A COST-ANALYSIS STUDY OF THE GRAPE HARVEST MECHANIZATION

by

Guillermo A. Atkins

A thesis
submitted in partial
fulfillment of the requirements for the degree of
Master of Science in the School of Agriculture
California State University, Fresno
September 1972

ACKNOWLEDGMENTS

As I traveled the path toward a more fuller understanding of machinery economics and grape harvesting in particular, I encountered many obstacles. Fortunately, there were those about me who helped me maintain a sense of direction, marked the way for me when uncertainties existed, as well as helping me bring my studies to a conclusion.

Appreciation and sincere gratitude for making this study possible are owed to the following:

Dr. Badr for exposing me to the realm of the biological factors encountered in mechanical harvesting.

Dr. Chancellor for extending his guidance beyond that of his own institution whenever asked to do so. Patience and the keen sense of knowing what pertinent information I needed made my visit to his office always a bonanza.

Professor Ben From for providing me with some of the essential inputs that were incorporated into the paper as the results of his work with the grape mechanization problem.

Dr. Hagen for his ability to make a pending research disaster blend back into the mainstream of the study by his "what you may try" approach in his guidance of my work.

Professor Vincent Petrucci for his willingness to share his vast amount of knowledge with me on the production of grapes and for his collaboration of studies that he was conducting that paralled my effort.

Dr. Joo Kim, the Chairman, for his initiating me into the study of machinery economics. He is the man who started me off on this research sojourn, pointed the way when the need arose, as well as helping me out when I became bogged down due to my novice relationship with this type of study. He is responsible for making the study a very real and dynamic part of my graduate work, as well as for providing me with a knowledge level on which I will base future endeavors as I go on through life. Ultimate responsibility for the content of the paper, of course, rests with me as well as the burden or blessing that future events will have upon my work.

TABLE OF CONTENTS

	Page
LIST OF TABLES	x
LIST OF FIGURES	xi
LIST OF PHOTOGRAPHS	xiii
LIST OF ABBREVIATIONS	xiv
Chapter	
1. INTRODUCTION	1
MACHINERY MANAGEMENT AND THE HARVEST MECHANIZATION	1
SCOPE AND PURPOSE OF THE RESEARCH . . .	2
2. REVIEW OF LITERATURE	4
DEVELOPMENT OF THE MECHANICAL GRAPE HARVESTER	4
FIELD MACHINERY SELECTION	5
COST ANALYSIS	6
FIXED COSTS	7
Methods of Estimating Depreciation	7
Deprivation of the Interest Formulas	9
Uniform Annual Series of End-of-Year Payments	10
Service Life	11
Interest on Investment	12
Taxes	14

Chapter | Page

Insurance 14
Shelter 14
Purchase Price of Tractors and Equipment 14
VARIABLE COST 15
Fuel Cost 17
Oil Consumption 17
Power and Energy Considerations 19
Field Efficiency 21
TIMELINESS FACTOR FOR FIELD OPERATION . . 22
MACHINERY SELECTION 24
3. METHODOLOGY 29
ANALYSIS OF THE SURVEY 29
BASIC ASSUMPTIONS 32
4. RESULTS AND DISCUSSION 35
INTRODUCTORY REMARKS 35
MARKETING CONDITIONS 35
CULTURAL PRACTICES 36
DISCUSSION OF THE PROCEDURE 36
THE TIMELINESS FACTORS 44
THE COST ANALYSIS 47
EFFICIENCY 48
THE EFFECT OF MACHINE HARVEST EFFICIENCY VERSUS HAND HARVESTING ON GROSS INCOME 53
5. SUMMARY AND CONCLUSIONS 68

Chapter Page

LITERATURE CITED 72

APPENDIX A 74

APPENDIX B 75

APPENDIX C 77

LIST OF TABLES

Table		Page
1.	Life of Machines	13
2.	Specific Price of New Implements	16
3.	Repair and Maintenance Cost Percent of Purchase Price	18
4.	Fuel Requirements	19
5.	Oil Consumption of Tractors	20
6.	Typical Farm Implement Force Factors	21
7.	Typical Field Efficiencies	23
8.	Timeliness Factors	24
9.	Values for the Fixed Cost Percentage	28
10.	Timeliness Factor for the Grape Harvest Operation	45
11.	Effect of Picking Efficiency on Income on Thompson Seedless Grapes per Acre . . .	57
12.	Break-Even Point (Acres Required per Machine)	71

LIST OF FIGURES

Figures Page

1. Value of Timeliness Factor 25

2. Increase in Weight of the Crop in Relation to Time and the Increase in Soluble Solids 46

3. Cost of Harvesting per Ton is a Dollar per Ton in Relation to the Total Annual Tonnage Harvested per Machine 50

4. Cost of Harvesting per Ton is a Dollar per Ton in Relation to the Total Annual Tonnage Harvester per Machine 51

5. Cost of Harvesting per Ton is a Dollar per Ton in Relation to the Total Annual Tonnage Harvested per Machine 52

6. Production of Profit with the Decrease in Picking Efficiency or the Increase in Profit with Better Efficiency When Comparing the Machine Harvest with Hand Picking 56

7. Gross Profit per Harvested Acre Shown in Relation to Yield, Price per Ton, and the Alternatives of Harvesting Methods (Hand vs. Machine) 59

8. Gross Profit per Harvested Acre Shown in Relation to Yield, Price per Ton, and the Alternatives of Harvesting Methods (Hand vs. Machine) 60

9. Gross Profit per Harvested Acre Shown in Relation to Yield, Price per Ton, and the Alternatives of Harvesting Methods (Hand vs. Machine) 61

Figures | Page

10. Gross Profit per Harvested Acre Shown in Relation to Yield, Price per Ton, and the Alternatives of Harvesting Methods (Hand vs. Machine) 62

11. Gross Profit per Harvested Acre Shown in Relation to Yield, Price per Ton, and the Alternatives of Harvesting Methods (Hand vs. Machine) 63

12. Gross Profit per Harvested Acre Shown in Relation to Yield, Price per Ton, and the Alternatives of Harvesting Methods (Hand vs. Machine) 64

13. Gross Profit per Harvested Acre Shown in Relation to Yield, Price per Ton, and the Alternatives of Harvesting Methods (Hand vs. Machine) 65

14. Gross Profit per Harvested Acre Shown in Relation to Yield, Price per Ton, and the Alternatives of Harvesting Methods (Hand vs. Machine) 66

15. Gross Profit per Harvested Acre Shown in Relation to Yield, Price per Ton, and the Alternatives of Harvesting Methods (Hand vs. Machine) 67

LIST OF PHOTOGRAPHS

Photographs	Page
1. Basic Equipment: Hand Harvest	33
2. Basic Equipment: Mechanical Harvest . . .	33
3. Harvesting Operation	40
4. Vine Damage by the Mechanical Harvester	40
5. One of the Causes of Juicing	41
6. Juicing Symptom: Defoliations and Juicing	43
7. Juicing Symptom: Juice Over Leaves . . .	43

LIST OF ABBREVIATIONS

A	Annual use in acres
CAH	Cost of harvesting one ton
COP	Cost of production per acre
$COPT^1$	Cost of production of one ton by hand harvesting
$COPT^2$	Cost of production of one ton by mechanical harvesting
CR	Capital recovery rate
D	Annual depreciation charges
e	Field efficiency as decimal
EFF	Picking efficiency
F	Declining balance rate expressed as decimal
G	Gas and oil expenses per acre
GPTH	Gross income per acre by hand harvesting
GPTM	Gross income per acre by mechanical harvesting
i	Interest rate percentage
K	Timeliness factor
L	Salvage value
LA	Labor cost rate in dollars per hour
M	Maintenance
n	Estimated life of the machine in years
O	Oil cost
OW	Operators wages
P	Purchase price
PE	Number of tons harvested considering efficiency
PPT	Price paid per ton

R	Repairs
RML	Repairs, maintenance and labor
S	Forward speed in miles per hour
SF	Sinking fund
Sn	Sum of the digits
T	Cost of tractor use by the machine
TIS	Tax, insurance and shelter
TO	Tons per acre
V	Value of the crop
Vn-x	Value at the end of the year n-x
X	Cost of harvest per ton
Y	Potential yield bushels, tons, etc
Y_t	Total number of tons per season
W	Effective width of the machine in operation (in feet)

Chapter 1

INTRODUCTION

Machinery Management and the Harvest Mechanization

The economic management of machinery and power in agriculture represents only 5.5 percent of the capital engaged in this type of enterprise, but the cost of operating this equipment represents 36 percent of the annual cost of production (10). Consequently, the economic study of new machinery is essential in order to develop good management techniques that will help the farmer make sound decisions.

Mechanized harvesting is a comparatively new and developing field, especially in the harvesting of fruits from trees and vines. This task may be accomplished with the use of mechanical aids or complete mechanization of the harvesting operation; the latter of which presents a "brighter" future for agriculture during periods of labor shortages. All mechanization schemes for harvesting operations have common factors that must be considered when attempting to modify the existing harvest system. From a Horticultural point of view, there are five factors which should be considered when determining the feasability of machine harvesting. These factors are summarized by Claypool (7): 1) Selectivity for maturity; 2) Completeness of fruit removal; 3) Conditions of harvest fruit; 4) Tree damage; 5) Required modifications of cultural practices.

One of the fairly recent agricultural developments is the mechanical harvester for wine grape varieties. Mechanical grape harvesting offers a great promise to the viticulturist assuring him that the crop will be picked at optimum time. An economic study that determines the annual operational cost of this new machine will aid the farmer in making a sound decision.

Scope and Purpose of the Research

The cost of production for a grape operation is similar for hand and mechanical harvest, except for the cost of the actual harvest. Taking this into consideration the analysis of the multiple alternatives incurred by mechanical harvesting in comparison with the hand harvesting is very important. The alternatives were selected according to the information gathered from the questionnaires, previous studies (4), and other sources of information that were available (15). Two computer programs were developed in order to facilitate future calculations and to aid the farmer in the solution of management problems. The picking efficiency of the machine was evaluated in the field. Recommendations about the acreage to be harvested in one season were made for the Thompson Seedless variety, with the efficiency that resulted from the field evaluation. Graphs are presented so the viticulturist can evaluate his operation according to pertinent figures for the geographical region in which he is working.

Chapter 2

REVIEW OF LITERATURE

Development of the Mechanical Grape Harvester

The starting point for the invention of the grape harvester was at the University of California at Davis. The person most responsible for the mechanization of grape harvesting in that center is A. J. Winkler of the Department of Viticulture and Enology (6). His idea was based on the principle of arranging the vines in a specific manner so that they would grow in a predetermined space. In this way the grapes could easily be reached for picking with a harvester. The harvester was a product of teamwork between the Department of Agricultural Engineering and the Department of Viticulture and Enology, which resulted in working pilot models (1952). The pilot harvester utilized the principle of a cutter barhead (6).

The experimentation with the mechanical harvester in California was followed in 1957 by more experiments in New York (6). The use of this new machine had to be modified to improve the harvest capability of some grape cultural practices. For example, new trellis systems have been developed: The Geneva double curtain and duplex system which arranges the plant in such a way as to make the harvester more efficient. This modification not only facilitates the harvesting, but also improves the quality and increases the yield (18).

The early development of the grape harvester resulted in the design of a spiked wheel shaker that was later perfected for a continuous operation; this machine was called the Cornell Grape Harvester.

In the search for the best method of detaching the grapes from the vine, it was found that the removal of the Concord variety was possible by shaking the plant, or the wire of the trellis. The start of this theory was a simple pitman arm attached to the cordon wire with a U bolt clamp. The principle of forces actuating, that favor the detachment of the berry, is the rotation of the fruit along its axis on the pedicel.

<u>Field Machinery Selection</u>

There are many methods that are applicable in selecting field machinery for different purposes; some of them use computers in order to make this task easier, and to speed up the process. The use of computers is sometimes helpful, because some variables change with time and with the aid of this new science, solutions can be found in a shorter time. There are some systems already developed for the selection of machinery for specific farming enterprises. Simons (17) developed a program to select field machinery and analyze the cost of operation. Another, created by

Hunt (9) was aimed toward solving field selection of machinery on a least cost basis.

Cost Analysis

The depreciation of an asset may be divided into two components, variable and fixed. The fixed cost of operation is equivalent to the amortized cost, plus the difference in value between the existing old asset and a hypothetical new one, taking the latter as a standard of comparison. The variable cost is the Impaired Serviceability of the asset. There are four concepts of depreciation described by Bonbrigh (5). They are as follows:

1. Decrease in Value: This implies that the value of the asset is computed on two different dates. Consideration must be given to the value of the property to the owner, as well as the real market value of the property.

2. Amortized Cost: The cost of an asset is a prepaid operating expense to be apportioned among the years of its life by some systematic procedure.

3. Difference in Value Between an Existing Old Asset and a Hypothetical New Asset as a Standard of Comparison: The new asset may have certain advantages over an old existing one, such as longer life expectancy, lower annual disbursements for operation and maintenance, increased receipts for the sale of the product or services.

4. Impaired Serviceableness: As the machine

becomes older, it is unable to perform as well as when it was new.

Fixed Costs

Methods of estimating depreciation. There are several methods for estimating depreciation. The four methods most commonly used are (8): Straight-Line, Declining Balance, and Sum of the Year's Digits, and the Sinking Fund.

Straight-Line depreciation is the method by which the value of the machine is reduced by an equal amount each year throughout the life of a machine.

$$D = \frac{P - L}{n} \quad (1)$$

Where D = Annual depreciation charge

P = Purchase price

L = Salvage value

n = Estimated life of the machine

Declining Balance depreciation method permits a larger write-off at the beginning of the machine's life. This method is seldom used. One of the drawbacks is that this method cannot be used with a zero salvage value.

$$P \quad (1-f)^n \quad (2)$$

$$L = P\ (1 - f)^n$$

$$f = 1 - n\frac{L}{P}$$

Where P = First cost

L = Terminal salvage value

n = Estimated life of the machine

f = Declining balance rate expressed as decimal

Sum of the Year's Digits depreciation, as in the previous method, also permits a greater write-off at the beginning of the asset's life. The digits of the estimated number of years of the life of the asset are added together, then this sum is divided into the number of years of useful life remaining in the machine, including the current year.

$$Sn = 1 + 2 + 3 + \ldots\ldots + (n-1) + n \qquad (3)$$

$$D = (P - L)\left(\frac{n-5}{Sn}\right) \text{ (for the fifth)}$$

$$D = (P - L)\left(\frac{n}{Sn}\right)$$

Where D = Annual depreciation of the machine

P = First cost of the machine

L = Salvage value

n = Estimated life of the machine

Sn = Sum of the digits

Sinking Fund depreciation considers the cost of depreciation as an investment drawing a compound interest. The accumulation of this fund up until the time the machine is fully depreciated, plus the interest, is used to purchase the replacement machine.

$$SF = (P - L) \frac{i}{(1 = i)^n - 1} \qquad (4)$$

Where SF = Sinking fund

P = First cost

L = Salvage value

i = Interest rate percentage

n = Estimated life of the machine

Its value at the end of the year n is:

$$V_{n-x} (P - L) \frac{(1 + i)^n - (1 + i)^{n-x}}{(1 + i)^n - 1} \qquad (5)$$

Where n - x= Value at the end of the year n-x

Derivation of the interest formulas (8). Suppose that P is invested at interest rate i, the interest of the first year is iP and the total amount at the end of the first year is P + iP = P (1 + i).

