were apparently not impaired. Damage to the canes resulting from the shaking mechanism was very slight. Nonfruit-bearing laterals, either bent or broken, had no effect upon the immediate harvest. The effect upon the following harvest of the broken laterals was of such minor incidence as to not be of concern to the growers. The fruit on damaged fruit-bearing laterals generally was harvested or dropped by the end of the season.

Black raspberries harvested by this machine were limited to canes two or more years in age. Satisfactory harvesting of black raspberries during their first crop year is very difficult as the fruit-bearing canes are generally close to the ground. At the time

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1/ For a further percentage breakdown of drops and berries remaining on the canes after completion of the harvest, see Appendix Tables 12 and 13.

of this study, no first-year black raspberry crops were being mechanically harvested.

The length of harvester life was typically considered to be five years, with a 10 percent salvage value at the end of that period. This limited machine life was assumed because of expected obsolescence through continued harvester developments rather than the equipment actually wearing out or being used up in that time. Because the harvester studied was relatively new for commercial use, the exact acquisition cost had not been determined but was considered to be approximately $12,000.[1/]

At the present level of mechanical caneberry harvester performance, annual total fixed costs were estimated to be $2,955.09, or 3.28 cents per pound of harvested black raspberries. The total of all variable costs at this level was $1,345.58 or 1.50 cents per pound harvested, making the total cost per pound 4.78 cents. Fixed costs were approximately 69 percent of total harvest costs. Total harvest cost per acre was $107.52, with the variable cost per hour of operation being $7.41. Itemized fixed and variable costs of the present level of performance are shown in Table 5.

1/ A number of different arrangements regarding the cost of obtaining the use of the harvester were in effect during the time this study was conducted. However, in order to adequately analyze the costs of mechanical harvesting, it is assumed that the grower purchases the harvester outright.

Table 5. Estimated costs of mechanically harvesting black raspberries in the Willamette Valley with the 1963 level of machine performance. /1

Item	Cost	
Fixed annual costs of a mechanical harvester:		
Depreciation /2	$2,160.00	
Interest on investment /3	360.00	
Property tax /3	120.00	
Insurance /3	120.00	
Fixed repairs and maintenance /3	90.00	
Storage	50.00	
Total annual fixed cost of a mechanical harvester	$2,900.00	
Other fixed annual costs of mechanical harvesting:		
1-1/2 ton truck /4	$ 48.74	
State Industrial Accident Insurance fee /5 . .	3.75	
1 outdoor toilet /6	2.60	
Total other fixed annual costs	$ 55.09	
Total of all fixed costs		$2,955.09
Variable costs:		
Harvester crew @ $5.23 per hour /7	$ 949.72	
Harvester repairs and maintenance @ $1.00 per hour	181.59	
Harvester gasoline and lubrication @ $.33 per hour /8	59.92	
Truck driver /9	105.32	
1-1/2 ton truck operating requirements /10 .	29.05	
Record keeping /11	14.53	
Miscellaneous items	5.45	
Total of all variable costs		$1,345.58
TOTAL COST		$4,300.67

Harvest cost per pound is 4.78 cents.

/1 Based upon a total recovered yield of 90,000 pounds from four pickings for 40 acres and 181.59 hours of operation. The economic costs of berries dropped and left on the plants are not included.
/2 Computed on a straight line basis with a 10 percent salvage value at end of five years.
/3 These fixed costs were computed as a percent of replacement cost as follows: interest on investment - 3 percent (approximately 5.5 percent of the undepreciated balance); property tax - 1 percent; insurance - 1 percent; and fixed repairs and maintenance - 0.75 percent.
/4 Assumes 4,000 miles of annual use and 475 miles of use for this harvest, with a cost per mile of $.10.
/5 The annual registration fee is $7.50 and half is allocated to this harvest.
/6 Computed from a replacement cost of $20, a ten-year life, and 3 percent interest on investment.
/7 Based upon hourly wage rates of $1.50 for the operator and $1.00 for the other three members plus Social Security and State Industrial Accident Insurance.
/8 Computed from a gasoline consumption of 1.5 gallons per hour and a cost per gallon of $.20 with an oil and lubrication cost of $.03 per hour.
/9 Based upon an hourly rate of $1.25, plus Social Security and State Industrial Accident Insurance for four hours per ten-hour operating day.
/10 Assumes a cost of $.06 per mile.
/11 Based upon an hourly rate of $1.50 per hour, plus Social Security and State Industrial Accident Insurance for one-half hour per ten-hour operating day.

Performance for the Other Caneberries

The use of the machine studied on caneberries other than black raspberries, although experimental in 1963, appeared to have approximately the same operating speed and crew size as for black raspberries. Because of the normally higher per-acre total recovered yields for these other caneberries, at least six pickings would be necessary to harvest red raspberries, Thornless Evergreen blackberries, and Marion blackberries.

Damage to the canes and fruit of these other caneberries is more frequent at this early stage of harvester development. However, advances being made in the picking mechanisms, as well as in pruning and training practices, will undoubtedly reduce this damage. Also, because of the experimental nature of the machine on these other caneberries, reliable field loss data were not collected.

If the same harvesting requirements were to be applied to these other caneberries, the total harvesting cost per acre would be similar to that for black raspberries. Assuming the annual fixed cost and the variable cost per hour of operation do remain the same as for black raspberries, the total picking cost per pound would be reduced with the greater yields. Based upon 40 acres and a total recovered yield per acre from six pickings of 8,000 pounds, the total picking cost for any of the other three caneberries is estimated to be 1.63 cents per pound or $130.40 per acre.

Analysis of Major Variables

The level of performance as described above is not expected to be the ultimate in mechanical caneberry harvesting. These harvesters are continually being improved and refined, and improvements are expected to be made in their performance. With this in mind, improved levels of performance have been assumed here for a number of variable factors affecting mechanical harvesting; and their impact on costs of harvesting black raspberries shown. Because the rate at which these improvements may be expected is not known, a probable range for each of the variables has been considered. In this manner, the economic impact of these improvements may be made more explicit. The variables treated in this vein are harvester replacement cost, expected years of harvester life, acreage harvested, and total recovered yield. Unless through indication to the contrary, all factors other than the one under consideration are the same as the performance shown in Table 5.

Harvester Replacement Cost. The replacement cost of the harvester amortized over the estimated useful life of the machine presently amounts to over 50 percent of total harvest costs. If replacement costs were to be reduced, this would decrease annual fixed cost. For this reason consideration needs to be given to the importance of this cost upon harvest cost per pound.

Costs both higher and lower than the present level were selected for consideration here since the direction an improved harvester may take concerning replacement costs is not certain. Reduced cost is a possibility which may occur through simplified harvester design and through assembly line construction. On the other hand, increased cost may occur as a result of complexity in harvester design. In addition to the present harvester replacement cost of $12,000, costs of $9,000 and $15,000 are used to demonstrate the impact upon total harvest costs. This influence is shown in Figure 3. The $9,000 machine replacement cost reduces the total harvest

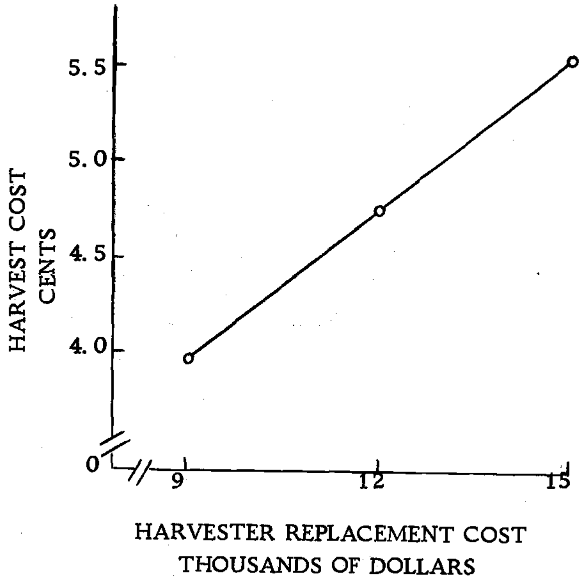

Figure 3. Estimated mechanical harvesting costs per pound for black raspberries with assumed levels of harvester replacement cost. /1

/1 For a further breakdown of the impact of harvester replacement cost upon fixed harvest costs see Appendix Table 14. All other costs and efficiencies remain at the present level of machine performance.

cost an estimated 0.79 cents per pound or an estimated $17.78 per acre below the present level of performance. A similar cost increase above the present performance level is estimated for the $15,000 machine.

Harvester Life. Fixed cost per unit depends not only on the initial replacement cost of a machine but also on the estimated useful life of that machine. The principal factor influencing harvester life is technological obsolescence, or how soon a better machine will be built to render the present harvesters out of date. Certainly with the rapid developments which have taken place and which presently are taking place, this factor is of great importance. Other factors influencing harvester life are depreciation due to wear and tear, or through nonuse. The short span of useful life estimated for the mechanical harvester is due to expected technological obsolescence. In fact, an even shorter life of three years may be considered if an increased rate of technological advance is expected in this field. However, in the future it might be expected that the rate of technological advance will subside and technological obsolescence will not be so eminent. In that case the life of the machine may be expected to exceed the present estimated five years.

In addition to the present performance level of five years, the following lengths of harvester life were selected: 3 years, 7 years, and 10 years. These various years of harvester life were chosen to demonstrate the importance of this variable upon the cost per pound of caneberries harvested. The salvage value is assumed to vary with the expected years of machine life as follows: 3 years - 14 percent; 7 years - 6 percent; and 10 years - 4 percent.

The 3-year harvester life increases total cost per pound harvested 1.42 cents from the present performance level on black raspberries, while the 7 and 10-year lives respectively reduce the cost per pound harvested by 0.61 and 1.12 cents. These costs for selected years of harvester life are shown in Figure 4.

Acreage Harvested. The relatively high fixed cost in comparison to variable cost per unit harvested points to the opportunity

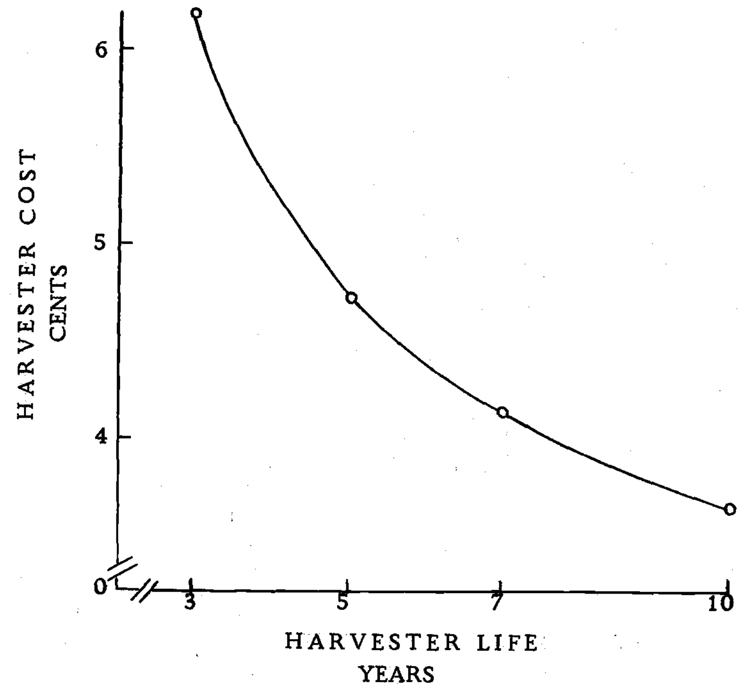

Figure 4. Estimated mechanical harvesting costs per pound for black raspberries with assumed levels of harvester life./1

/1 For a more detailed consideration see Appendix Table 15. All other costs and efficiencies remain at the present level of machine performance.

for decreasing harvest cost per pound by increasing the number of pounds harvested. This may be accomplished through an increase in either the acreage harvested, or the total recovered yield per acre, or a combination of the two. The variable cost per hour of operation remains approximately the same as the harvested acreage of a single variety of caneberry is increased. Fixed costs, however, are spread over more harvested units, resulting in a decrease in total cost per unit harvested.