First year	= iP
At the End of the First Year	= P + iP or P(1 + i)
Second Year Interest	= iP (1 + i)
At the End of Second Year	= P(1 + i) + iP (1 + i)
or	$P(1 + i)^2$
At the End of N years	$= P(1 + i)^n$

The formula for the Compound Amount F, obtainable in n years from a principal payment P is as follows:

$$F = P\ (1 + i)^n \qquad (6)$$

$$P = F\ \frac{1}{(1 + i)^n}$$

Uniform annual series of end-of-year payments. If A is invested at the end of each year, then this A will earn interest only on the year that follows, or (n-1), n being the number of years. If we want to find the interest for a year, then the amount can be expressed as $A(1 + i)^{n-1}$. The second year of the investment (end of the year) will be $A(1 + i)^{n-2}$ and the third year will be $A(1 + i)^{n-3}$. The total sum of future payments will be:

$$F = A\ 1 + (1 + i)^1 + (1 + i)^2 + (1 + i)^3 + \ldots + (1 + i)^{n-1}$$

$$(1 + i)\ F = A\ 1 + (1 + i)^1 + (1 + i)^2 + (1 + i)^3 + \ldots + (1 + i)^n$$

Subtracting the first equation from the second equation

$$iF = A\ (1 + i)^n - 1 \qquad (7)$$

$$A = F\ \frac{i}{(1 + i)^n - 1} = P\ (1 + i)^n \frac{1}{(1 + i)^n - 1}$$

$$A = P\ \frac{i\ (1 + i)^n}{(1 + i)^n - 1}$$

$$A/P = \frac{i\ (1 + i)^n}{(1 + i)^n - 1} \qquad \text{(capital recovery factor)}$$

$$CR = (P - L)\ \frac{i\ (1 + i)^n}{(1 + i)^n - 1} + Li \quad (8)$$

$$CR = (P - L)\ (A/P,\ i,\ n) + Li$$

CR = Capital recovery rate

P = Capital invested

L = Salvage value

i = Interest rate percentage

n = Estimated life of the machine in years

<u>Service life</u>. The service life of the machine must be determined in order to calculate its depreciation rate. There are many assets, such as automobiles, which may have different owners before becoming scrap. For each owner, "life" of the asset is the service life of the machine, while serving that particular owner. This expression is for accounting purposes. Grant (8) states:

> An economic study usually relates to the primary or initial type of service of an asset and it's rarely appropriate in an economic study to consider possible stand-by or other inferior services very much during the final years of an asset's life.

The machine's economic life is a more relevant measure of the time period for which depreciation should be estimated, because in actual practice, machine life may be extended as long as the owner wishes to repair or replace the worn parts, in order to keep the machine operable. The sudden termination of the machine's life, due to irreparable or irreplaceable part failure, presents a very difficult problem when estimating the economic life of the machine.

The asset's economic life is the period during which the machine can provide services economically. Its life terminates when it's reasonable to replace the existing machine for a newer one.

There are certain expenses known as overhead cost, which occur whether or not the machine is in use, causing the cost per hour of use to vary inversely with the annual use of the machine. A machinery schedule showing the years of useful life prior to economical obsolescence, wear-out life in hours, and annual average use is presented in Table I, extracted from the 1970 Agricultural Engineers Yearbook (3).

Interest on investment. To estimate the costs of machine operations, the interest on investment in machinery must be included, since the capital invested in the purchase of the asset cannot be committed into another enterprise to earn a financial return. An interest rate of six percent per year has been commonly used (3) and included as one of the ownership costs. Other higher interest rates are commonly used in economic studies.

When the capital recovery formula is used, it is more convenient to allocate similar or higher interest charges, depending upon the actual established interest rates. The capital recovery formula is as follows:

TABLE I

LIFE OF MACHINES

Machines M. . .	Years Until Obsolete	Wear-out Life Hours	Hour per Year for Wear-out Life to Equal Obsolescence Life
Tillage			
Cultivator	12	2,500	208
Disk harrow	15	2,500	167
One-way disk	15	2,500	167
Plow, disk	15	2,500	167
Plow, moldboard	15	2,500	167
Spike-tooth harrow	20	2,500	125
Spring-tooth harrow	20	2,500	100
Planting			
Grain drill	20	1,200	60
Row-crop planter	15	1,200	80
Harvesting			
Combine 5-7 feet trailed	10	2,000	200
Combine, self-propelled	10	2,000	200
Corn picker	10	2,000	200
Cotton picker, drum	8	2,000	250
Cotton stripper, two row	10	2,000	200
Field chopper, aux. eng.	10	2,000	200
Field chopper PTO	10	2,000	200
Forage Blower	12	2,000	167
Hay baler, aux. eng.	10	2,500	250
Hay baler, PTO	10	2,500	250
Hay conditioner	10	2,500	250
Mower	12	2,000	167
Rake, side delivery	12	2,500	208
Sugar beet harvester	10	2,500	250
Windrower, self propelled	8	2,500	313
Tractors and miscellaneous			
Tractor, track type	15	12,000	800
Tractor, wheel type	15	12,000	800
Wagon, rubber-tired	15	5,000	333

Where $CR = (P - L)(A/P, i, n) + Li$ (8)

CR = Capital recovery

P = Purchase price

L = Salvage value

A/P = Capital recovery factor

i = Interest rate

n = Years of life of the machine

Taxes. Tax charges on overhead cost vary widely with location, but a rate of two percent is commonly used (3).

Insurance. The information obtained recommends a charge of one percent of the initial cost of the machine (3) for insurance against the loss of the machine.

Shelter. Since the life expectancy of a sheltered machine is longer than a non-sheltered machine (3) and the shelter functions as a repair facility during idle periods; an average shelter charge of one percent of the initial cost of the machine is recommended (1).

Table VI contains data extracted from information published in the 1968 Agricultural Engineering Yearbook (2) and may be used to estimate the power requirements of agricultural machinery.

Purchase price of tractors and equipment. The information related to the actual price of agricultural machines is not often available, due to the fact that the price is negotiated between the seller and the purchaser. Because of this, a reasonable estimate of machinery prices has to be arrived at, when evaluating machinery costs on a regional basis. Hunt (9) one of the first to do extensive work in this area, tabulated the selling price on a working width and on increments of one foot basis. Southwell (19) also did some work correlating the selling price of machinery using tractors based on 1966 prices. A summary of his study is presented in Table II. This table expresses the purchase price of the machines on a cost per pound or cost per horsepower basis, depending on the type of equipment. The cost per horsepower is derived from the horsepower rating established by the Nebraska tests (14).

Variable Cost

The cost of maintenance, repairs and lubrication is reasonably proportional to the time the machine has been in operation. Actual field conditions, operator handling and maintenance policy of the individual owner are other factors that have to be considered in the cost analysis of the machinery. These variable costs are fairly low during the early life period of the machine and increase in magnitude as the machine accumulates operating time and/or years of age. The repair cost included the cost of the labor incurred when replacing worn or broken parts. The approximate repair cost for a machine throughout its economic life has been established for certain machinery.

TABLE II

SPECIFIC PRICE OF NEW IMPLEMENTS

IMPLEMENT	PRICE RANGE	
Tillage		
Cultivator	38 - 54	dollars/ft.
Disk harrow	60 - 90	dollars/ft.
One-way disk	44 - 55	dollars/ft.
Disk plow	160 - 250	dollars/disk
Moldboard plow	100 - 250	dollars/ bottom
Spike-tooth harrow	15	dollars/ft.
Spring-tooth harrow	18 - 25	dollars/ft.
Planting		
Grain drill	55 - 65	dollars/ft.
Row-crop planter	100 - 180	dollars/row
Harvesting		
Pull-type combine	300 - 400	dollars/ft.
Self-propelled combine	500 - 650	dollars/ft.
Corn picker	1500 - 1700	dollars/row
Cotton picker	7300 - 10,000	dollars/row
Cotton stripper	1000	
Forage harvester	350 - 625	dollars/ft.
Hay conditionery	900	dollars
Mower	75 - 90	dollars/ft.
Side-delivery rake	400 - 500	dollars
Beet harvester	3000	dollars/row
Self-propelled windrower	300 - 400	dollars/ft.

Work on the repair cost for specialized equipment such as the grape harvester is not at this time available. Hunt (10) evaluates repair cost on average constant percentage per hour of use over the economic life of the machine (Table III).

Fuel cost. Consideration must be given to the power requirement when determining the fuel consumption of the tractor for a specific operation. The equivalent power take-off horsepower may be obtained by dividing the required drawbar horsepower by the traction-and-transmission coefficient. The fuel consumption is preported in the Nebraska Test Reports (14) but it should be noted that these tests are conducted under ideal conditions. There are some studies that correlate these results with the actual field conditions. The actual fuel used under field conditions is higher than the consumption obtained under ideal test conditions; these figures range from 15 to 30 percent higher fuel consumption per horsepower hour (3). The recommended fuel values of specific fuel consumption in gallons per horsepower-hour, are shown in Table IV.

Oil consumption. The oil cost of operating an engine is relatively small but it has to be considered on the machine cost analysis. The total amount of oil consumed by the machine during a period of time is the resultant of three factors: 1) Oil burned while the machine is operating;

TABLE III

REPAIR AND MAINTENANCE COST
PERCENT OF PURCHASE PRICE

Machine	Average per Hour	Total During Wear-Out Life
Tillage		
Cultivator	0.060	150
Disk harrow	0.065	168
One-way disk	0.050	125
Disk plow	0.045	113
Moldboard plow	0.070	175
Spike-tooth harrow	0.040	100
Spring-tooth harrow	0.060	120
Planting		
Grain drill	0.080	96
Row-crop planter	0.070	84
Harvesting		
Combine, 5-7 ft. trailed	0.045	90
Combine, self-propelled	0.027	54
Corn picker	0.032[a]	64
Cotton picker, drum type	0.026[a, c]	52
Cotton stripper	0.020[a]	40
Forage harvester, aux, eng.	0.024	48
Forage harvester, PTO	0.029	58
Forage blower	0.025	50
Hay baler, aux, eng.	0.022[b]	55
Hay baler, PTO	0.031[b]	78
Hay conditioner	0.040	100
Mower	0.020	240
Rake, side-delivery	0.070	175
Beet harvester	0.025[a]	63
Windrower, self-propelled	0.040	100
Tractors and Miscellaneous		
Tractor, track type	0.0080	78
Tractor, wheel type	0.0120	120
Wagon, rubber-tired	0.018	90

[a]Add a total of one percent of the purchase price for each time machine is mounted and dismounted (normally once a year).

[b]Add the cost of wire or twine. Average requirement per ton is 8 pound of wire or 3 pound of twine.

[c]Includes detergent and spindle oil.

2) Oil changes; 3) Filter changes. The latter two come from factory specifications. The oil consumption for agricultural machinery is related to the three factors mentioned above. This data is summarized in Table V. Another widely used method is to consider fifteen percent of the fuel cost as oil expenditure (3).

TABLE IV

FUEL REQUIREMENTS

Tractor Type	Average Fuel Consumption in Gallon per Hour per Rated DHP
Wheel-type, gasoline	0.085
Wheel-type, LP gas	0.105
Wheel-type, diesel	0.065
Track-type, gasoline	0.090
Track-type, diesel	0.075

Rated drawbar horsepower is 75 percent of the maximum.

Power and energy considerations. It is very common to find the gross energy requirement of the field operations by the force factors (3). Force factors are usually expressed as pounds of force per foot of effective width of a field machine. These factors are based on draft and power requirements with the auxiliary rolling resistance, if any, included. Since the capacity of a field implement is directly related to its effective width, the power requirement of a machine may be determined by its force factors and its effective width.

Table VI contains data adopted from Hunt (10) and other information published in the Agricultural Engineering Yearbook (3) may be used to estimate the power requirements of agricultural machinery.

TABLE V

OIL CONSUMPTION OF TRACTORS

Tractor Size (Maximum PTO Horsepower)	Oil Consumption (gallons per hour)		
	Gasoline Engine	L-P Gas Engine	Diesel Engine
30	.009	.010	.008
40	.010	.010	.014
50	.012	.011	.016
60	.013	.012	.019
70	.014	.014	.019
80	.015	.014	.025
Over 90	.016	.015	.023

TABLE VI

TYPICAL FARM IMPLEMENT
FORCE FACTORS

Machine	Force Factors pounds per feet width
Tillage	
Cultivator	240
Disk harrow	250 - 280
One-way disk	400
Moldboard plow	850
Spike-tooth harrow	105
Spring-tooth harrow	180
Planting	
Grain drill	115
Row-crop planting	110
Harvesting	
Combine	375
Corn picker	650
Forage harvester	400
Hay conditioner	140
Mower	130
Side delivered rake	80

Field efficiency. The efficiency when performing an operation must also be considered in calculating the cost of the machine doing work.

Field efficiency is the comparison between the actual time that it takes a machine to perform a determined job, and the theoretical capacity of the machine under optimum conditions for the same job, taking into consideration the speed and width of the machine without delays. The field efficiency averages, taken from the

1970 Agricultural Engineers Yearbook (3), are presented in Table VII.

Timeliness Factor for Field Operation

The capacity of the machine, which is function of width, speed, and field efficiency, is an important factor in any harvest operation. The importance radicates in the time available for harvest in order to obtain maximum profit. The profit is related to the yield and the price. The latter depends, among other factors, upon the quality of the end product. The proper combination of the two factors will result in higher gain for the operation. The timeliness factor takes into consideration both yield and quality as a decimal expression of the increase or reduction of the crop yield in relation to the time of harvest. This factor is used to determine the optimum size of machinery necessary to maximize the profit per acre.