The machine was currently being used on an estimated 40 acres of black raspberries. This could be expanded to 80 acres per typical year by operating 20 hours per day for 20 picking days. For the other caneberries, the limit to the acreage expansion is reached more quickly because of the generally greater recovered per-acre yields, necessitating at least six pickings. A 60-acre "maximum" for one harvester per typical year appears to be a conservative limit for the other caneberries by operating 20 hours per day for 25 to 40 picking days.

These acreage limits to expansion would allow some time for more ripening of the fruit if needed and slack time for unforeseen events. Harvesting 20 hours per day poses the problem of supervising two shifts. If capable harvester operators are employed, no difficulties of supervision should be encountered.

The acreage harvested may also be increased and the harvest season lengthened by harvesting more than one caneberry type or variety. The effect again is to lower fixed cost per pound harvested by increasing the acreage and thereby the pounds harvested. The harvest season may be lengthened by mechanically harvesting caneberries which mature at different times in the total caneberry harvest season.

In Oregon, the harvesting season for red raspberries begins first, followed in order by the harvest of black raspberries, Marion blackberries, and Thornless Evergreen blackberries. The over-all caneberry harvest season lasts from 78 to 102 days (39), depending upon weather conditions, level of elevation, and total fruit set. See Figure 5 for the estimated dates and maximum lengths of harvest season for selected caneberries in Oregon.

A maximum number of acres and pounds may be "picked" by one harvester if it is used throughout the entire caneberry harvest season. This may entail either co-ownership of a harvester or custom harvesting. With both custom harvesting and co-ownership, timeliness of harvesting is important to all concerned.

There is considerable overlap in the harvest seasons for red and black raspberries and Marion blackberries. Harvesting any of these in combination would do little to lengthen the harvest season. However, one harvester might feasibly be used to "pick" either red raspberries, black raspberries, or Marion blackberries in addition

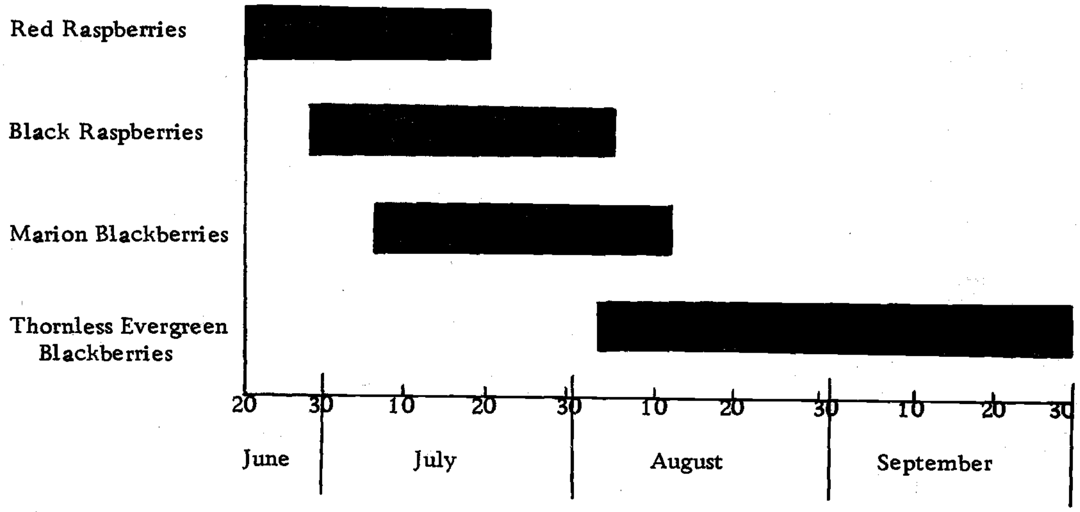

Figure 5. Estimated maximum harvest season for selected caneberries in Oregon (39).

to an acreage of Thornless Evergreens and have a rather long harvest season.[1/]

By using a harvester throughout the entire caneberry harvest season, a conservatively estimated 160 acres of berries may be harvested. Increasing the acreage harvested by a single harvester during the season significantly reduces the fixed cost per unit harvested and thereby reduces total harvest cost per unit. The total costs per pound harvested for varying acreages of black raspberries are shown in Figure 6 as the curve labeled "0 acres used for other

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1/ This may be accomplished through the development of either a universal or interchangeable shaking mechanism (see page 43 Chapter III).

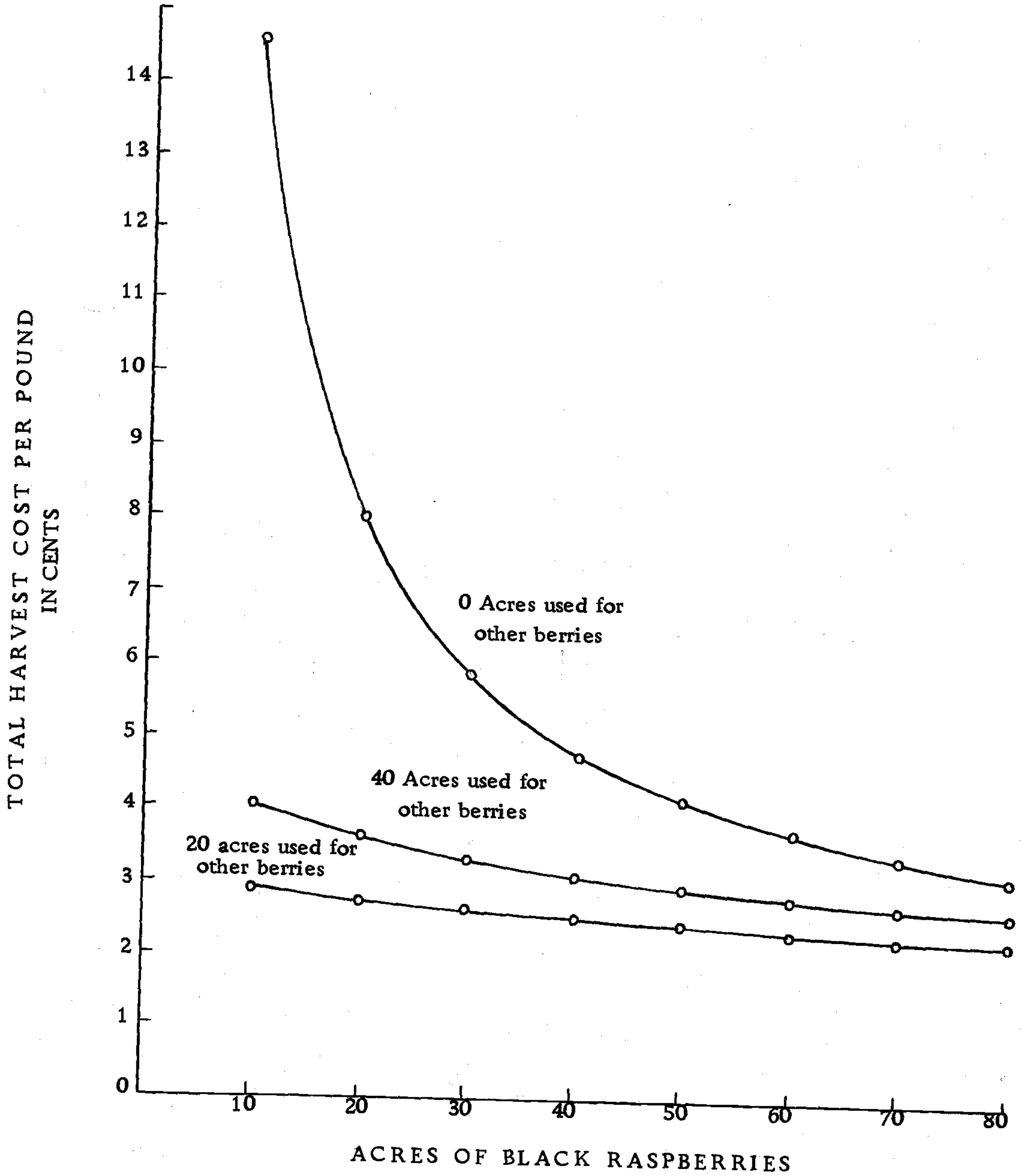

Figure 6. Estimated mechanical harvesting costs per pound for black raspberries with assumed levels of harvester use during the season. /1

/1 Based upon the present performance levels as shown in Table 5. A more detailed breakdown of these harvest costs is available in Appendix Table 16.

berries." Increasing the acreage of black raspberries harvested from the present level to the "maximum" of 80 acres reduces total harvest costs per pound by 1.64 cents to 3.14 cents.

When a combination of 160 acres of caneberries, including 80 acres of black raspberries and 80 acres of other caneberries, are harvested, the total cost per pound of black raspberries harvested is estimated to be 2.32 cents. This is more than a 50 percent reduction from the present performance level. The effect upon estimated black raspberry total harvest costs per pound for varying acreages, where either 40 or 80 acres of other caneberries are harvested during a season, is shown in Figure 6.

Total Recovered Yield. Reasons for variation in total recovered yield may be cultural practices, pounds of berries dropped by the harvester or left on the canes after harvest, or year-to-year fluctuations brought about by weather. Through continuing improvements in the mechanical harvesters and cultural practices, it is expected that the pounds of berries dropped as a percentage of total recovered yield will be reduced.[1/]

As total recovered yield per acre increases, the cost per pound of berries harvested is reduced by a reduction in both fixed and variable costs per pound. Fixed costs per unit are decreased

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1/ The economic value of the difference in recovered yield by the two harvesting methods is considered in Chapter IV.

by spreading them over a greater total recovered yield. Variable costs tend to be variable on a per-acre basis but not truly variable on a per-pound basis. The reason for the decrease in variable costs per pound is that greater yields per acre may be harvested almost as rapidly as smaller per-acre yields. Harvester loading and unloading time increased as recovered yield per acre increased. Machine speed, however, appeared to be maintained regardless of yield, and the same amount of travel time per acre for the machine was required. Therefore, costs of machine travel time were spread over more units of output as yields increased, thus reducing variable costs per pound.

The range of total recovered yields per acre considered is 1,500 pounds to 6,000 pounds. Total harvest cost per pound changes with varying total recovered yield per acre as shown in Figure 7. For example, total harvest cost per pound is decreased by 2.03 cents from the present level of performance when a 4,000 pound total recovered yield per acre is assumed.

Other Factors Affecting Mechanical Caneberry Harvesting

Other factors affecting the cost of mechanically harvesting caneberries are row length, frequency of unloading and loading the harvester, turning space at each end of the field, turning time at the end of each row, harvester speed, crew size, and the cost of

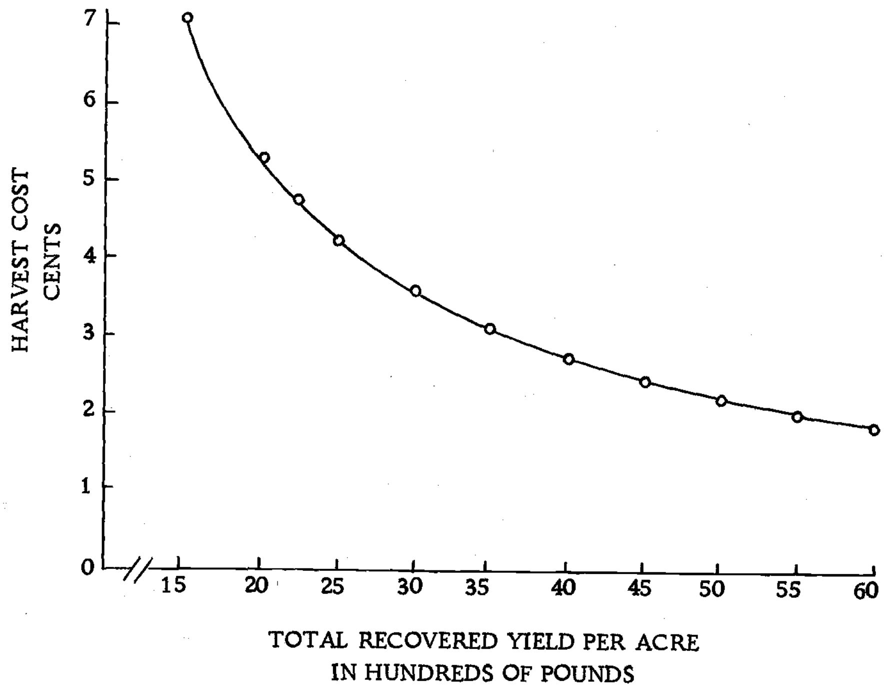

Figure 7. Estimated mechanical harvesting costs per pound for black raspberries with varying levels of recovered yield per acre. /1

/1 See Appendix Table 17 for more detail regarding fixed and variable costs per pound.

variable repairs and maintenance. 1/ These factors have a minor influence upon the costs of mechanically harvesting caneberries. The optimum field length is determined by the capacity of the harvester in filled crates. When the yield for a row for the heaviest possible picking is equal to the machine capacity for one unloading, the optimum field length has been attained. The time required to unload and load the harvester may be decreased in the future by

1/ Cultural practices are considered in Chapter V.

improved handling methods. However, more frequent unloading and loading may be required in an attempt to improve berry quality.

The turning space at each end of the field and the turning time at each end of a row, of course, do affect costs, but the impact is not great over reasonable ranges. The harvester speed influences the time necessary to complete a picking, and slower speeds would reduce the possible acreage which a machine might harvest during a season.

With greater recovered yields per acre, an increased number of sorting workers may be needed to maintain berry quality. It seems doubtful that more than a maximum of four sorting workers would be required. This is the maximum number which can be accommodated by the present machine. Berry mold conditions are also a reason for increasing the harvester crew size.

The cost of variable repairs and maintenance might be expected to vary if the harvester were used for a period of years other than the present performance level. As harvesters are improved, the cost of variable repairs and maintenance for the new machines would most likely be reduced.

Assuming that the harvest requirements for the other caneberries will be similar to those for black raspberries at improved performance levels, effects resembling those demonstrated above for black raspberries would be expected for the other caneberries.

The typically greater total recovered yield per acre would, of course, reduce harvest costs per unit below those for black raspberries.

Additional Pickings

As mentioned previously, usually four pickings are presently performed in mechanically harvesting black raspberries. The opportunity of making an additional picking or pickings often is possible if conditions warrant it. The grower is then faced with a decision as to whether or not it is profitable to make an additional machine picking.

The grower, in order to determine the economic feasibility of performing an additional picking, would need to consider the following factors: expected recovered yield per acre for the additional picking, the total variable cost of doing the additional picking, the price which would be received for these berries, and the opportunity cost or other alternative uses of the harvester and labor. Only the total variable costs of performing an additional picking need be considered by the grower. Total fixed cost of the harvester has already been incurred and will not be greatly affected whether or not the grower makes an additional picking. If the grower is able to recover any value above the variable cost of performing an additional picking, he would then be further reducing the fixed cost per pound during the season for all berries harvested.

Based upon an assumed price from the processor of 28.33 cents per pound (the average price received for black raspberries during the period 1961-1963 inclusive) and present variable costs as shown in Table 5, the break-even point between total variable cost per acre and total value of recovered yield per acre for an additional picking is shown in Figure 8. It is apparent from Figure 8 that variable cost per acre for an additional picking may be covered by harvesting very low recovered yields per acre. A recovered yield of only 27 pounds per acre will cover the total variable cost of harvesting an additional picking of 40 acres of black raspberries under conditions assumed above.

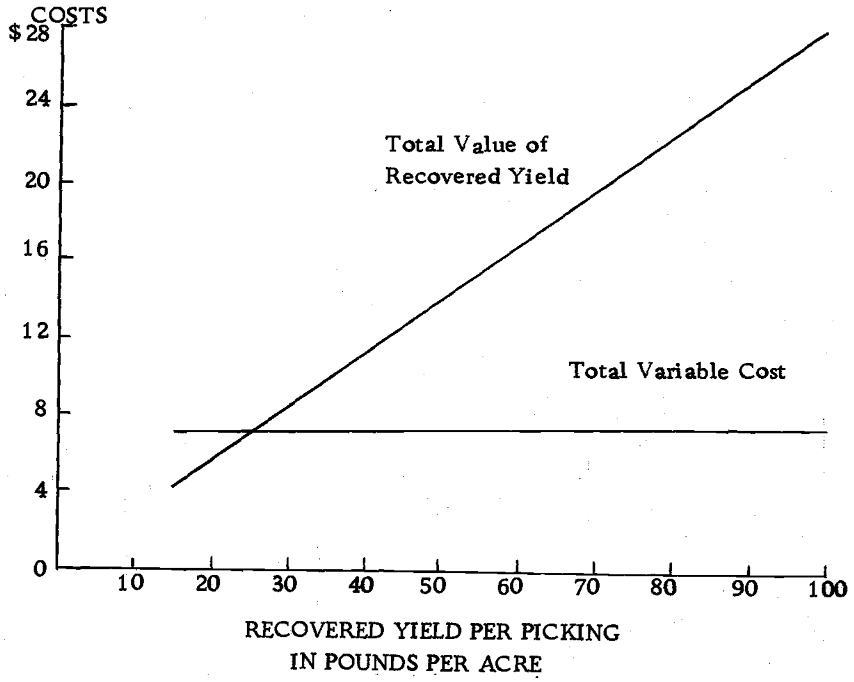

Figure 8. Comparison of estimated marginal costs and returns for an additional picking of black raspberries yielding various assumed levels of product. /1

/1 See Appendix Table 18 for net dollar difference.

Mechanical Harvesting Cost Estimating Equations

In the early stage of development and commercial adoption of a new harvesting method such as this, there is a need among growers for a means by which the new method may be analyzed for individual grower situations. Several cost estimating equations are presented below for this purpose. These equations are useful only to the extent that assumptions made in the analysis are applicable to an individual using the equations. The effects of changing the field length, feet of turning space, harvester turning time, and harvester operating speed were discussed earlier in the chapter. Although the assumptions are subject to change as caneberry harvesting developments progress, the equations definitely provide a foundation for grower consideration of mechanical harvesting.

The annual fixed cost per pound of berries harvested may be obtained from Equation 1. Annual variable cost per pound may be found by use of Equations 2 and 3. The total cost per pound is then determined through addition of fixed and variable costs per pound in Equation 4.

Equation 1:

$$F = \frac{\frac{R-S}{L} + (0.0575)\, R + \$105.09}{AY} \; \underline{1/}$$

where

F = fixed cost per pound in cents.
R = harvester replacement cost in dollars.
S = harvester salvage value in dollars.
L = harvester life in years.
A = number of acres harvested.
Y = total recovered yield per acre in pounds.

Equation 2:

$$H = \left[(0.4)\, T + 0 + CK\right] (1.16025) + (\$.002)\, C + M + \$.60. \; \underline{2/}$$

where

H = variable cost per hour in dollars.
T = truck driver's hourly wage in dollars.
O = harvest operator's hourly wage in dollars.
C = one less than the number in the harvester crew.
K = hourly wage for one harvester crew member other than the operator in dollars.
M = hourly rate for variable repairs and maintenance in dollars.

1/ The coefficient 0.0575 is the sum of those fixed costs which are calculated as a percent of harvester replacement cost as follows: interest on investment - 3 percent (approximately 5.5 percent of the undepreciated balance); insurance - 1 percent; property taxes - 1 percent; and fixed repairs and maintenance - 0.75 percent. The constant $105.09 consists of the following costs: harvester storage - $50; 1-1/2 ton truck - $48.74; State Industrial Accident Insurance fee - $3.75; and outdoor toilet - $2.60.

2/ The coefficient 1.16025 is multiplied by hourly wages paid to obtain Social Security and State Industrial Accident Insurance costs in addition to hourly wages. The coefficient $.002 is an additional portion of State Industrial Accident Insurance of $.02 per employee per day, here based upon a ten-hour operating day. The constant $.60 consists of the following costs, again based upon a ten-hour shift: harvester gasoline and lubrication - $.33; 1-1/2 ton truck, $.16; record keeping - $.08; and miscellaneous equipment and costs - $.03.

Equation 3:

$$V = H\left[(0.0001852) + \frac{\left\{\begin{matrix}(3.67)\ A-1 \\ \text{round to the} \\ \text{lowest whole} \\ \text{number}\end{matrix}\right\} P\ (0.2843)}{AY}\right]^{1/}$$

where

V = variable cost per pound in cents.
H = variable cost per hour in dollars.
A = number of acres harvested.
P = number of pickings.
Y = total recovered yield per acre in pounds.

Equation 4:

$$T = F+V$$

where

T = total cost per pound in cents.
F = fixed cost per pound in cents.
V = variable cost per pound in cents.