Hunt and Patterson (11) defined the timeliness factor as the state of being opportune for optimum field operations. They derived the timeliness factor by considering the loss as being inopportune for harvest.

Figure 1 shows one of the patterns of curves which may occur in an operation where an optimum time exists, and where a loss occurs if the operation is premature or delayed. Taking also into consideration 40 percent of the total available time for the operation to be performed.

TABLE VII

TYPICAL FIELD EFFICIENCIES

Operation	Field Efficiency Percent
Tillage	
Harrowing	70 - 85
Most other tillage operations (plowing, disking, cultivating, etc.)	75 - 90
Planting	
Drilling or fertilizing row crops or grain	60 - 80
Check row planting	50 - 65
Harvesting	
Combine harvesting	65 - 80
Picking corn	55 - 70
Picking cotton (spindle-type picker)	60 - 75
Mowing	75 - 85
Raking	75 - 90
Direct windrowing of hay or grain (self propelled windrower)	
In field with irrigation levees	65 - 80
In field with no levees	75 - 85
Baling hay	
Bales discharged onto ground	65 - 80
With bale wagon trailed behind	55 - 70
Field chopping	50 - 75

For example, to illustrate the findings of the timeliness factor, consider the harvesting of 100 acres of corn yielding 100 bushels per acre and valued at $1.00 per bushel. The total value of the crop is $10,000. Obtaining the value of K = .0003 from Table VIII and multiplying it for the total value of the crop produces an hourly charge of $3.00 against the machine's operations for each hour spent following data; that 95% of the time only 40% of the available time is actually used for the operation (20).

Values of timeliness factors for various field operations as determined by Hunt and Patterson (11) are presented in Table VIII.

TABLE VIII

TIMELINESS FACTORS

Operation	Timeliness Factor
Tillage	0.00005 to .0003
Seeding	.0003
Cultivation	.0002
Small grain harvest	.0002
Soybean harvest	.0005
Corn harvest	.0003
Hay harvest	.0010
Green forage harvest	.0001

Figure 1. Total Cost of Timeliness (page 25)

Machinery Selection

In selecting the machinery for farm operations, one of the most important factors to consider is the width of

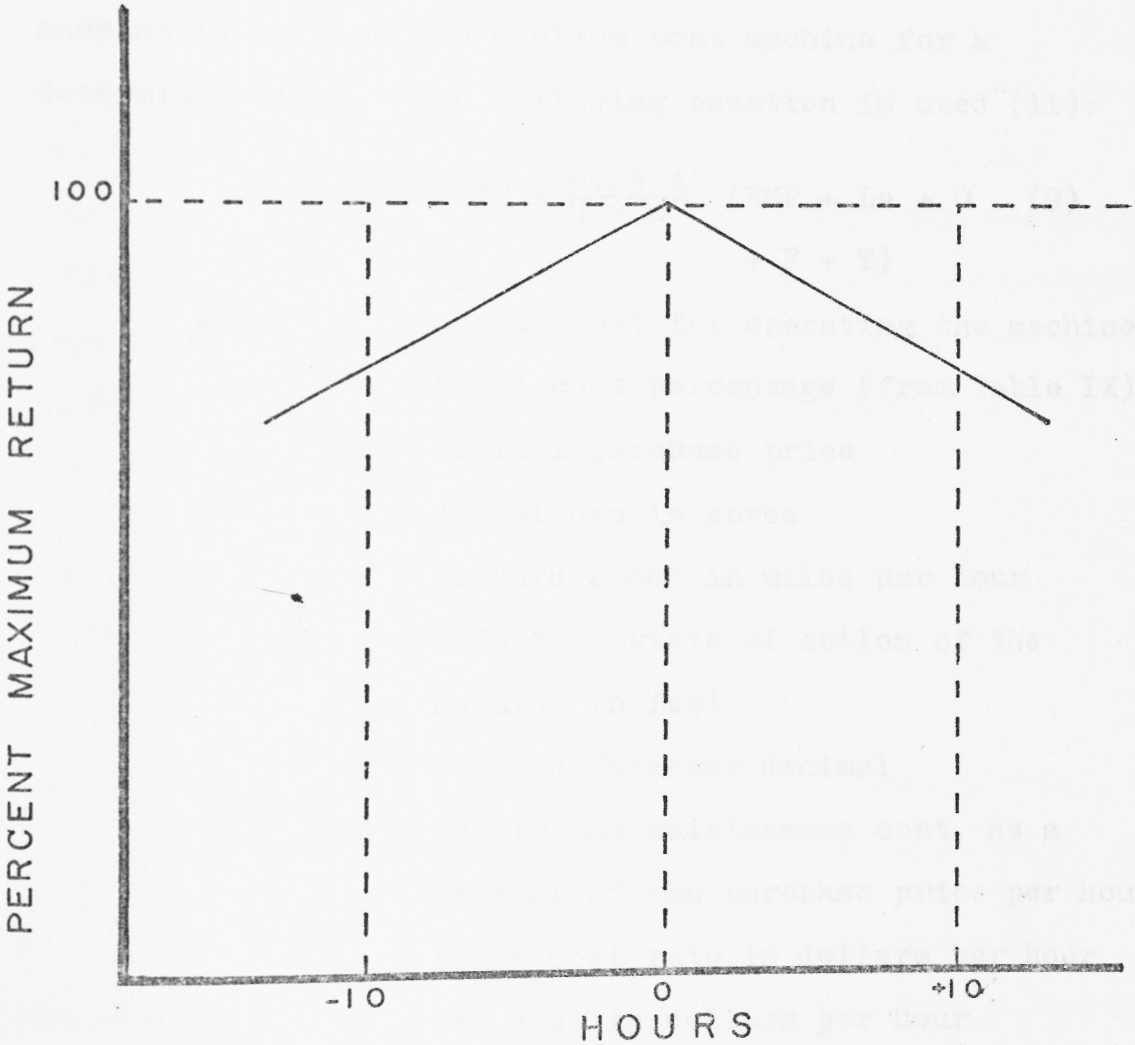


FIGURE 1. Value of Timeliness Factor

the machine, assuming that both machines are capable of the same forward speed during their operation. The efficiency will not drop with a larger machine (usually the larger machines have lower field efficiency).

The first step in finding the proper field capacity machine is to find the minimum cost machine for a determined field. The following equation is used (11):

$$AC = FC\%P + \frac{8.25\ A}{S\ w\ e}\ (RMP + La + O + F + T) \qquad (9)$$

Where AC = Annual cost for operating the machine

FC% = Fixed cost percentage (from Table IX)

P = Initial purchase price

A = Annual use in acres

S = Forward speed in miles per hour

w = Effective width of action of the machine in feet

e = Field efficiency decimal

RM = Repair and maintenance cost, as a decimal of the purchase price per hour

La = Labor cost rate in dollars per hour

O = Oil cost in dollars per hour

T = Cost of the tractor used by the machine (T = 0 if self propelled)

The equation (9) is transformed into:

$$AC = FC\%Pw + \frac{8.25A}{S\ w\ e} (RMPw + L + O + fw + T) \qquad (10)$$

$$W = \frac{8.25\ A}{FC\%P\ S\ e} (L + T) \qquad (11)$$

The equation (11) represents the lowest point on the cost curve represented by equation (10). It is necessary to consider the timeliness factor, the charge for untimely operations, before or after the point of maximum return in such operation. Equation (11) may now be modified in order to include the timeliness factor.

$$w = \frac{8.25\ A}{FC\%P\ S\ e} (L + T + KAYV) \qquad (12)$$

Where the added symbols are:

K = Timeliness factor

Y = Potential crop yield, bushels, tons, etc

V = Value of the crop, \$/bushel, \$/ton, etc.

The equation (12) is called the optimum width equation and is used to find the most economical implement size.

TABLE IX

VALUES FOR THE FIXED
COST PERCENTAGE

Service Life, Years	Value of FC%
1	100
2	53
3	37
4	29
5	24
6	21
7	19
8	17
9	16
10	15
11	14
12	13
15	11
20	9

Chapter 3

METHODOLOGY

The use of new harvesting machinery has brought about different harvesting costs. These costs have to be determined prior to studying the annual operational charges for the machine in conjunction with any economic analysis. In order to collect data for this study questionnaires were sent to all known owners of mechanical grape harvesters within the United States as of July 1971. One hundred questionnaires were mailed and forty-seven of them were returned with information. Thirty-two of those questionnaires returned were from areas that produced Concord grapes, mainly the Northeastern region of the United States. Fifteen questionnaires returned were from wine-producing areas of California that produced Thompson grapes. This response was the source of basic data used in this study.

Analysis of the Survey

The data received was divided into two sections, not because of the geographical location, but for the variety of grape grown in each area. The first location is the Western part of the United States where the most popular variety is the Thompson Seedless. This variety is used mainly for production of raisins and wine. The second region is the East Coast and other sections of the nation where the Concord variety is grown. Both Thompson Seedless and Concord varieties are adaptable to mechanical harvesting.

The computation and analysis of the data required that some of this data be analyzed together, from both sections. This was done to get information about the operational charges of the picking machine throughout the industry. Furthermore, the type of expense considered is related to the amount of work performed by the machine more than to the variety harvested. The data collected from the questionnaires was analyzed with the use of the regression method. From this method the basic variables were obtained for the use in this economic study.

In conjunction with this primary data, selected information from government publications (12), articles and studies (16) pertinent to this research were also included whenever needed to clarify a point or establish a bridgehead for the investigation.

In this study, the elimination of certain additional costs of production that are not directly related with the recovery of the berries from the vine by machine as well as the costs that can be prevented through proper management, were not taken into consideration. The reason for excluding such costs to reduction of the number of variables is extremely important if a clear confrontation between two alternatives in the harvesting of grapes is to be achieved.

The charge for delivering the product to the processor is not taken into consideration due to the complexity of the alternatives and the great number of variables that are involved in over the road transportation of an agricultural product. This cost can change as the distance from the harvest location to the winery varies. The type of arrangement for delivering the grapes (grower hauled, harvest contractor hauled, or commercial hauled) causes the charge for transportation grapes to vary. This charge does not vary with the method of harvest, hand harvest or mechanical harvest, but varies directly with the factor stated above. This extra expenditure can be avoided when planning a vineyard if the mechanization of harvest is considered at the time of planning. In cases where the modification of the existing trellis system is required, this cost should be charged against the overall cost of production rather than against the harvesting machine or actual harvesting cost. This arrangement permits a direct comparison of harvest cost regardless of when the vine was trained for mechanical harvesting.

After the data was analyzed the selected information was tabulated into a matrix in Fortran coded program. This program was designed to compare the two methods of harvesting in dollars per acre of profit; from these figures the minimum acreage could be derived to justify the machine under different variables obtained from the analysis of the questionnaires.

Basic Assumptions

1. The interest rate will not change.

2. Mechanically harvested grapes require two additional tractors and two gondolas; therefore, the use of two tractor drivers and one harvester driver is necessary; this expense will be represented in this study by operators wages (OW).

3. The insurance charges, tax and shelter will be represented by TIS.

4. The hand harvesting crew will be composed of eight persons, and for this harvesting operation it will be necessary to use two tractors with two gondolas; this equipment is also necessary for the mechanical harvesting of grapes. The equipment is shown in Photographs 1 and 2.

5. The contract for hand harvesting usually requires the crew members to supply the tractor drivers; therefore no extra wage is necessary for the tractor drivers when hand harvesting, but wages are necessary for the tractor drivers in the mechanical harvest operation.

6. The hauling operation to the dehydrator or the winery is the same for both operations; this means that hand harvesting and machine harvesting requires the same equipment and labor after harvest.

BASIC EQUIPMENT

Photograph 1

Basic Equipment: Hand Harvest

Photograph 2

Basic Equipment: Mechanical Harvest

7. In order to compare hand harvesting and mechanical harvesting of grapes, we shall consider hand harvesting as 92 percent of the real output of the field.

8. The speed of the harvester is one mile per hour, and the field efficiency is 70 percent because of turning, washing conveyer belt, stopping, minor adjustments, minor repairs and moving from field to field.

9. Taxes are different for each state; therefore this will change with the state.

10. The quality of wine grapes is not affected by the current alternative method of harvesting, at least at this stage in the processing sequence. The ultimate quality of the finish product may or may not be affected by these harvesting variations, but at the present time there is no supportive information on this topic.

Chapter 4

RESULTS AND DISCUSSION

Introductory Remarks

Mechanical grape harvesting offers an opportunity to study the economics harvest mechanization, because of the use of relatively new machinery that bring different operational costs. These costs were not evaluated before by taking into consideration the picking efficiency of the machine. In the previous pages a study of the formulas was presented, including interest, machinery bestfit formulas, etc. Although some machinery bestfit formulas were developed for large grain farming enterprises, some of these models can be applied to the mechanization of wine grape harvesting. Some other methods can be modified in order to fit the grape production practices, particularly the type of harvest most feasible, under a given situation.

Marketing Conditions

An important factor in the economic success of the California grape industry is the quality of the product, and the balance between the supply and demand for crushing grapes. The importance of the wine grape is increasing with the higher demand for wine by the consumer.

Cultural Practices

There are many important grape varieties in the San Joaquin Valley, but considering the acreage planted, the Thompson Seedless is the most widely planted variety. Along the Eastern coast of the United States only American grapes are grown with the Concord, which is used for wine, jams, preserves, etc., being the most common variety. Both are mainly machine picked.

The grape vine is a perennial plant that is planted in parallel rows, usually ten to twelve feet apart. The space between the plants within the rows varies from six to eight feet depending upon the variety, climate and soil condition. The trellis provides physical support as well as keeping the fruit away from the ground, and helps arrange the vine in such a manner that makes it easier to reach the fruit. There are many different systems, but the most practical ones may be classified into four groups: stakes, vertical one or two wire trellises, and wide cross-arm or short cross arm trellises.

Discussion of the Procedure

In order to calculate the capital recovery rate for the capital invested in mechanical harvesting, formula 8 (page 14) was used instead of the straight line depreciation plus interest on the first cost method. This method was selected because in the special case where a salvage value of 100 percent of the original value, the straight line depreciation method gives invariably too high a figure for the equivalent annual cost. The use of formula 8 is to account for the interest on the investment, since the majority of farmers use commercial credit in order to purchase machinery and the type of interest used by such credit institutions in lending to farmer is of the compound interest type. The cost of the use of the capital, interest, has to be charged against the machinery purchased on credit, since the capital could have been invested in another type of business that would yield a return on the capital invested. This gain will be represented by the interest charge added to the annual fixed cost of the machine ownership. Another consideration when the capital invested is borrowed from credit institutions the interest charged is taken into account by the capital recovery formula. The depreciation charges in this type of study are taken into consideration only when tax computations are involved.

The use of the university computer was required and two computer programs designed in order to facilitate calculations and achieve a wider range of conditions than could be accomplished without its use. The program number one is used to determine the optimum acreage harvestable by a machine during one season. Incorporated into this program is the timeliness factor. Program number two is used to determine the gross profit per acre by the two harvesting methods during one season; this program is based on the assumptions listed on Chapter 3 (page 29) of this study. Program one will differ from program two in that it uses a specific percentage in place of the capital recovery formula in order to adapt it to a developed formula that is published by Hunt (10).

The procedure used to find the gross income per acre on the grape harvesting operation for the two methods (i.e. hand and machine) was based upon the information gathered from the following sources. Information pertaining to the purchase price of the harvester, repairs, lubrication, maintenance, insurance and field efficiency was tabulated from the questionnaires developed for the study (Appendix C). The speed and the field efficiency were computed from data obtained by harvesting machine performance in the university vineyards at Fresno. This was combined with the field efficiency extracted from returned questionnaires and the average of the sources was used. The picking efficiency was derived from field observations of different varieties conforming to different pruning and trellis systems. These values were compared with other published data (4). The data for the harvesting efficiency, based on the weight of the fruit delivered at the winery, was obtained at the field in conjunction with the study carried out in Madera County, California (4). In this study, high, medium and low harvesting efficiency rates were established to be used in the economic study of different types of harvesting operations. The reason for the use of different levels of harvesting efficiency was to delineate the different capability levels and the type of harvester in use at the time. The medium is the efficiency obtained for the Thompson Seedless grapes. The operator's wages, along with the harvester driver and two tractor drivers' wages, were used when the grapes were mechanically harvested. The hand harvesting costs were deviated from the mean in order to satisfy varied field conditions. This variation was included to take into consideration the labor availability for the different geographical locations, along with differences in individual picking abilities

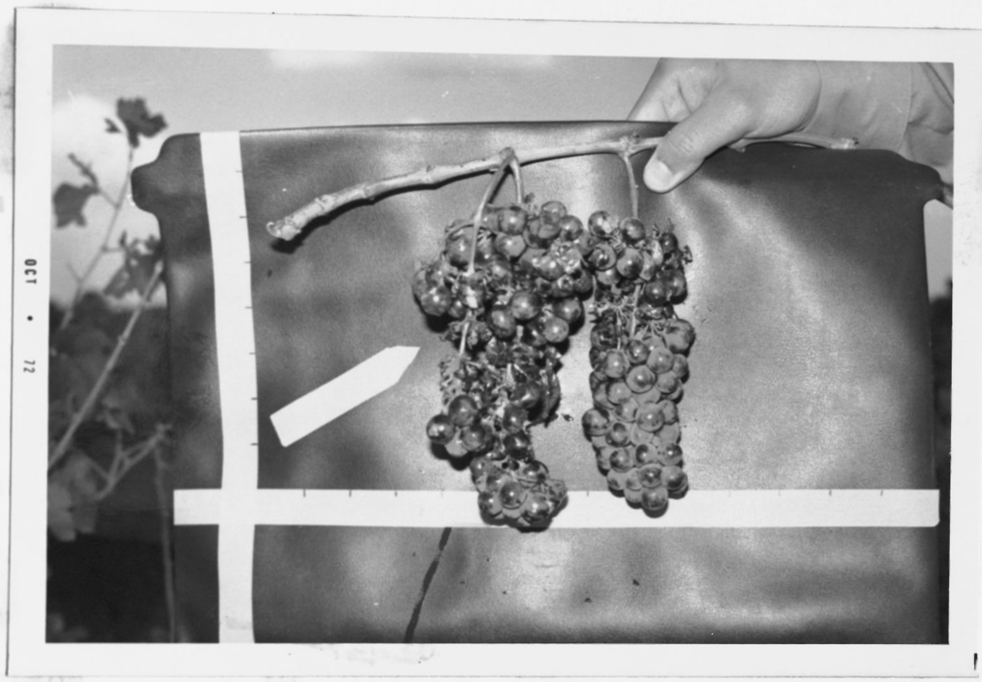
Vine damage by mechanical harvesting was observed during this study. However, because of the complexity in evaluating this damage and the time required to determine the effect of the physical damage on the physiological response of the vine and its effects upon the subsequent yields, vine damage caused by the harvester was not included in this study. The physical damage to the vine could bring a drop in production, depending upon the magnitude of the injury and the disease contamination brought about by an open wound. An example of the type of damage occurring on vines not trained for mechanical harvesting is shown in Photographs 3 and 4 and Photograph 5 shows one of the causes of juicing produced by the impactor units of the harvester. Photograph 6 shows the defoliation attributed to mechanical harvesting and the juice covering the leaf surfaces. The juice over the leaves is also shown

Photograph 3

HARVESTING OPERATION

Photograph 4

VINE DAMAGE BY THE MECHANICAL HARVESTER



Photograph 5

ONE OF THE CAUSES OF JUICING

in Photograph 6, where you can appreciate the dry juice on the leaves. This is one of the reasons that the picking efficiency of the harvester cannot be calculated from the amount of grapes that are left on the vine and on the ground. Photographs 6 and 7 were taken when harvesting a grape variety with a high juice content. This type of damage should always be of concern to the viticulturist, but cannot be considered in the study until data is available in which the reduction of the yield caused by such injuries is evaluated quantitatively. At the time of this writing Petrucci is conducting a study on the mechanical injury caused by the harvesting. Based on observations during years of the study he has found that in comparison there was less vine damage in 1971 than in 1970 in the vertical and horizontal type of trellis. This is because of the retrellising and modification in vine training; the canes that were in unfavorable position were destroyed by the machine and therefore were eliminated the following year. There was some trellis damage in certain grape varieties and trellis systems but this was not consistent.

The use of new trellis system and modified training of the vines may significantly reduce the physical damage caused by the harvester. It is anticipated that modified cultural practices will be used in newly developed vineyards, thus reducing the damage to a minimum.

JUICING SYMPTOMS

Photograph 6

Juicing Symptoms: Defolications and Juicing

Photograph 7

Juicing Symptoms: Juice Over Leaves

The Timeliness Factors

Before the formula 12 (page 27) can be applied, the timeliness factor has to be determined. As defined before, timeliness is the hourly charge for premature or delayed operation. For the grape harvesting, taking into consideration the different yields as well as the time available for harvesting, the derived information is shown in Table X (page 45).

This fractional value varies with the change in production, total available time considering the harvestability and marketability of the crops and the usable time available for harvest. The usable time for the machine varies with the field conditions, for example, it is critical for certain varieties to be harvested under certain atmospheric conditions, like temperature. In the San Joaquin Valley it has been observed that the best time to harvest is between four and eleven in the morning. But some farmers choose to run the machines for longer periods of time during the day; with the use of two harvesting crews, the machine is capable of running twenty-four hours a day. The timeliness factor is presented in Table X using 30, 40, 50 and 60 percent of the available time for harvesting. This is based on the data (12). Figure 2 shows that the yield per acre is correlated with the percent of soluble solids; furthermore, the percentage of soluble solids of the berries increases progressively with time until the fruit reaches optimun maturity. Premature harvesting of the grape will result in a reduction of both total soluble solids and yield.

TABLE X

TIMELINESS FACTOR FOR THE GRAPE HARVEST OPERATION

Percent of Total Available Time	Timeliness Factor 1/hours
30	0.001710
40	0.001283
50	0.001026
60	0.000855

The previously determined factors were used in formula 12 (page 27) which is used to find the optimun acreage to be harvested during one season's operation. Other variables necessary to solve this equation are listed on page 28. In Appendix A the solution of formula 12 is given with the use of alternate variables which represent characteristic field conditions for the grape harvester. The timeliness factor was selected according to the yield per acre and the actual operating time of the machine. These values are consistent with those shown in Table X. As one can appreciate the optimun acreage varies inversely with the price of the crop and is inversely related to the magnitude of the timeliness factor. One will also notice in Appendix A that the increment of the operator's wages of one dollar does not make a significant difference in the acreage to be

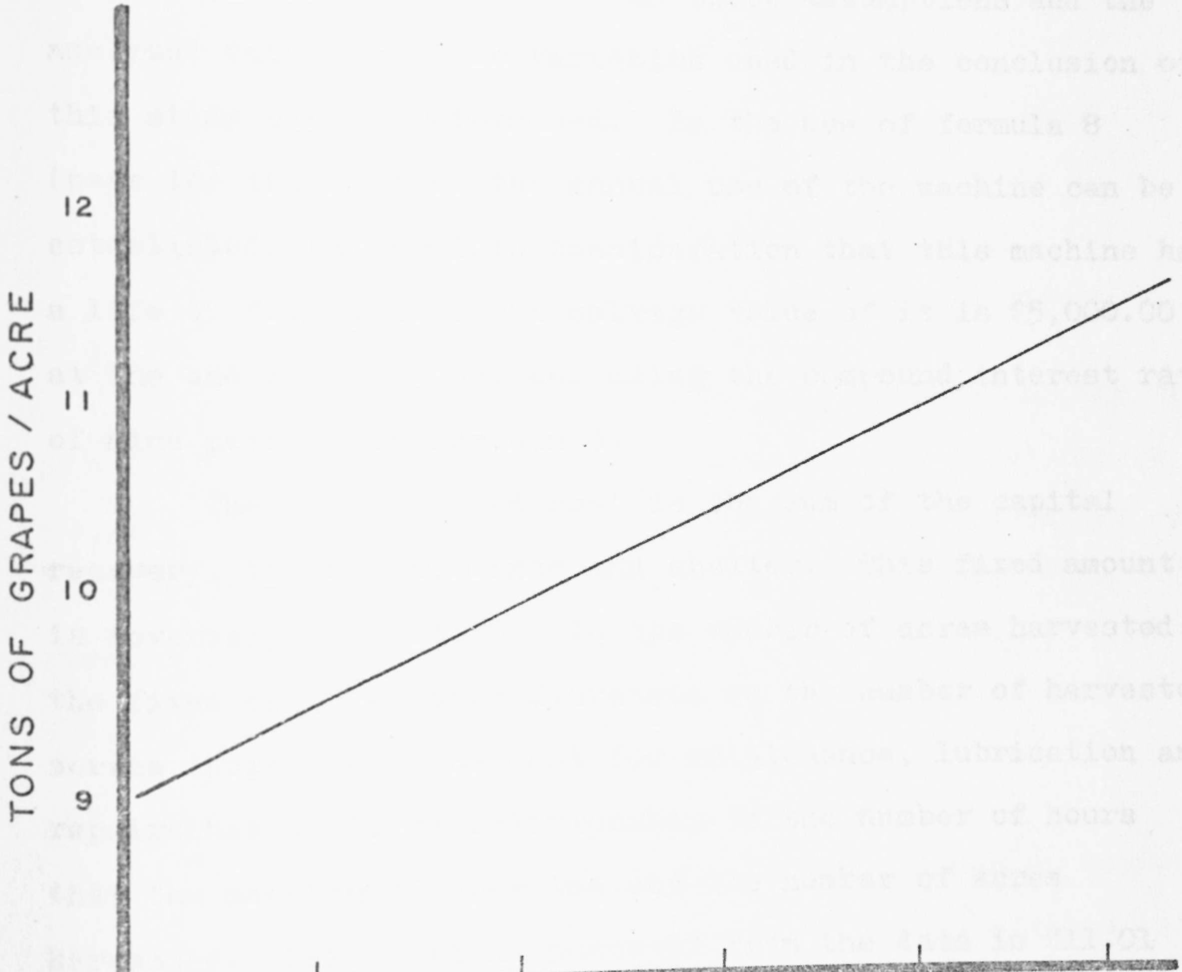


FIGURE 2. Increase in Weight of the Crop in Relation to Time and the Increase in Soluble Solids

harvested under the determined conditions.

The Cost Analysis

The cost analysis study of the grape harvester will take into consideration all the assumptions mentioned before in previous sections. Based on these assumptions and the analyzed data the basic variables used in the conclusion of this study can be determined. By the use of formula 8 (page 14) the cost of the annual use of the machine can be established, taking into consideration that this machine has a life of five years, the salvage value of it is $5,000.00 at the end of its life, and using the compound interest rate of nine percent in formula 8.

The annual fixed cost is the sum of the capital recovery, taxes, insurance and shelter. This fixed amount is inversely proportional to the number of acres harvested; the fixed cost per acre decreases as the number of harvested acreas increases. The cost for maintenance, lubrication and repairs has a direct relationship to the number of hours that the machine is operated and the number of acres harvested. This cost as computed from the data is $11.01 per acre, assuming that the harvest capability of the machine is in one acre per hour in the Thompson Seedless and .75 acre per hours for harvesting Concord grapes. Figures 3 - 5 show the price of harvesting grapes for different quantities taking into consideration the influence of yield per acre. This difference is greater for low-yielding varieties. The cost of harvesting a determined number of tons when the acre yield varies from 9 to 11 tons per acre can be calculated as follows:

$$\text{Log } x = 3.3972 - 0.8178 \text{ Log } Y_t \text{ (9 tons/acre)} \quad (13)$$

$$\text{Log } x = 3.4255 - 0.8310 \text{ Log } Y_t \text{ (10 tons/acre)} \quad (14)$$

$$\text{Log } x = 3.3982 - 0.8237 \text{ Log } Y_t \text{ (11 tons/acre)} \quad (15)$$

x = cost of harvest per ton

yi = total number of tons per season

These formulas give a close approximation of the cost per ton when the total amount of tons harvested per season is known. This does not take into consideration the effect of harvest efficiency on the delivery to the winery. This facet will be studied in the Effect of the Picking Efficiency on Gross Income.