1/ This equation has been simplified from the following equation:

$$\begin{matrix}\text{variable} \\ \text{cost per} \\ \text{pound}\end{matrix} = \frac{\begin{pmatrix}\text{variable} \\ \text{cost per} \\ \text{hour}\end{pmatrix}\left[\dfrac{\dfrac{\begin{pmatrix}\text{total} \\ \text{recovered} \\ \text{yield per} \\ \text{acre}\end{pmatrix}\begin{pmatrix}\text{number} \\ \text{of} \\ \text{acres}\end{pmatrix}}{(2,250\ \text{pounds})}(25\ \text{minutes}) + \left\{\begin{matrix}(3.67)\begin{pmatrix}\text{number of} \\ \text{acres}\end{pmatrix}-1 \\ \text{round to the lowest} \\ \text{whole number}\end{matrix}\right\}\begin{pmatrix}17.06 \\ \text{min.}\end{pmatrix}\begin{bmatrix}\text{number} \\ \text{of} \\ \text{pickings}\end{bmatrix}}{(60\ \text{minutes})}\right]}{(\text{total recovered yield per acre})\qquad(\text{number of acres})}$$

where the coefficient 17.06 minutes is the time required to harvest a row 1,260 feet in length and turn the harvester around to start another row. The figure 3.67 is the number of rows per acre if the rows are nine feet apart and one-fourth mile long.

Effects of Mechanical Harvesting on Processors

Unfortunately, because of the early stage of mechanical caneberry harvesting development, it was not possible to obtain reliable quantitative estimates of the costs of processing mechanically harvested caneberries. Cost measurements could not be made because of the small quantity of mechanically harvested caneberries being processed. In most operations, the relatively small quantities of caneberries which had been mechanically harvested were blended together with hand harvested berries, further complicating cost measurements. Methods of handling the few mechanically harvested berries which were processed without blending were somewhat temporary as the processors were not always sure what changes if any were necessary in the processing lines to insure an efficient operation.

Interviews were conducted as an alternative means of obtaining information concerning the impact on the processing operation of mechanically harvested berries. Although inconclusive, these did provide some insight into the problem. All processors interviewed did not agree in their opinions of the impact of mechanically harvested berries on their operations. In general, there appeared to be both advantages and disadvantages for mechanically harvested caneberries.

The most important advantage pointed out by the processors interviewed was that mechanically harvested caneberries have a soluble solids content about one percentage point higher than that of hand picked berries. The increased soluble solids or sugar content results from the berries being harvested at a more optimum stage of maturity. Studies conducted at the Arkansas Agricultural Experiment Station in 1961 with Raven blackberries also concluded that mechanical harvesting results in higher soluble solids than hand picking (21).

Disadvantages pointed out dealt with increases in costs of processing mechanically harvested as opposed to hand harvested berries, and the possible reduction in berry quality for use in some types of finished products.

The apparent increase in processing costs is a result of the condition of the fruit when it is delivered to the plant. It was generally believed that most mechanically harvested berries arrive at the plant intermixed with more cull fruit and foreign material than hand picked berries. This results in a slowing down of plant capacity with the existing number of sorters and items of equipment in the line, or the addition of workers and equipment in order to maintain plant output at a given rate. Both increase unit costs of processing.

The quality of mechanically harvested caneberries seemed to be influenced by the type of container into which the grower placed them. Caneberries crush and "juice" quite easily, especially when placed in a container having a depth greater than that of the conventional berry crate. With present technology of harvesting, handling, and processing, those berries deposited immediately after harvest into bulk containers are extremely difficult to clean and sort. However, depending upon the processing and use for which the berries are intended, containers other than the conventional berry crate may be practical.

Containers observed in use during the study other than the conventional crate included conventional size crates lined with a wax-coated paper to replace the hallocks, and 30-pound tins and 55-gallon drums, both of which contained plastic liners. Further study concerning harvesting containers in relation to the processing and end use of the caneberries is needed.

One processor who handled black raspberries which had been mechanically harvested into conventional berry crates, commented that "The product or end use of the berry is no different because it is machine picked than if it were hand picked." This particular processing line was not slowed down for the machine picked berries, but the following changes were made: A smaller sieve was added to catch more of the crumbled berries that exist with machine picked fruit, a suction fan for cleaning was necessary (used at times with hand picked berries also), and four extra female workers were required (at times, extra women were required for hand picked fruit also). The increased cost as a result of these changes was not disclosed.

Other processors have commented that mechanically harvested caneberries have little effect on processing costs and that they are quite capable of handling the machine picked berries. But these processors generally blended the mechanically harvested berries with hand harvested berries. If in the future mechanical caneberry harvesting is used for a larger percentage of the berries, it would seem that this temporary practice of blending could not be continued.

Caneberries, when processed, are used in a number of different products. Their end use depends somewhat on type and variety of caneberry, but any given berry may be used in a number of ways. It may be used in whole berry form and packed either fresh, frozen, or canned. It may be used in jellies, jams, or purees. Or, as in the case of the black raspberry, it may be used as flavoring or dye.

A determination of the finished product into which each lot of fruit should be processed depends not only on market conditions but also upon the quality of fruit. Lower quality of fruit generally is used in jellies, jams, or purees where the whole form of the berry is not maintained. In most cases in 1963, processors limited the use of mechanically harvested berries to those products not requiring the berry in whole form. Whether this was more a matter of marketing conditions or was necessitated because of the fruit condition is not known at this time. Further study of this aspect of the problem is needed as this may have very important implications to the future of mechanical harvesting. For black raspberries, where a large percentage of the total crop is used in such products as jams, jellies, purees, dye, and flavoring, this limited product use is not so important. But for some of the other caneberries where a larger percentage of the fruit is utilized in products requiring the berry in whole form, this could be extremely important.

The impact of mechanical harvesting upon processing costs is not at all conclusive at this time. At the present time, a limited product use and increased processing costs for at least some types and varieties of berries appears to be the opinion of many people in the industry. Any increase in processor costs or any discounting of prices for the finished product would tend to offset the mechanical harvesting advantage at the grower level. Future developments in mechanical harvesting may help to eliminate the possibility of these drawbacks.

CHAPTER IV

HAND VERSUS MECHANICAL HARVESTING OF CANEBERRIES -- A COMPARISON

In Chapter II the estimated typical costs of hand picking selected types and varieties of caneberries were presented. Costs of mechanically harvesting these berries were estimated in Chapter III for the performance level observed during the 1963 harvest season. Because mechanical harvesters are continually being improved and refined, the effects of varying certain important factors over selected improved performance levels were also considered.

It is now appropriate to bring these two harvesting methods together for comparison in this chapter. First this is done by considering picking costs of hand and mechanical harvesting at the present level of harvester performance and not taking into account difference in field loss or recovered yield for the two methods. Again because of the early stage of harvester development, the synthesized costs for the assumed improved performance levels for the mechanical harvester also are compared with hand picking costs. Finally the difference in field loss for the two harvesting methods is compared and the over-all impact of mechanical harvesting at the grower level evaluated.

Comparison of Present Performance at the Grower Level

Black Raspberry Harvesting

Based upon costs developed in this study for the 1963 harvest season, total cost of mechanically harvesting black raspberries is 41 percent less than that for hand picking. Hand picking costs were estimated to be 8.08 cents per pound while the mechanized harvest costs were only 4.78 cents per pound. For a 2,250 pound recovered yield per acre, this amounts to a savings of $74.25 per acre. A further comparison of costs and efficiencies of the two methods is shown in Table 6.

Much of the savings in cost between the two methods is due to the reduction in the number of workers required for mechanical harvesting. Labor requirements in obtaining a total recovered yield per acre of 2,250 pounds are reduced from an estimated 210 to 20.2 man-hours by using the mechanical harvester rather than hand picking.

Harvesting the Other Caneberries

Although mechanical harvesting operations with the machine studied were experimental on red raspberries, Thornless Evergreen blackberries, and Marion blackberries during the 1963 harvest season, much insight regarding their harvest requirements was gained.

Table 6. Comparison of costs and efficiencies for hand and mechanically harvesting black raspberries at present levels of performance, 1963.

Item	Hand Harvesting	Mechanical Harvesting
Total recovered yield per acre in pounds	2,250	2,250
Number of Pickings	3	4
Number of acres harvested (typical size operation)	20	40
Total picking cost per pound in cents	8.08	4.78
Total picking cost per acre in dollars	181.80	107.55
Labor cost per pound in cents	7.49	1.19
Harvest Labor cost per man-hour in dollars	$ .80	$1.32

It is believed that harvesting requirements for these other berries will be similar to those for black raspberries if a suitable shaking mechanism can be developed for their harvest. The only apparent difference will be that at least six pickings will be necessary because of the higher yields for these caneberries.

If the harvesting of these other caneberries with the machine studied is perfected and input requirements do turn out to be similar, then harvesting costs for these other berries may be obtained through use of relationships developed in this study for black raspberries. Assuming that these relationships do apply and that 20 acres of each of these berries may be harvested in six pickings, harvest requirements and costs are compared with hand picking costs in Table 7.

Table 7. Comparison of costs and efficiencies for hand and mechanically harvesting red raspberries, Thornless Evergreen blackberries, and Marion blackberries with assumed levels of mechanical harvester performance. /1

ITEM	Red Raspberries		Thornless Evergreen Blackberries		Marion Blackberries	
	Hand Harvesting	Mechanical Harvesting	Hand Harvesting	Mechanical Harvesting	Hand Harvesting	Mechanical Harvesting
Total recovered yield per acre in pounds	9,000	9,000	10,000	10,000	8,000	8,000
Number of pickings	5	6	5	6	4	6
Number of acres harvested	20	20	5	20	4	20
Total picking cost per pound in cents	7.09	2.28	5.38	2.07	5.44	2.56
Total picking cost per acre in dollars	638.10	205.20	538.00	207.00	435.20	204.80
Man-hours of labor per acre	768	35	504	36	378	34

/1 These caneberries were not commercially harvested in 1963 by the machine studied. Assuming that a shaking mechanism will be developed for these berries for this machine which will not alter operating requirements, synthesized costs presented in this table will be applicable.

Comparison With Selected Improved Harvester Performance Levels

To compare hand and mechanical caneberry harvesting at only the present level of performance would be an injustice to mechanical harvesting as this new harvest method is in its early stages of development. It is not known what level of performance will be achieved in the future by mechanical caneberry harvesters; therefore, comparisons are presented over several assumed levels of performance for each of the important variables analyzed in Chapter III. Comparisons are made between hand and mechanical harvesting of black raspberries only. Assuming the harvest requirements for the other caneberries would be similar to those for black raspberries at improved performance levels, effects resembling those to be demonstrated below would be expected for the other caneberries.

Harvester Replacement Costs

Harvester replacement costs both higher and lower than the present level of $12,000 were considered in Chapter III. A comparison of mechanical harvesting costs with the various assumed levels of replacement cost is made with hand harvesting costs in Table 8.

Table 8. Comparison of estimated costs for hand and mechanically harvesting black raspberries when various levels of har- harvester replacement cost are assumed. /1

Harvester replacement cost (dollars)	Mechanical harvesting cost per pound /2 (cents)	Hand harvesting cost per pound /3 (cents)	Difference in Favor of mechanical harvesting (cents)
$ 9,000	3.99	8.08	4.09
12,000	4.78	8.08	3.30
15,000	5.57	8.08	2.51

/1 Costs are based upon the 1963 level of harvester performance.

/2 See Appendix Table 14 for a further breakdown of costs.

/3 See Table 1 for a further breakdown of hand harvest costs.

The $9,000 harvester would reduce the estimated picking cost per acre by $17.78 below the present mechanical harvester performance level. This would increase the present mechanical picking cost advantage of $74.25 per acre to $92.03 per acre. An increased harvester cost of $15,000, on the other hand, would reduce the picking cost advantage for mechanical harvesting to $56.47 per acre.

Harvester Life

Estimated costs of mechanical harvesting with different assumed periods of useful harvester life are compared with hand picking costs in Table 9. In addition to the 5-year life presently being assumed for the machine by the industry, periods of 3, 7, and 10 years are also considered. Results of this cost comparison show that savings in harvesting costs per pound by mechanical harvesting increase with longer lengths of harvester life.

Acreage Harvested

Mechanical picking costs per pound may be substantially decreased by harvesting a greater caneberry acreage than was typically harvested in 1963. This may be accomplished either by harvesting more acres of one caneberry type or variety, lengthening the harvest season by picking more than one caneberry, or a

Table 9. Comparison of estimated costs for hand and mechanically harvesting black raspberries when various levels of harvester life are assumed. /1

Harvester Life (years)	Mechanical harvesting cost per pound /2 (cents)	Hand harvesting cost per pound /3 (cents)	Difference in Favor of mechanical harvesting (cents)
3	6.20	8.08	1.88
5	4.78	8.08	3.30
7	4.17	8.08	3.91
10	3.66	8.08	4.42

/1 Costs are based upon the 1963 level of harvester performance except salvage value which is computed as a percentage of the $12,000 replacement cost as follows: 3 years - 14 percent; 5 years - 10 percent; 7 years - 6 percent; and 10 years -4 percent.

/2 See Appendix Table 15 for a component breakdown of costs.

/3 See Table 1 for a component breakdown of hand harvest costs.

combination of these two. As acreage harvested is increased, the large annual fixed cost of the mechanical harvester is spread over more units, resulting in lower harvesting costs per unit. Three combinations of machine usage for black raspberries and other caneberries are shown in Figure 9. Harvesting of the other caneberries assumes that multi-caneberry or interchangeable shaking mechanisms will be developed to permit the harvest of these berries by one machine.

Fixed costs are a small portion of total harvest costs for the hand picking method. These are added in somewhat indivisible

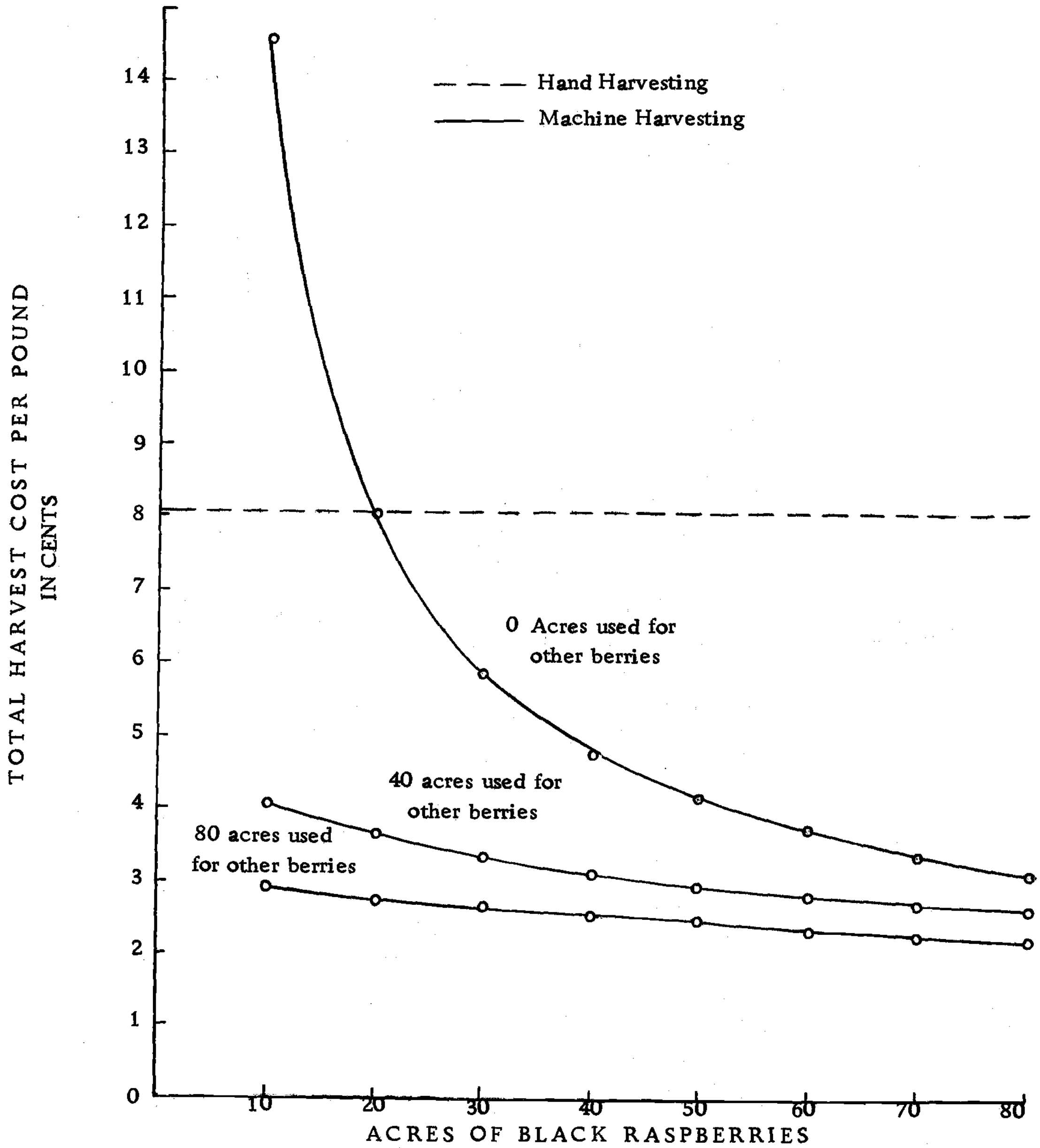

Figure 9. Comparison of estimated costs for hand and mechanically harvesting black raspberries when various levels of harvester use per season are assumed. /1

/1 Based upon the present mechanical harvester costs as shown in Table 5, and the hand picking costs as shown in Table 1. A breakdown of machine harvest costs is available in Appendix Table 16.

units as acreage is increased. Aside from this lumpiness, growers estimated that hand harvesting costs per unit remained fairly constant regardless of acreage harvested. It was assumed for practical purposes that hand harvesting costs remain constant as acreage harvested is increased in the analysis presented in Figure 9.

For a harvester used only on black raspberries, about 20 acres with a recovered yield of 2,250 pounds per acre are required before machine picking costs are as low as hand picking costs. This comparison and others are shown in Figure 9. If the 160-acre "practical maximum" of caneberries consisting of 80 acres of black raspberries and 80 acres of other caneberries were harvested, the picking costs for a 2,250 pound recovered yield per acre would be an estimated $52.20. This is a savings in picking costs over the hand harvest method of $129.30 per acre. The mechanical harvesting advantage increases rapidly as larger caneberry acreages are harvested.

Total Recovered Yield

Increased recovered yield per acre reduces the picking costs per unit for both harvesting methods. Cultural practices, year-to-year fluctuations, field loss, and additional pickings may all influence the recovered yield per acre. For a given acreage, fixed costs for both methods remain relatively constant per acre regardless of yield. These costs are spread over more units as total recovered yield per acre increases. Figure 10 shows a comparison of picking costs per pound for the two harvesting methods for varying recovered yields per acre. Hand picking costs are less than machine picking costs until the recovered yield per acre is increased to approximately 1, 170 pounds. The difference favoring mechanical harvesting increases rapidly beyond this point because of the higher fixed costs for this method.

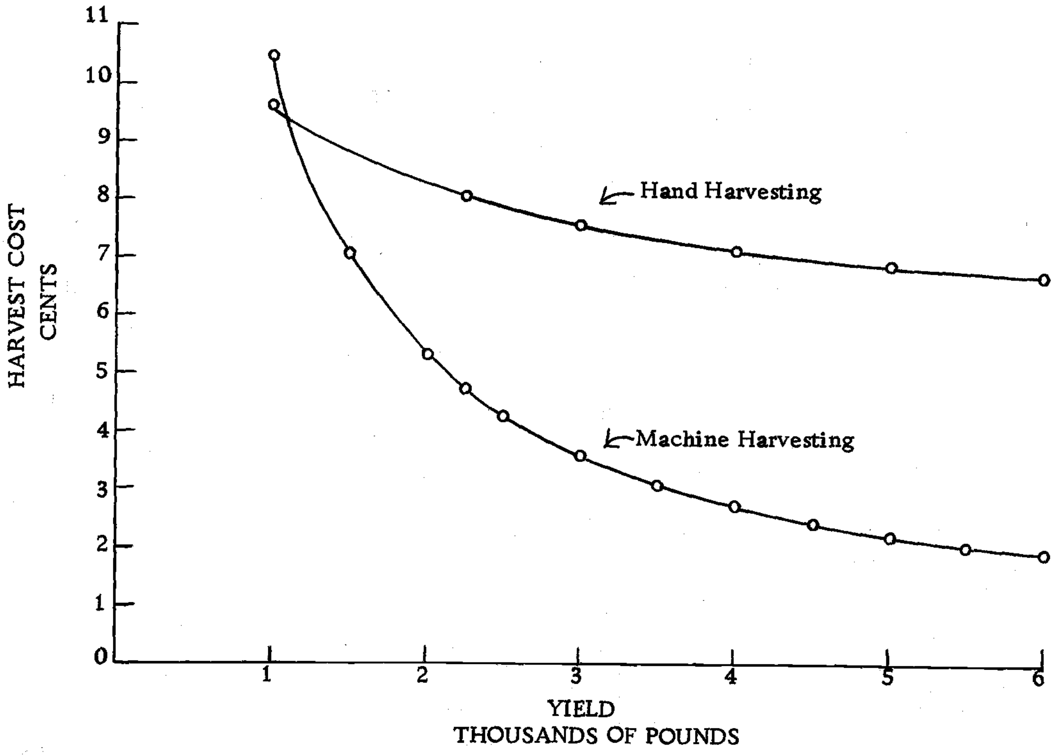

Figure 10. Comparison of estimated costs per pound for hand and mechanically harvesting black raspberries when various levels of recovered yields per acre are assumed. /1

/1 A breakdown of machine picking costs is available in Appendix Table 17. A breakdown of hand picking costs is available in Appendix Table 5.

Joint Consideration of Selected Improved Performance Levels

Improved levels of certain factors affecting mechanical harvesting costs have been assumed and compared individually with hand picking costs above. It now seems appropriate to consider jointly the effect of several of these factors on machine picking costs and to compare these with hand picking costs. The general consensus of the machine operators during the 1963 harvest season was that the following improved performance levels are close to attainment: a $9,000 harvester having a 4 percent salvage value after 10 years of useful life, 80 acres of caneberries harvested per season by one machine where 40 are black raspberries, and a total recovered yield per acre of 4,000 pounds for black raspberries. With these assumptions and using relationships previously developed, the estimated cost per acre for mechanically harvesting black raspberries is $54.40. The hand picking cost for a 4,000 pound total recovered yield per acre was estimated earlier to be $211.60. Machine picking under these assumptions would result in a savings of $157.20 per acre, or a reduction in cost of approximately 74 percent for black raspberries.