Efficiency

The machine efficiency for harvesters can be divided into two different types. One is called "field efficiency" which is how well the machine is adaptable to field conditions (e.g. turning corners, plugging up and break-down time, etc.). Another type of harvest efficiency is the fruit recovery rate (picking efficienty) from the vine and all other losses that reduce the yield per acre, during the harvesting operation. In a recent study, Baranek found

96.1 percent of the crop was removed from the vines but only 86.9 percent of the crop was delivered to the winery. This difference between the amount of picked and delivered fruits is an expression of the machine operator's skill and the condition of the trellising systems' ability to provide optimun harvesting conditions. A well designed trellis system, proper vine training, and a good operator can bring a high percentage of fruit recovery from the vines, which could approach that of a good hand crew.

Not all grape varieties can be picked with the same amount of ease, either by hand or machine. While some varieties lend themselves to be picked either by hand or machine, others are easily picked with the machine while they may be hard to pick by hand.

Petrucci (16) is currently evaluating different harvest techniques and the vine damage caused by the mechanical harvester, and the responses of the plant upon later yields. In this work the final tonage delivered to the winery ranges from 75 to 85 percent of the harvestable crop. Assuming that 92 percent of the available crop is removed by hand picking, under normal field conditions the mechanical picker efficiency can be evaluated.

The ability to deliver to the winery or other processing facility the maximum amount of marketable fruit from the total amount available on the vine, is one of the determinants of economic production. Since all the inputs into the cost of production are charged against the

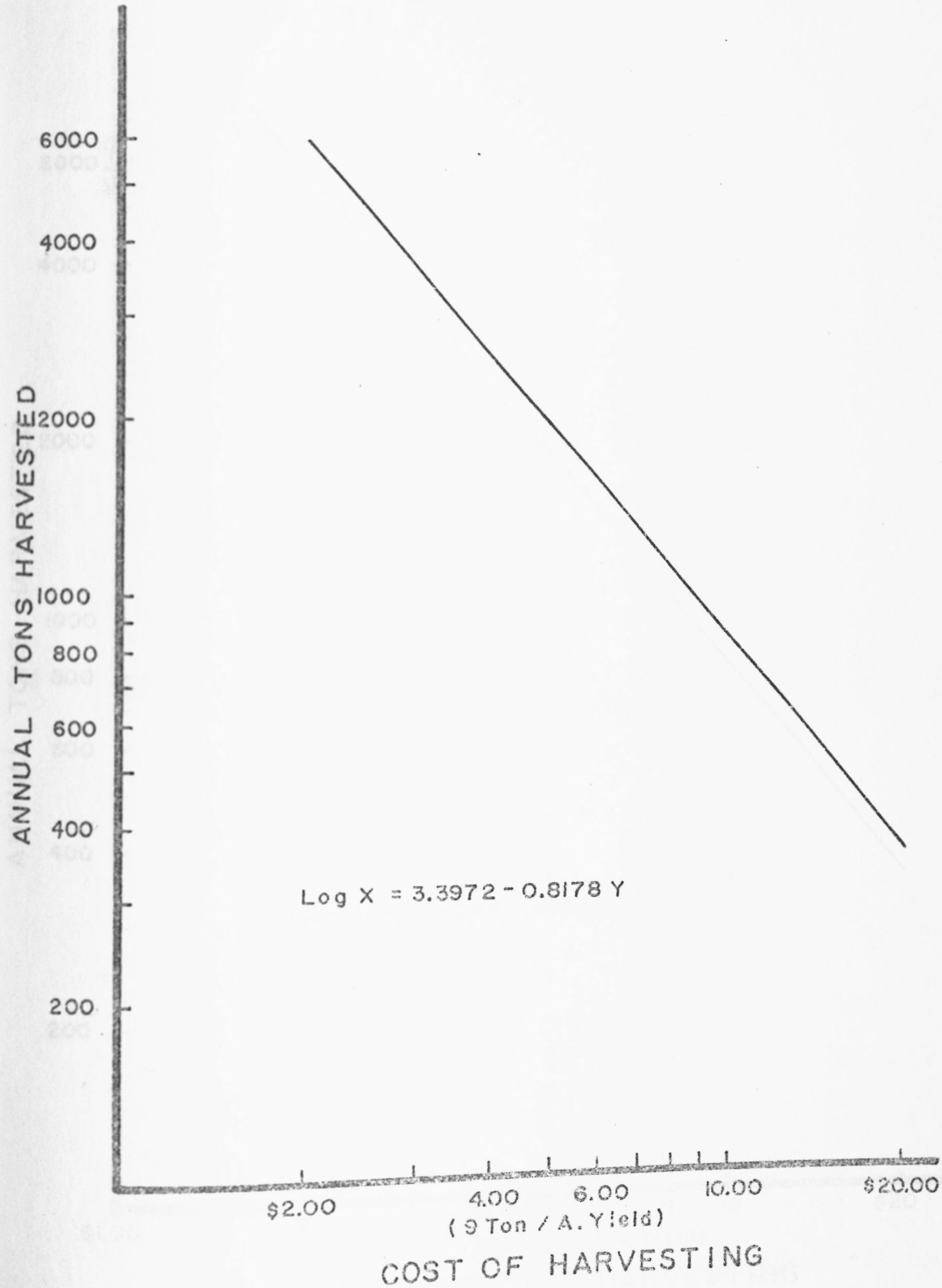


FIGURE 3. Cost of Harvesting Per Ton is a Dollar per Ton in Relation to the Total Annual Tonnage Harvested per Machine.

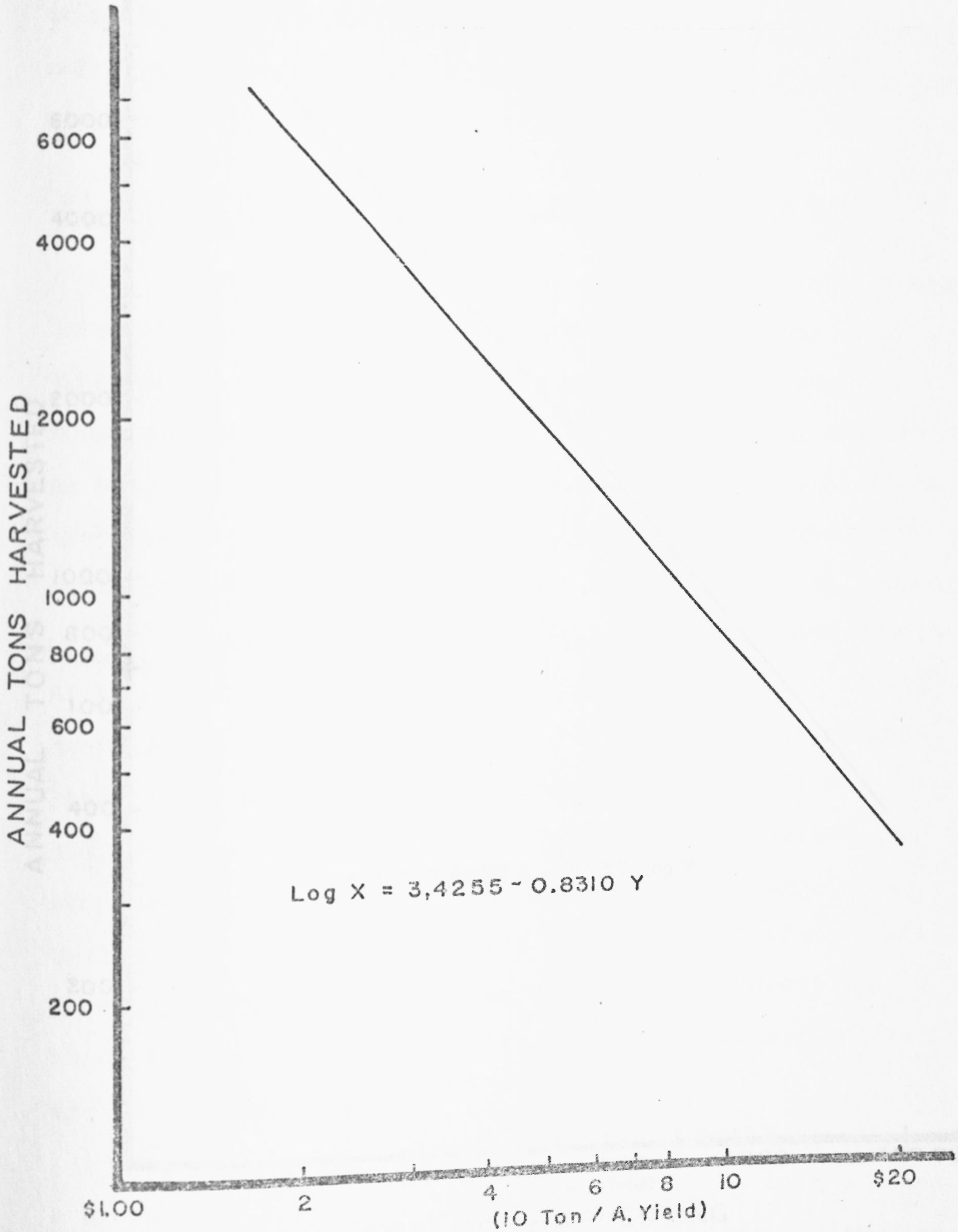


FIGURE 4. Cost of Harvesting Per Ton is a Dollar per Ton in Relation to the Total Annual Tonnage Harvested per Machine.

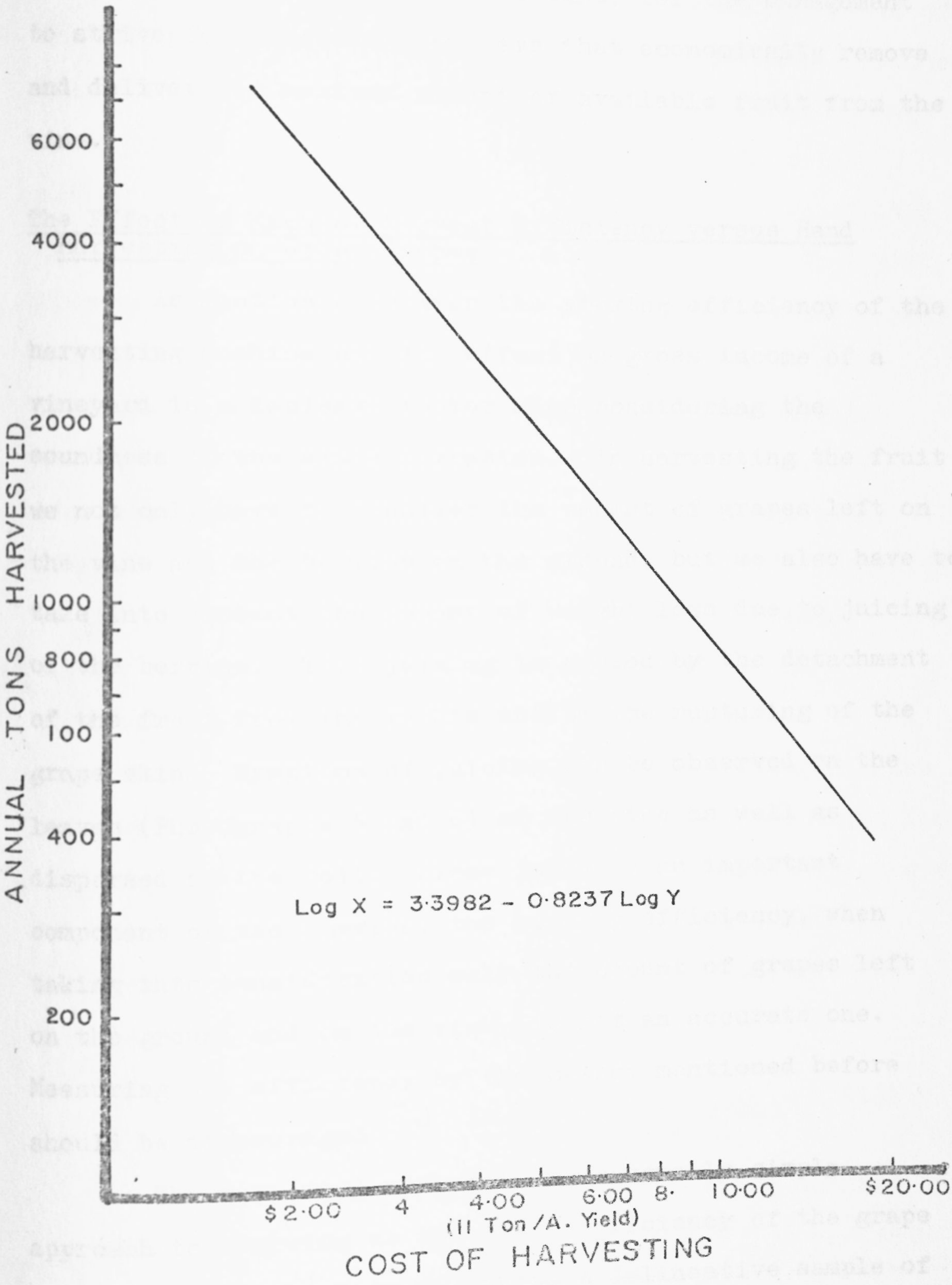


FIGURE 5. Cost of Harvesting Per Ton is a Dollar per Ton in Relation to the Total Annual Tonnage Harvested per Machine.

marketed yield, it is very important, for the management to strive for harvesting systems that economically remove and deliver the maximum amount of available fruit from the vine.

The Effect of Machine Harvest Efficiency versus Hand Harvesting on Gross Income

As mentioned earlier the picking efficiency of the harvesting machine and its effect on gross income of a vineyard is a decisive factor when considering the soundness of the grape operation. In harvesting the fruit we not only have to consider the amount of grapes left on the vine and the berries on the ground, but we also have to take into account the amount of weight loss due to juicing of the berries. This juicing is caused by the detachment of the fruit from the rachis and/or the rupturing of the grape skin. Symptoms of juicing can be observed on the leaves (Photographs 5 and 6) of the vine as well as dispersed on the soil. Since juice is an important component of the berries, the picking efficiency, when taking into consideration only the amount of grapes left on the ground and on the vine, is not an accurate one. Measuring the efficiency by the method mentioned before should be discouraged.

The following method is a reasonably simple approach to arriving at the field efficiency of the grape harvester. It consists of taking a delineative sample of vines from the field to be harvested, then hand harvesting these vines with care; this will give a potential yield of the field. The total amount of weight from the hand-picked vines, divided by the total number of hand-picked vines, will give an average production per vine. The total number of vines per acre in a vineyard is then multiplied by the average yield of the hand-picked vines. This will give an approximation of the potential yield on a per acre basis. This potential yield can then be used in determining the picking efficiency of the mechanical harvester. In order to obtain the picking efficiency expressed as a percentage for the mechanical harvester, divide the potential yield into the actual yield delivered to the winery per acre, then multiply by one hundred. It should be noted that the method is as good as the representative selection and size of the sample.

The harvest efficiency is directly related to the net profit of the operation, taking into consideration the yield and the price paid per unit of production. Figure 4 shows the amount of money gained, or lost, per acre in relation to each percentage of varying efficiency. The formula used in arriving at this value is:

$$\frac{\text{Whole PPT}}{100}\ (\text{tons of production}) + \frac{\text{Decimal PPT}}{10} = \text{Amount of money gained or lost per acre per each percent of varying efficiency.} \quad (16)$$

Therefore in such a field a five percent lower efficiency will represent a reduction on net profit of 24.40 dollars, as one can see in Table XI and Figure 6 (the effect of picking efficiency on income on Thompson grapes per acre).

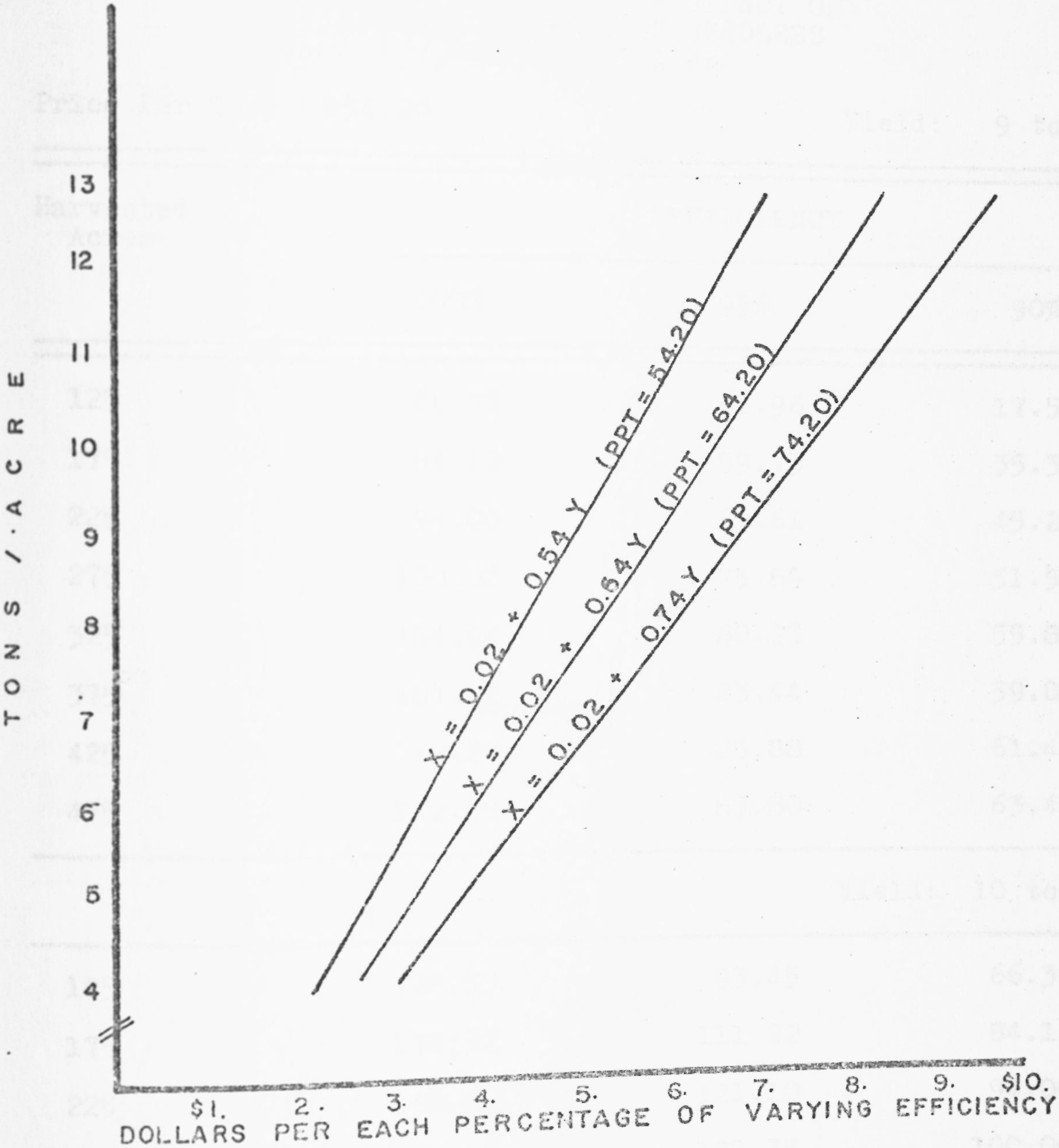


FIGURE 6. Production of Profit with the Decrease in Picking Efficiency or the Increase in Profit with Better Efficiency When Comparing the Machine Harvest with Hand Picking.

TABLE XI

EFFECT OF PICKING EFFICIENCY ON INCOME ON THOMPSON SEEDLESS GRAPES PER ACRE

Price Per Ton: $54.20

Yield: 9 tons*

Harvested Acres	EFFICIENCY		
	100%	95%	90%
125	66.35	41.96	17.57
175	84.12	59.73	35.34
225	94.00	69.61	45.22
275	100.28	75.89	51.50
325	104.64	80.25	55.86
375	107.83	83.44	59.04
425	110.27	85.88	61.49
475	112.19	87.80	63.41

Yield: 10 tons*

125	120.55	93.45	66.35
175	138.32	111.22	84.12
225	148.20	121.10	94.00
275	154.48	127.38	100.00
325	158.84	131.74	104.64
375	162.03	134.93	107.83
425	164.47	137.37	110.27
475	166.39	139.29	112.19

TABLE XI (CONTINUED)

Price Per Ton: $54.20

Yield: 11 tons*

Harvested Acres	EFFICIENCY		
	100%	95%	90%
125	174.75	144.94	155.13
175	192.52	162.71	132.90
225	202.40	172.59	148.78
275	208.68	178.87	149.06
325	313.04	183.23	153.42
375	216.23	186.42	156.61
425	218.67	188.86	159.05
475	220.59	190.78	160.97

* This is taking into consideration that the hand harvesting method is 92 percent efficient and when the machine will reach the point in which it equals the hand harvest method it is considered 100 percent efficient.

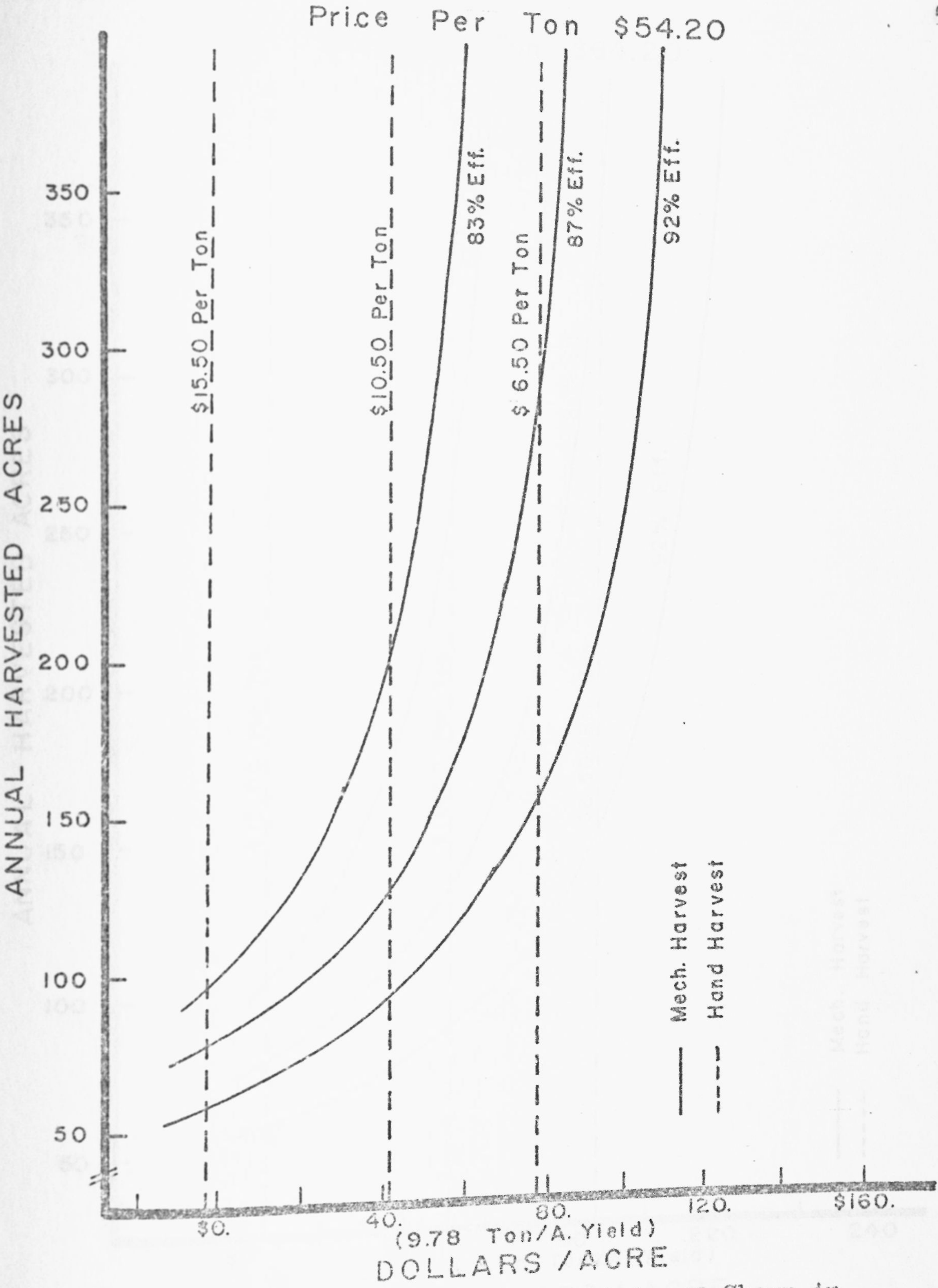


FIGURE 7. Gross Profit per Harvested Acres Shown in Relation to Yield, Price per Ton, and the Alternatives of Harvesting Methods (Hand vs. Machine).

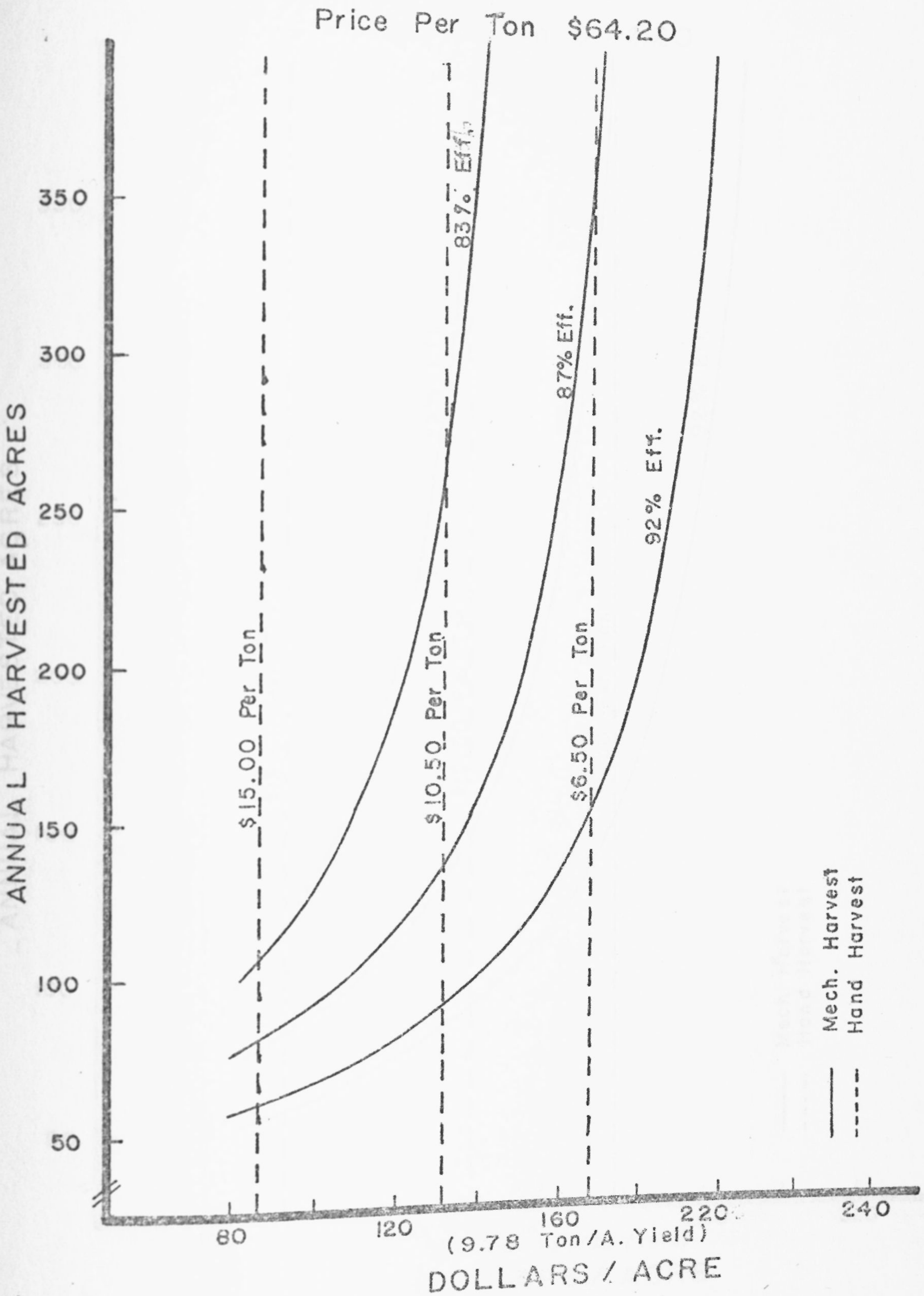


FIGURE 8. Gross Profit per Harvested Acre Shown in Relation to Yield, Price per Ton, and the Alternatives of Harvesting Methods (Hand vs. Machine).