Other Economic Considerations at the Grower Level

An economic evaluation of machine and hand harvesting at the grower level involves more than just a comparison of picking costs. Other factors to be taken into account are field loss or recovered yield attainable by the two methods and the impact of harvesting methods on cultural practices and nonharvest costs.

Intensive field studies were made during the 1963 harvest season for both hand and machine picking operations to determine the relative picking efficiency of each method. In order to evaluate the field loss resulting from berries dropped, samples were taken in various rows throughout machine and hand harvested fields, and the berries dropped after each picking were counted. These berry counts were converted to pounds by sampling berries already harvested and determining the number of berries per pound for each picking. The hand pickers dropped an estimated 116 pounds of black raspberries per acre over all pickings. The machine, by comparison, dropped an estimated 670 pounds of black raspberries per acre over all pickings at the present level of performance.

Field loss consists not only of berries dropped, but also of those remaining on the canes at the end of the harvesting season. Hand pickers left an estimated 392 pounds of black raspberries on the canes after the normal three pickings, compared to only 106 pounds after mechanically harvesting four pickings.[1/]

1/ Sample data were analyzed statistically to determine that there was a significant difference between the two methods with respect to field loss. Both berries dropped and berries remaining on the canes after final picking were significantly different for the two methods at the 1 percent level. See Appendix Table 19 for results of the tests.

During the 1963 harvest season with the usual practice of four pickings by machine harvest and three pickings by hand harvest, it was the consensus of opinion of the cooperators in the study that the typical black raspberry total recovered yield per acre was 2, 250 pounds for both harvest methods. The field loss as a percentage of this estimated total recovered yield is shown in Table 10 for both harvest methods. The over-all picking efficiency or recovery of black raspberries by machine harvesting was approximately 74 percent at the present performance level and approximately 82 percent by hand harvesting.

Since the recovered yield per acre was estimated to be the same for both harvest methods, the total yield (both recovered and lost) would have to be greater for the mechanical harvesting operation because the field loss was greater. An explanation of this discrepancy in total yield is not readily apparent. Present cultural

Table 10. Comparison of estimated black raspberry field loss for hand and machine harvesting as percentages of total recovered yield. /1

Field Loss	Machine Harvest (Percent)	Hand Harvest (Percent)
Drop	29.8	5.2
Remaining on the canes after harvest	4.7	17.4
Total field loss	34.5	22.6

/1 See Appendix Tables 9 and 11 for a more detailed consideration.

practices directly related to the two harvest methods are not sufficiently different to cause any yield variation. In the author's opinion, this may be partially explained by the fact that these growers mechanically harvesting in 1963 were more progressive than the typical black raspberry grower who hand picked. The more progressive growers might be expected to have higher total yields per acre. This difference in total yield per acre would not be expected to prevail as more growers adopt mechanical harvesting, and cultural practices do not indicate a higher total yield in either case.

In order to make an economic comparison of field loss for the two harvesting methods, the same total yield per acre (recovered and lost) has been assumed for each. If the picking efficiencies as estimated in this study are applied to a 3, 000 pound total yield per acre, recovered yield for hand harvesting would be 2, 445 pounds and for mechanical harvesting 2, 231 pounds. Hand harvesting results in an estimated 214 pounds greater total recovered yield per acre compared to mechanical harvesting. Valuing this difference at the average price of 28. 33 cents per pound (the price paid by processors for black raspberries in Oregon during the period 1961-1963) results in an additional $60. 63 per acre received by the grower using the hand pick method over and above that received by the grower mechanically picking his crop.

Cost of hand picking a 2, 445 pound per acre recovered yield is estimated to be $193.16 per acre, while that of picking 2,231 pounds recovered yield per acre mechanically is $107.53.[1/] The resulting $85.63 per acre advantage for machine harvest is partially offset by the difference in the amount received for saleable berries by the grower hand picking. This reduces the estimated net savings for mechanical harvesting to $25 per acre.

In the above comparison, the field loss has been valued at 28.33 cents per pound. However, the price paid by processors for black raspberries tends to vary from year to year. A higher price than the one used here would decrease the advantage of mechanical harvesting as the economic value of the difference in total recovered yield per acre would be greater. Conversely, a lower price would increase the advantage of machine harvesting as the difference in the economic value of the berries not recovered would be less.

It is recognized that the field loss through berries dropped is somewhat high at the 1963 level of harvester performance. A reduced level of harvester drop may be obtained through conscientious machine operation, improved catching devices, and improved caneberry training systems. Reduction of the pounds of berries dropped by machine harvest from the present 22 percent to about 15 percent

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1/ The hand harvesting cost for the 2,445 pounds recovered yield has been computed from a picking cost of 7.90 cents per pound (Figure 2). The machine harvesting cost for the 2,231 pounds recovered yield has been computed from a picking cost of 4.82 cents per pound (Figure 6).

of total yield per acre would give this harvest method the same total field loss as hand harvesting.

Improved cultural practices being recommended by research workers, such as new training systems and closer in-row spacing, although beneficial to both harvesting methods, appear to benefit mechanical harvesting to a greater extent. These practices may result in greater total yields, a more uniform fruit set, and fruit-bearing canes on the outside of the row. As these training systems and cultural practices are adopted, any increase in total yield would be available to both harvesting methods. Although recovered yield may be increased for both harvesting methods by following these practices, the picking efficiency for a mechanical harvester should be increased considerably by them. Increased picking efficiency might be expected for a mechanical harvester because of the uniform fruiting surface presented by a hedge-type row. Also, having the fruit-bearing canes trained to the outside of a row would reduce field loss resulting from dropped berries, the reason being that the berries would more likely fall onto the catch plates than between them when shaken loose (12).

Only grower costs have been dealt with in this chapter. However, these are only a part of the over-all influence of mechanical caneberry harvesting. In Chapter III the effects of harvest mechanization upon the processor also were discussed. The implications of these processor effects in addition to those for other marketing firms, growers, and ultimately the consumer are considered in the following chapter.

CHAPTER V

IMPLICATIONS TO THE INDUSTRY

This study, initiated early in the development of mechanical caneberry harvesting, is intended to provide timely information for management decisions concerning mechanical harvesting. The analysis, although based on performance data from only one type of harvester, has application to other harvesters and caneberries because of the similarity in operating requirements among the various machines.

Implications to Growers

The particular type of harvester studied, although operating commercially only on black raspberries, looked somewhat promising in experimental operations during the 1963 season for harvesting other caneberries. It seems likely that either a single multi-berry shaking mechanism or interchangeable mechanisms will be developed in the near future to commercially pick all of the caneberries considered in this study.

Mechanical black raspberry harvesting presently offers growers the opportunity to reduce their harvesting costs per unit compared to the alternative of hand harvesting. However, in order to take advantage of this cost reducing opportunity, a grower must harvest at least 30 acres either by (1) producing enough acreage to justify ownership of a machine, (2) arranging for co-ownership of a machine, or (3) arranging for custom harvesting of other growers' berries.[1/]

Fixed costs are proportionately high for mechanical harvesting; and as a result, it becomes important for a grower to get the maximum use of his machine in a season. If a satisfactory shaking mechanism is developed for red raspberries, Thornless Evergreen blackberries, and Marion blackberries, then it becomes possible to considerably lengthen the season's use of the machine by harvesting a combination of types and varieties of caneberries. The estimated "practical maximum" harvestable acreage under these conditions for one machine is 160 acres, consisting of 80 acres of black raspberries and 80 acres of other caneberries. This, of course, would require fairly constant operation of the machine over a period of 60 days and operating at least 20 hours per day.

Not all caneberry fields existing in 1963 were suited to harvest mechanization. Fields having long rows, relatively level terrain, and at least 30 feet of turning space at each end of the field are necessary prerequisites to efficient mechanical harvesting.

1/ This 30-acre minimum differs from the 20-acre point mentioned in Chapter IV because in addition to costs, it takes into account the difference in recovered yield by the two harvesting methods at the 1963 performance level.

Black raspberries appear to be suited to harvest mechanization with little modification in cultural practices. More satisfactory results may be obtained with the other caneberries if training systems are developed to keep fruiting canes to the outside of a row and also to present a uniform fruiting surface. These practices might be expected to increase recovered yields for these other caneberries.

Because this study was conducted during the early stages of mechanical caneberry harvesting, synthesized costs for improved levels of performance were also developed. This phase of the study shows that mechanical harvesting costs per pound may be further reduced by: increasing the acreage harvested during a season, increasing the recovered yield per acre, reducing the harvester replacement cost, and lengthening expected harvester life. Successful attempts to reduce the field loss resulting from berries dropped will substantially increase the advantage of mechanical harvesting. If the field loss from black raspberries dropped during mechanical harvest can be reduced from the present estimated 22 percent to about 15 percent of total yield, total field loss by each harvesting method would be the same.

Since only one truck driver and four people are required to mechanically harvest caneberries, labor is no longer such an important factor. Other areas more remote from labor supplies may enter caneberry production as mechanical harvesting is further developed and adopted.

In addition to difficulties in obtaining the needed supply of harvest labor for the hand picking operations, developments in recent years indicate the possibility of farm labor wage increases. To obtain competent supervisory labor necessitates wages somewhat comparable to those wages paid in nonfarm industry. The piece rate paid to hand pickers for harvesting each of the selected caneberries has, in the past, remained quite stable. However, the future holds no guarantee that this situation will continue. The mechanical harvesting method substitutes capital for labor, and its use will be relatively more profitable if wages do increase over time.

Implications to Processors

Interviews with processors, although inconclusive, revealed both advantages and disadvantages of mechanically harvested caneberries for processing. Processors generally agreed that the higher soluble solids content of machine picked berries is an advantage over hand picked berries. Disadvantages mentioned were increases in costs of processing mechanically harvested as opposed to hand harvested berries and the possible reduction in berry quality for use in some finished products.

It appeared that in general mechanically harvested berries required more careful cleaning and sorting because of the cull fruit and foreign material intermixed with the berries when they arrived at the plant. This tended to increase processing costs per unit either by a reduction in plant capacity or because of additional sorting labor and cleaning equipment. It was noted too that mechanically harvested caneberries were more crushed or "juiced" than were hand picked berries, particularly those handled in large containers. This also resulted in difficulty in the cleaning operation.

Mechanical harvesting in 1963 appeared to have some influence on the type of finished products into which these berries were processed. In most cases mechanically harvested berries were utilized in products such as jam, jelly, puree, flavoring, and dye. For black raspberries these uses were not limiting because this particular type of berry is not utilized to any extent in products requiring the whole berry form. For other berries used to a larger extent in whole berry form their end use would be more restricted.