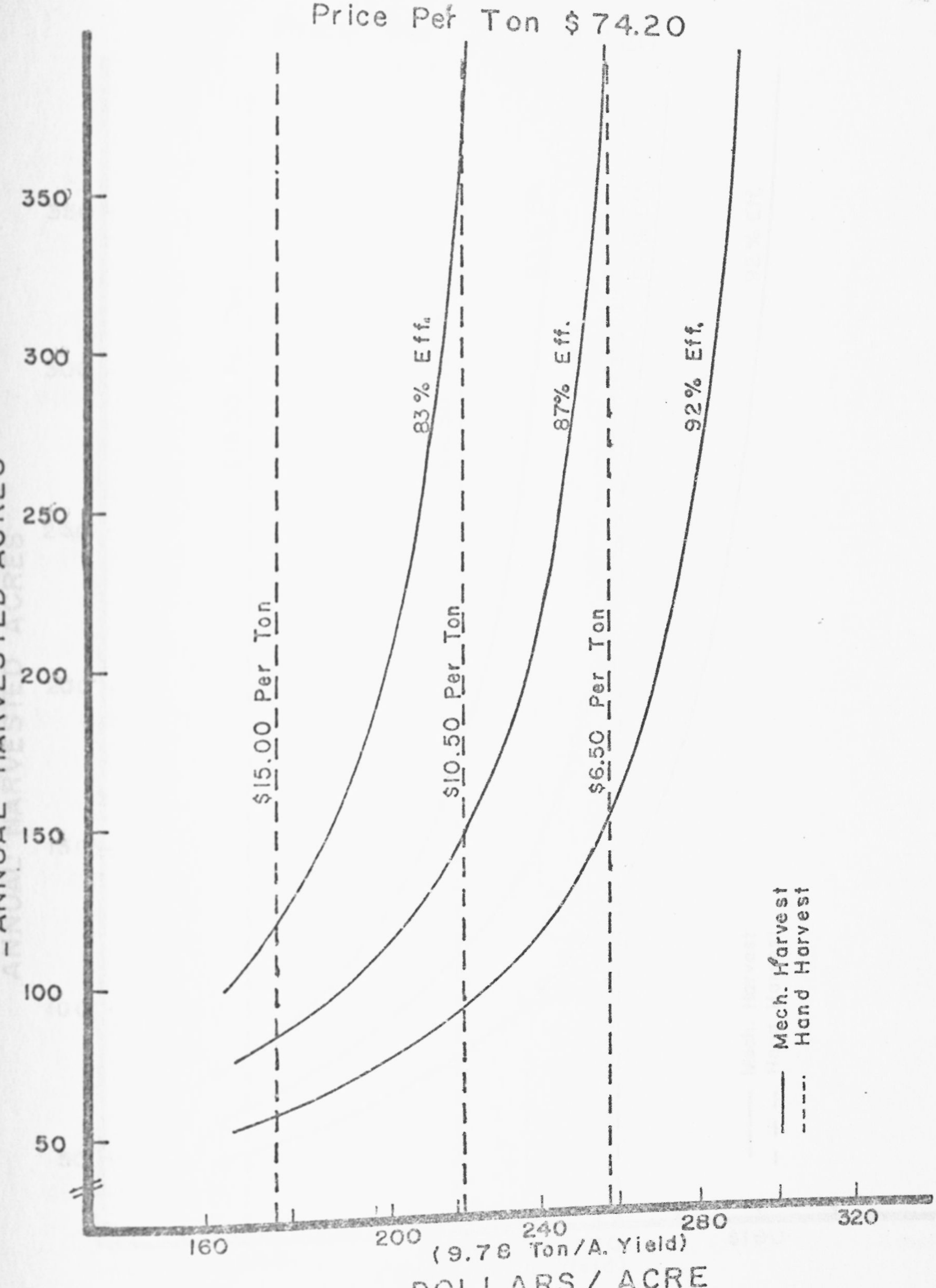


FIGURE 9. Gross Profit per Harvested Acre Shown in Relation to Yield, Price per Ton, and the Alternatives of Harvesting Methods (Hand vs. Machine).

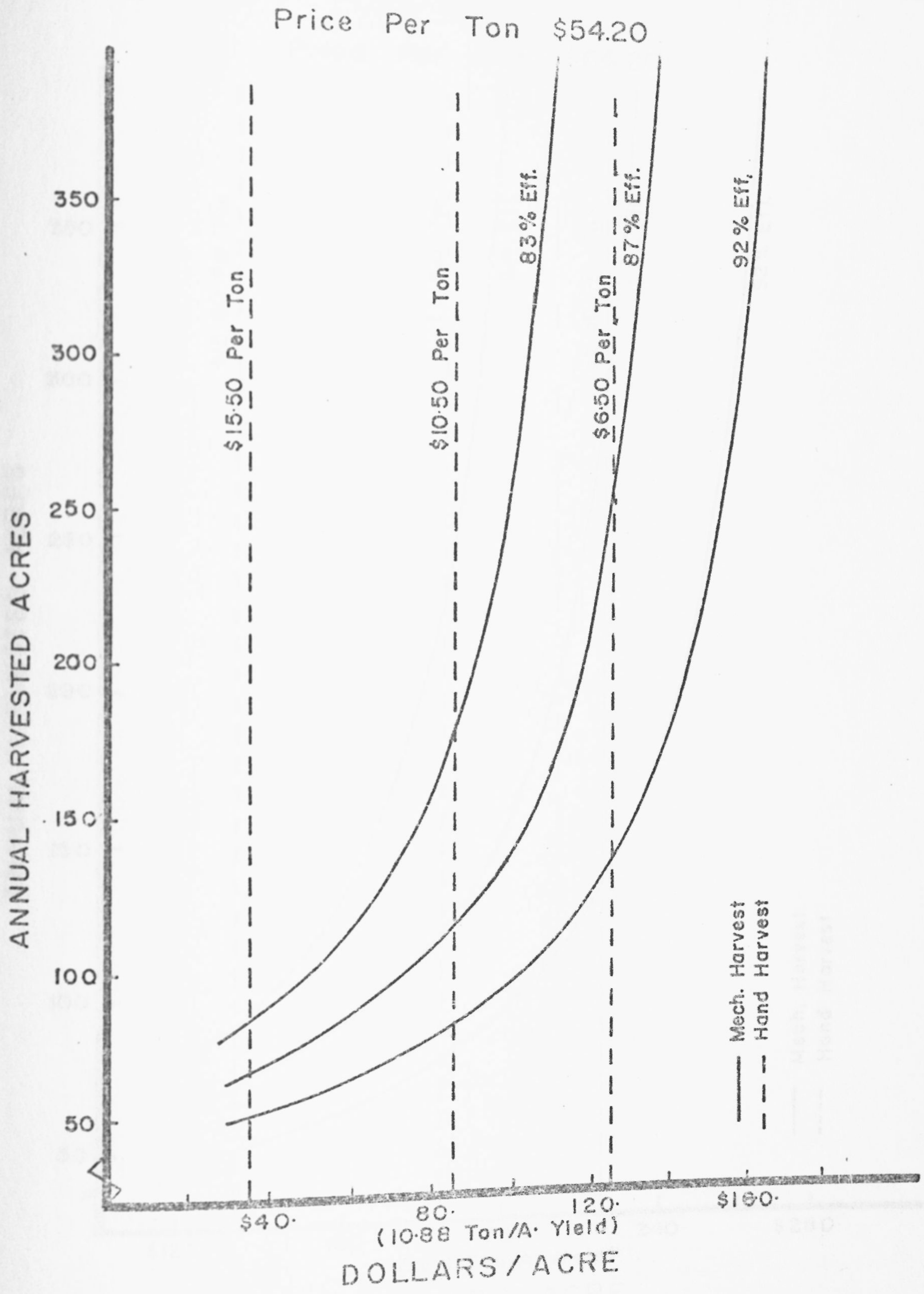


FIGURE 10. Gross Profit per Harvested Acre Shown in Relation to Yield, Price per Ton, and the Alternatives of Harvesting Methods (Hand vs. Machine).

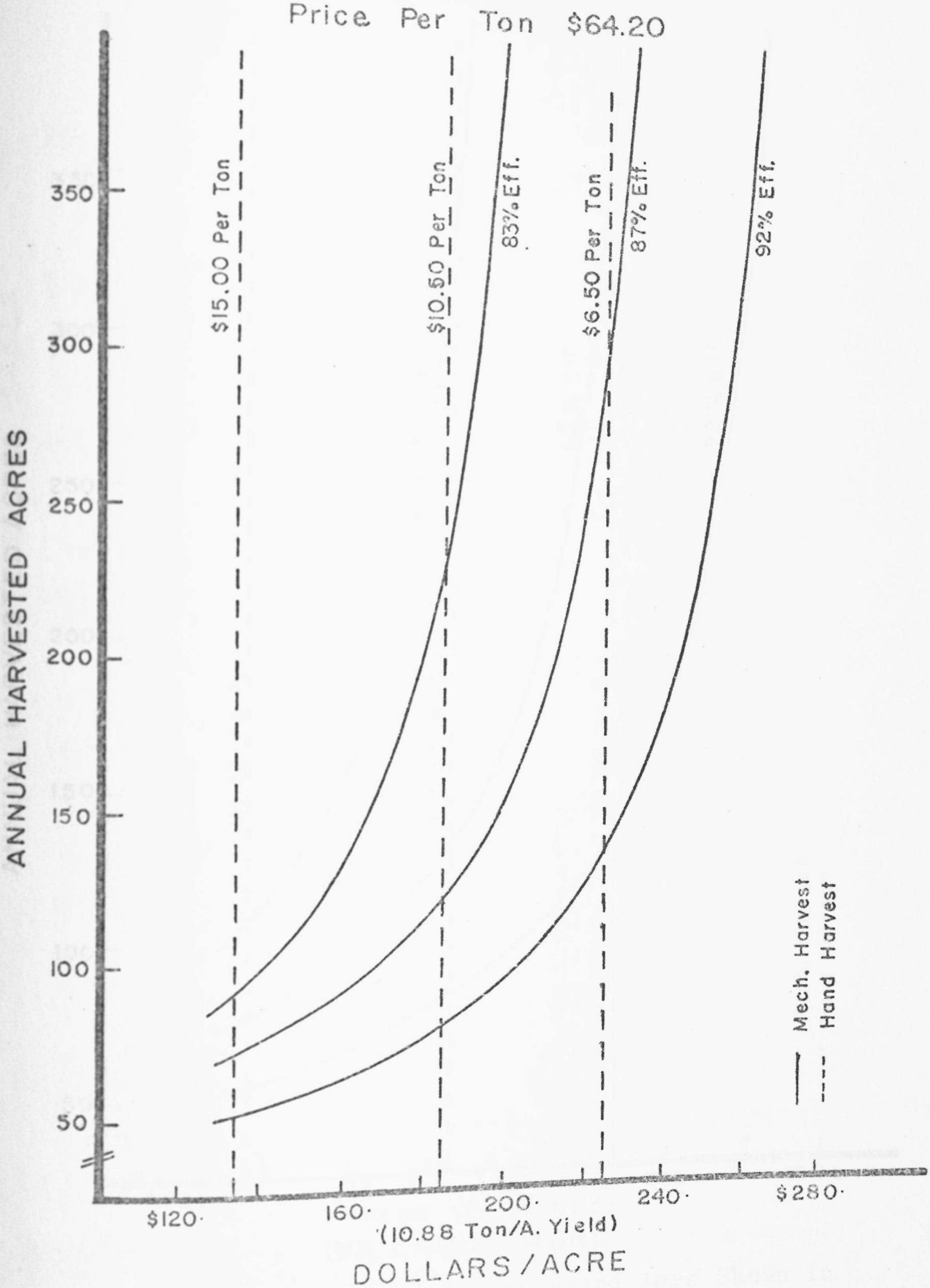


FIGURE 11. Gross Profit per Harvested Acre Shown in Relation to Yield, Price per Ton, and the Alternatives of Harvesting Methods (Hand vs. Machine).

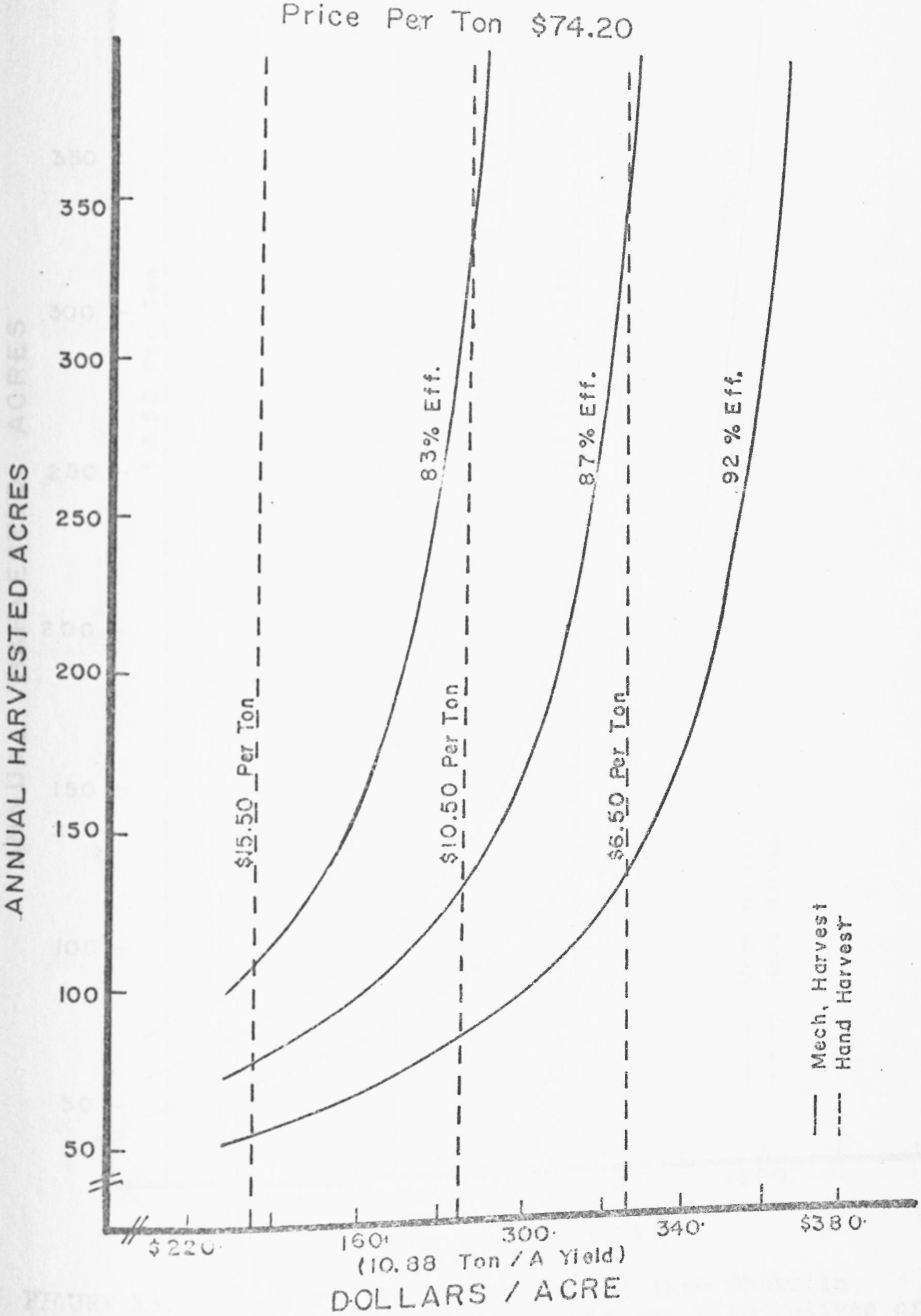


FIGURE 12. Gross Profit per Harvested Acre Shown in Relation to Yield, Price per Ton, and the Alternatives of Harvesting Methods (Hand vs. Machine).