Ultimately mechanical harvesting of caneberries will have an impact on the consumer. Net cost reductions occurring at the grower and processor levels will probably in the long run at least partially be passed on to the consumer. If this should occur, an increase in quantity of caneberries purchased may result. Any decrease in quality in the finished product as a result of mechanical harvesting could have the opposite effect, however. This aspect of the problem warrants additional study.

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APPENDIX

Appendix Table 1. Production of caneberries in the Pacific Coast states, 1950 - 1963.

Crop Year	Oregon	Washington/1	California	Total Pacific Coast States
		- - - - -Thousands of Pounds - - - - -		
1950	12,050	14,095	21,640	47,785
1951	25,300	21,783	16,360	63,443
1952	30,200	21,554	N.A.	51,754/3
1953	29,600	25,640	16,700	71,940
1954	37,200	19,380	2,180/2	58,760/4
1955	39,600	22,940	24,230	86,770
1956	25,600	1,550	31,360	58,510
1957	52,700	27,641	28,730	109,071
1958	43,150	22,275	33,260	98,685
1959	44,100	21,067	27,010	92,177
1960	46,100	23,284	20,810	90,194
1961	38,573	19,986	21,620	80,176
1962	42,810	20,935	21,580	85,325
1963	41,940	23,357	16,910	82,207

/1 Does not include Boysen, Young, and Loganberries.

/2 Includes only Loganberries.

/3 Oregon and Washington only.

/4 Oregon and Washington, and only Loganberries for California.

Source: Data were obtained from the Oregon Berry Crop Annual Summary, 1950-1964, California Bushberry Report, 1950-1964, and Berry Crops, 1963. U.S. Department of Agriculture (35)(36)(37).

Appendix Table 2. Production of caneberries in Oregon, 1950-1963.

Crop Year	Red Raspberries	Black Raspberries	Tame Blackberries	Boysen and Youngberries	Loganberries	Total
			- - - - - Thousands of Pounds - - - - -			
1950	3,250	3,400	1,350	2,700	1,350	12,050
1951	4,600	4,600	7,500	6,100	2,500	25,300
1952	6,100	5,200	9,200	6,800	2,900	30,200
1953	6,000	3,300	11,600	6,100	2,600	29,600
1954	9,900	3,700	13,000	8,400	2,200	37,200
1955	9,300	5,700	14,800	8,200	1,600	39,600
1956	7,400	3,600	12,300	2,000	300	25,600
1957	14,500	8,800	18,600	9,200	1,600	52,700
1958	11,600	9,300	14,600	6,600	1,050	43,150
1959	10,900	5,800	18,000	7,700	1,700	44,100
1960	11,800	4,200	22,900	5,300	1,900	46,100
1961	9,800	3,273	18,480	4,560	2,460	38,573
1962	12,500	2,470	22,800	3,240	1,800	42,810
1963	14,820	3,450	18,240	3,360	2,070	41,940

Source: Data were obtained from the Oregon Berry Crop Annual Summary, U. S. Department of Agriculture (36).

Appendix Table 3. Production of caneberries in California, 1950 - 1963.

Crop Year	Red Raspberries	Loganberries	Boysen and Youngberries	Blackberries/1	Total
	- - - - - - Thousands of Pounds - - - - -				
1950	900	1,820	18,920/2		21,640
1951	1,000	1,400	13,960/2		16,360
1952	N. A.	N. A.	N. A.	N. A.	N. A.
1953	900	1,420	13,660	720	16,700
1954	1,080	1,100	N. A.	N. A.	2,180
1955	1,440	990	19,560	2,240	24,230
1956	1,280	860	24,220	5,000	31,360
1957	1,160	700	21,060	5,810	28,730
1958	1,700	330	24,040	7,190	33,260
1959	1,410	350	17,560	7,690	27,010
1960	1,700	530	13,080	5,500	20,810
1961	860	340	14,320	6,100	21,620
1962	1,220	440	13,720	6,200	21,580
1963	810	350	11,160	4,590	16,910

/1 Includes Olallieberries.

/2 Figure is for Boysen, Young, and blackberries combined.

Source: Data were obtained from the California Bushberry Report 1950 - 1964. U.S. Department of Agriculture (35).

Appendix Table 4. Production of caneberries in Washington, 1950 - 1963.

Crop Year	Red Raspberries	Black Raspberries	Tame Blackberries	Total
	- - - -Thousands of Pounds - - - -			
1950	12,870	625	600	14,095
1951	13,065	468	8,250	21,783
1952	12,900	624	8,030	21,554
1953	15,660	550	9,430	25,640
1954	13,440	420	5,520	19,380
1955	15,340	520	7,080	22,940
1956	980	120	450	1,550
1957	19,665	851	7,125	27,641
1958	15,045	600	6,630	22,275
1959	15,080	437	5,550	21,067
1960	16,640	414	6,230	23,284
1961	14,400	360	5,226	19,986
1962	14,805	240	5,890	20,935
1963	18,105	280	4,972	23,357

/1 Does not include Boysen, Young, and Loganberries.

Source: Data were obtained from Berry Crops 1963. U.S. Department of Agriculture (37).

Appendix Table 5. Estimated hand harvesting costs per pound by component for black raspberries with varying levels of recovered yield per acre. /1

Total Recovered Yield Per Acre (Pounds)	Pickers S. I. A. I. /2 (Dollars)	Supervisory Labor (Dollars)	Supervisors S. I. A. I. and S. S. (Dollars)	All Other Indirect Costs (Dollars)	Total Indirect Costs (Dollars)	Indirect Costs Per Pound (Cents)	Direct Harvest Costs Per Pound (Cents)	Total Harvest Costs Per Pound (Cents)
1,000	29.63	445.00	35.30	267.47	777.40	3.89	5.75	9.64
2,250	61.25	667.50	52.24	267.47	1,048.46	2.33	5.75	8.08
3,000	81.68	667.50	52.24	341.47 /3	1,142.89	1.91	5.75	7.66
4,000	108.90	667.50	52.24	341.47 /3	1,170.11	1.46	5.75	7.21
5,000	136.13	667.50	52.24	341.47 /3	1,197.34	1.20	5.75	6.95
6,000	163.35	667.50	52.24	341.47 /3	1,224.56	1.02	5.75	6.77

/1 Based upon the estimated typical harvest requirements and costs for 20 acres as presented in Chapter II. The 1,000 pound total recovered yield per acre is harvested in two pickings and all others in three pickings. The economic value of the berries not recovered is not included here.

/2 S. I. A. I. and S. S. stand respectively for State Industrial Accident Insurance and Social Security.

/3 The school bus is driven twice the mileage.

Appendix Table 6. Estimated hand harvesting costs per pound by component for red raspberries with varying levels of recovered yield per acre. /1

Total Recovered Yield Per Acre (Pounds)	Pickers S. I. A. I. /2 (Dollars)	Supervisory Labor (Dollars)	Supervisors S. I. A. I. and S. S. (Dollars)	All Other Indirect Costs (Dollars)	Total Indirect Costs (Dollars)	Indirect Costs Per Pound (Cents)	Direct Harvest Costs Per Pound (Cents)	Total Harvest Costs Per Pound (Cents)
2,000	53.01	733.13	30.69	1,151.42 /3	1,968.25	4.92	5.42	10.34
4,000	106.01	1,294.50	107.11	1,357.92	2,865.54	3.58	5.42	9.00
6,000	159.00	1,294.50	107.11	1,357.92	2,918.53	2.43	5.42	7.85
8,000	211.99	1,294.50	107.11	1,357.92	2,971.52	1.86	5.42	7.28
9,000	238.13	1,294.50	107.11	1,357.92	2,997.66	1.67	5.42	7.09
10,000	264.98	1,294.50	107.11	1,357.92	3,024.51	1.51	5.42	6.93
12,000	317.98	1,294.50	107.11	1,357.92	3,077.51	1.28	5.42	6.60
14,000	370.97	1,294.50	107.11	1,357.92	3,130.50	1.12	5.42	6.54
16,000	423.96	1,294.50	107.11	1,357.92	3,183.49	1.00	5.42	6.42

/1 Based upon the estimated typical harvest requirements and costs for 20 acres as presented in Chapter II. All total recovered yields per acre are assumed to be harvested in five pickings, except at the 2,000 pound level, which is assumed to be harvested in four pickings. The economic value of the berries not recovered is not included here.

/2 S. I. A. I. and S. S. respectively represent State Industrial Accident Insurance and Social Security.

/3 It is assumed that only one school bus is used and that the car is used 1,000 miles for the harvest at this yield level.

Appendix Table 7. Estimated hand harvesting costs per pound by component for Thornless Evergreen blackberries with varying levels of recovered yield per acre. /1

Total Recovered Yield Per Acre (Pounds)	Pickers S. I. A. I. /2 (Dollars)	Supervisory Labor (Dollars)	Supervisors S. I. A. I. and S. S. (Dollars)	All Other Indirect Costs (Dollars)	Total Indirect Costs (Dollars)	Indirect Costs Per Pound (Cents)	Direct Harvest Costs Per Pound (Cents)	Total Harvest Costs Per Pound (Cents)
2,000	11.17	271.50	21.83	158.38 /3	462.88	4.63	4.17	8.80
4,000	16.57	339.00	27.84	186.56	569.97	2.85	4.17	7.02
6,000	24.84	339.00	27.84	186.56	578.24	1.93	4.17	6.10
8,000	33.12	339.00	27.84	186.56	586.52	1.47	4.17	5.64
10,000	48.28	339.00	27.84	186.56	601.68	1.20	4.17	5.37
12,000	57.93	339.00	27.84	186.56	611.33	1.02	4.17	5.19
14,000	67.58	339.00	27.84	186.56	620.98	0.89	4.17	5.06
16,000	77.25	339.00	27.84	186.56	630.65	0.79	4.17	4.96

/1 Based upon the estimated typical harvest requirements and costs for five acres as presented in Chapter II. All total recovered yields per acre are assumed to be harvested in five pickings, except at the 2,000 pound level, which is assumed to be harvested in four pickings. The economic value of the berries not recovered is not included here.

/2 S. I. A. I. and S. S. respectively represent State Industrial Accident Insurance and Social Security.

/3 It is assumed that the car is used 350 miles for harvest at this yield level.

Appendix Table 8. Estimated hand harvesting costs per pound by component for Marion blackberries with varying levels of recovered yield per acre. /1

Total Recovered Yield Per Acre (Pounds)	Pickers S. I. A. I. /2 (Dollars)	Supervisory Labor (Dollars)	Supervisors S. I. A. I. and S. S. (Dollars)	All Other Indirect Costs (Dollars)	Total Indirect Costs (Dollars)	Indirect Costs Per Pound (Cents)	Direct Harvest Costs Per Pound (Cents)	Total Harvest Costs Per Pound (Cents)
2,000	6.26	262.50	11.78	98.65	379.19	4.74	3.50	8.24
4,000	12.52	348.00	28.43	138.65	527.60	3.30	3.50	6.80
6,000	18.78	348.00	28.43	178.65	573.86	2.39	3.50	5.89
8,000	25.04	348.00	28.43	218.65	620.12	1.94	3.50	5.44
10,000	31.30	348.00	28.43	258.65	666.38	1.67	3.50	5.17
12,000	37.56	348.00	28.43	298.65	712.64	1.48	3.50	4.98
14,000	43.82	348.00	28.43	338.65	758.90	1.36	3.50	4.86
16,000	50.08	348.00	28.43	378.65	805.16	1.26	3.50	4.76

/1 Based upon the estimated typical harvest requirements and costs for four acres as presented in Chapter II. All total recovered yields per acre are assumed to be harvested in four pickings, except at the 2,000 pound level, which is assumed to be harvested in three pickings. The economic value of the berries not recovered is not included here.

/2 S. I. A. I. and S. S. respectively represent State Industrial Accident Insurance and Social Security.

Appendix Table 9. Estimated quantity of black raspberries dropped by picking for hand harvesting expressed as percentages of recovered yield.

Field Code	Number of Picking	Total Recovered Yield (Pounds)	Berries Dropped (Pounds)	Drop as a Percent of Recovered Yield (Percent)	Average Percent of Recovered Yield (Percent)
R	1	46,177.2	2,773.6	6.0	
M	1	12,422.0	825.8	6.6	
W	1	19,968.8	2,016.8	10.1	
Total		78,568.0	5,616.2		7.1
R	2	35,914.8	1,978.8	5.5	
W	2	35,943.8	926.8	2.6	
Total		71,858.6	2,905.6		4.0
W	3	15,975.0	478.8	3.0	3.0
W	4	7,987.5	202.0	2.5	2.5

Appendix Table 10. Estimated quantity of black raspberries remaining on the canes after hand harvest completion expressed as a percent of recovered yield.

Field Code	Total Recovered Yield (Pounds)	Berries Remaining On The Canes After Harvest (Pounds)	Berries Remaining On The Canes After Harvest as a Percent of Total Recovered Yield (Percent)	Average Percent Of Total Recovered Yield Remaining on the Canes After Harvest (Percent)
W	79,875	13,920	17.4	
T	22,000	3,835	17.4	
Total	101,875	17,755		17.4

Appendix Table 11. Estimated quantity of Thornless Evergreen blackberries dropped by picking for hand harvesting expressed as percentages of recovered yield.

Field Code	Number of Picking	Total Recovered Yield (Pounds)	Berries Dropped (Pounds)	Drop as a Percent of Recovered Yield (Percent)	Average Percent of Recovered Yield Dropped (Percent)
K	1	18,492	473.2	2.6	
R	1	18,765	744.9	4.0	
Total		37,257	1,218.1		3.3
K	2	24,088	2,669.3	11.1	
R	2	12,965	738.4	5.7	
Total		37,053	3,407.7		9.2
K	3	18,488	1,063.7	5.8	
R	3	8,467	330.5	3.9	
Total		26,955	1,394.2		5.2
K	4	19,711	692.4	3.5	
R	4	4,649	227.0	4.9	
Total		24,360	919.4		3.8
K	5	9,176	347.0	3.8	3.8

Appendix Table 12. Estimated quantity of black raspberries dropped by picking for mechanical harvesting expressed as percentages of recovered yield.

Field Code	Number of Picking	Recovered Yield Per Picking (Pounds)	Drop Per Picking (Pounds)	Drop as a Percent of Recovered Yield (Percent)	Average Percent of Recovered Yield Dropped (Percent)
P	1	11,668	2,049.9	17.6	
M	1	25,856	9,345.9	36.1	
Total		32,524	11,395.8		35.0
H	2	8,047	1,995.5	24.8	
J	2	10,539	2,019.5	19.2	
P	2	28,910	6,574.0	22.7	
R	2	20,605	7,521.6	36.5	
M	2	10,843	4,368.3	40.3	
Total		78,944	22,478.9		28.5
P	3	13,817	2,004.2	14.5	
R	3	10,806	3,041.2	28.1	
M	3	19,035	4,862.0	25.5	
Total		43,658	9,907.4		22.7
P	4	5,157	931.7	18.1	
R	4	2,776	1,110.4	40.0	
M	4	5,776	2,531.3	43.8	
Total		13,709	4,573.4		33.4

Appendix Table 13. Estimated quantity of black raspberries remaining on the canes after mechanical harvest completion expressed as a percent of recovered yield.

Field Code	Total Recovered Yield (Pounds)	Berries Remaining On the Canes After Harvest (Pounds)	Berries Remaining On the Canes After Harvest as a Percent of Total Recovered Yield (Percent)	Average Percent Of Total Recovered Yield Remaining On the Canes After Harvest (Percent)
P	60,575	3,458	5.7	
M	70,052	4,488	6.4	
R	88,287	2,400	2.7	
Total	218,914	10,346		4.7

Appendix Table 14. Estimated mechanical harvesting costs by component for black raspberries with assumed levels of harvester replacement cost. /1

Harvester Replacement Cost	$9,000.00	$12,000.00	$15,000.00
Salvage value	900.00	1,200.00	1,500.00
Replacement cost less salvage value	8,100.00	10,800.00	13,500.00
Depreciation	1,620.00	2,160.00	2,700.00
Interest on Investment	270.00	360.00	450.00
Insurance	90.00	120.00	150.00
Property Tax	90.00	120.00	150.00
Fixed Repairs and Maintenance	67.50	90.00	112.50
Storage	50.00	50.00	50.00
Total annual fixed cost of mechanical harvester	2,187.50	2,900.00	3,612.50
Total other fixed annual costs	55.09	55.09	55.09
Total of all fixed costs	2,242.59	2,955.09	3,667.59
Total of all variable costs	1,345.58	1,345.58	1,345.58
Total harvest cost	$3,588.17	$4,300.67	$5,013.17
Harvest cost per pound in cents	3.99	4.78	5.57

/1 Based upon the present level of performance as shown in Table 5.

Appendix Table 15. Estimated mechanical harvesting costs by component for black raspberries with assumed levels of harvester life. /1

Expected years of harvester life	3	5	7	10
Salvage value /2	$1,680.00	$1,200.00	$ 720.00	$ 480.00
Replacement cost less salvage value	10,320.00	10,800.00	11,280.00	11,520.00
Depreciation	3,440.00	2,160.00	1,611.43	1,152.00
Interest on investment	360.00	360.00	360.00	360.00
Insurance	120.00	120.00	120.00	120.00
Property Tax	120.00	120.00	120.00	120.00
Fixed Repairs and Maintenance	90.00	90.00	90.00	90.00
Storage	50.00	50.00	50.00	50.00
Total annual fixed cost of a mechanical harvester	4,180.00	2,900.00	2,351.43	1,892.00
Total other fixed annual costs	55.09	55.09	55.09	55.09
Total of all fixed costs	4,235.09	2,955.09	2,406.52	1,947.09
Total of all variable costs	1,345.58	1,345.58	1,345.58	1,345.58
Total harvest cost	$5,580.67	$4,300.67	$3,752.10	$3,292.67
Harvest cost per pound in cents	6.20	4.78	4.17	3.66

/1 Based upon the present level of performance as shown in Table 5.

/2 Computed as a percent of the $12,000 replacement cost as follows: 3 years - 14 percent; 5 years - 10 percent; 7 years - 6 percent; and 10 years - 4 percent.

Appendix Table 16. Estimated fixed and variable costs per pound for mechanically harvesting black raspberries with various assumed levels of harvester use during the season. /1

		ACRES OF HARVESTER USE FOR OTHER CANEBERRIES				ACRES OF HARVESTER USE FOR OTHER CANEBERRIES		
		0	40	80		0	40	80
Number of Acres	Total Recovered Yield (Pounds)	Fixed Cost Per Pound (Cents)	Fixed Cost Per Pound (Cents)	Fixed Cost Per Pound (Cents)	Variable Cost Per Pound (Cents)	Total Cost Per Pound (Cents)	Total Cost Per Pound (Cents)	Total Cost Per Pound (Cents)
10	22,500	13.13	2.63	1.46	1.45	14.58	4.08	2.91
20	45,000	6.57	2.18	1.31	1.49	8.06	3.67	2.80
30	67,500	4.38	1.89	1.19	1.50	5.88	3.39	2.69
40	90,000	3.28	1.64	1.09	1.50	4.78	3.14	2.59
50	112,000	2.63	1.47	1.01	1.50	4.13	2.97	2.51
60	135,000	2.19	1.31	0.94	1.50	3.69	2.81	2.44
70	157,500	1.88	1.19	0.88	1.50	3.38	2.69	2.38
80	180,000	1.64	1.09	0.82	1.50	3.14	2.59	2.32

/1 Based upon the present level of performance as shown in Table 5.

Appendix Table 17. Estimated fixed and variable costs per pound for mechanically harvesting black raspberries with various assumed levels of recovered yield. /1

Total Recovered Yield Per Acre (Pounds)	Fixed Cost Per Pound (Cents)	Variable Cost Per Pound (Cents)	Total Cost Per Pound /2 (Cents)
1,000	7.39	3.19	10.58
1,500	4.93	2.17	7.10
2,000	3.69	1.66	5.35
2,250	3.28	1.50	4.78
2,500	2.96	1.36	4.32
3,000	2.46	1.16	3.62
3,500	2.11	1.01	3.12
4,000	1.85	0.90	2.75
4,500	1.64	0.82	2.46
5,000	1.48	0.75	2.23
5,500	1.34	0.69	2.03
6,000	1.23	0.65	1.88

/1 Based upon the present level of performance as shown in Table 5.

/2 Fixed and variable costs per pound may not add to total cost per pound due to rounding. The economic cost of the pounds of berries dropped is not included here.

Appendix Table 18. Comparison of estimated marginal costs and returns for an additional picking of black raspberries yielding various assumed levels of product. /1

Recovered Yield Per Acre (Pounds)	Total Value of Recovered Yield Per Acre /2 (Dollars)	Total Variable Cost Per Acre (Dollars)	Net Difference Per Acre /3 (Dollars)
15	4.25	7.66	-3.41
25	7.08	7.67	-.59
27.08	7.67	7.67	.00
35	9.92	7.68	+2.24
50	14.17	7.61	+6.46
75	21.25	7.74	+13.51
100	28.33	7.77	+20.56

/1 The variable cost per hour of operation, field size, and harvester speed are assumed to be at the present performance level as shown in Table 5.

/2 The berries are valued at 28.33 cents per pound, which is the average price received by growers for black raspberries during the period 1961-1963.

/3 The economic cost of the berries dropped is not included.

Appendix Table 19. Statistical tests of significance to determine if a difference exists between hand and mechanical harvest with respect to black raspberries dropped by picking and remaining on canes after last picking.

Item	Degrees of Freedom	t Values
Number of berries dropped by picking /1		
First Picking	125	-7.216 *
Second Picking	110	-8.263 *
Third Picking	81	-6.547 *
All Pickings	393	-8.376 *
Number of berries remaining on the canes after harvest completion /2	108	6.908 *

* Significant at 1 percent level.

/1 Based upon the t tests, the conclusion was reached that there was a significant difference in the sample means of the number of berries dropped by hand and machine harvest. The machine harvest drop was higher in all cases tested.

/2 Based upon the t test, the conclusion was reached that there was a significant difference in the sample means of the number of berries remaining on the cones after hand and mechanical harvest, with the hand harvest loss being higher.