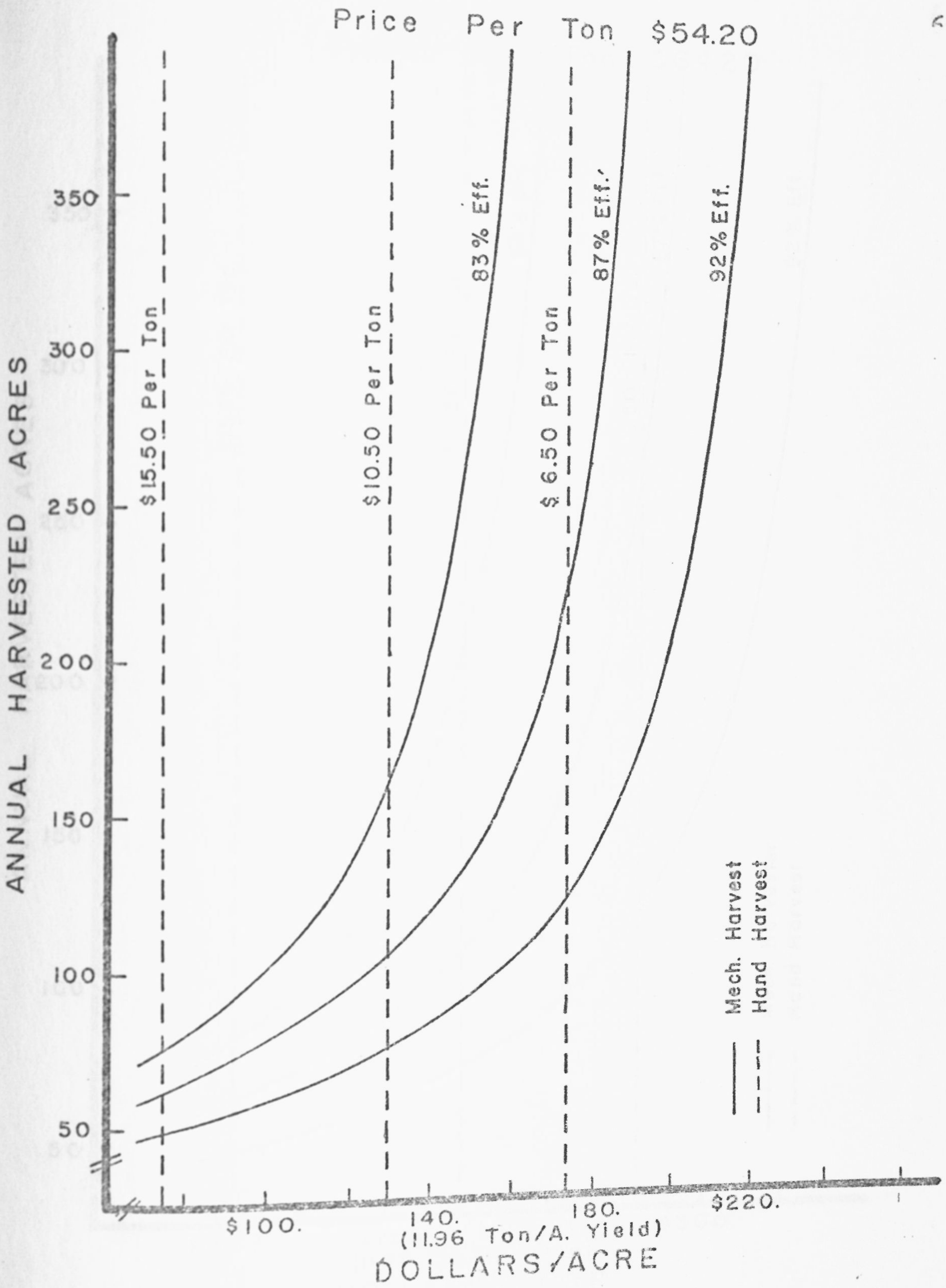


FIGURE 13. Gross Profit per Harvested Acre Shown in Relation to Yield, Price per Ton, and the Alternatives of Harvesting Methods (Hand vs. Machine).

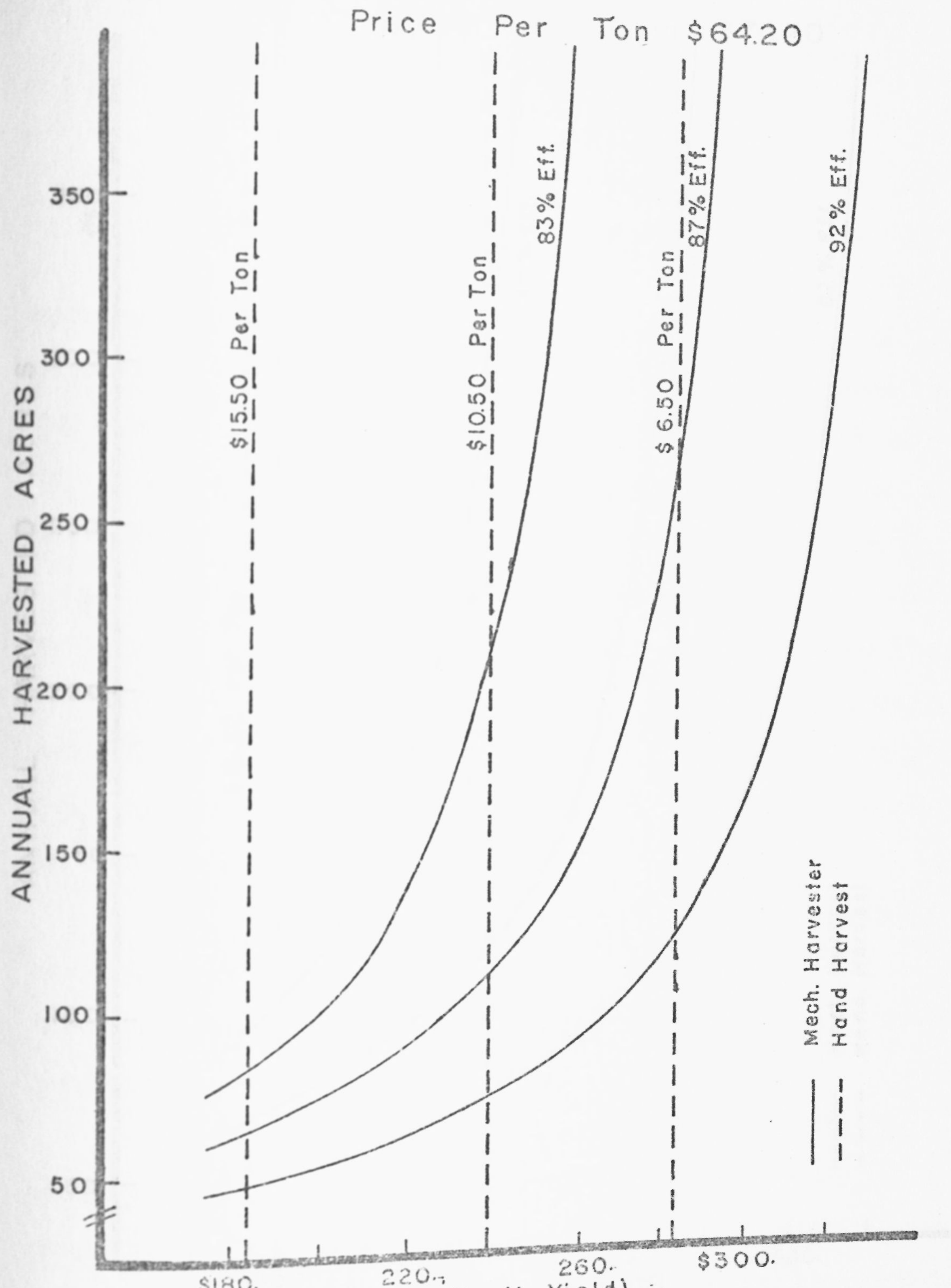


FIGURE 14. Gross Profit per Harvested Acre Shown in Relation to Yield, Price per Ton, and the Alternatives of Harvesting Methods (Hand vs. Machine).

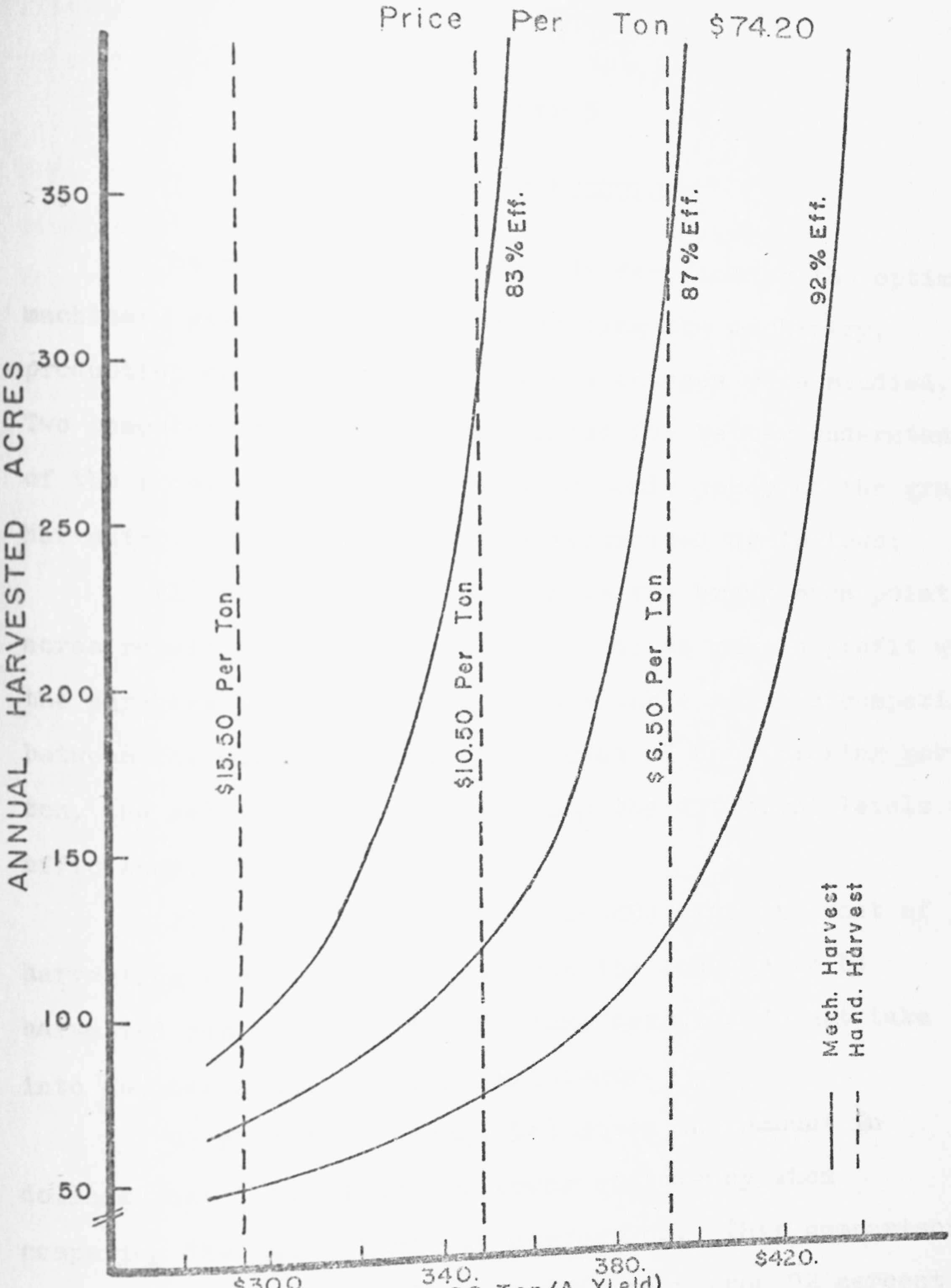


FIGURE 15. Gross Profit per Harvested Acre Shown in Relation to Yield, Price per Ton, and the Alternatives of Harvesting Methods (Hand vs. Machine).

Chapter 5

SUMMARY AND CONCLUSIONS

The procedures and methods for finding the optimun machinery size, the cost of operating the machinery, production cost and the timeliness charges were studied. Two computer programs were designed for better understanding of the problems incurred in an economic study of the grape harvester. The results may be summarized as follows:

(1) Data in Table XII shows the break-even point in acres required by the farmer in order to make a profit with the purchase of one machine. This table makes a comparison between the yield per acre, the cost of hand picking per ton, the selling price per ton and the different levels of efficiency.

(2) Formulas 13 - 15 (page 48) give the cost of harvesting grapes by machine when the tonnage to be harvested can be estimated. These formulas do not take into consideration picking efficiency.

(3) Formula 16 (page 54) gives the amount in dollars that is lost due to lower efficiency when comparing the two methods of harvesting. This comparison is for each degree of varying efficiency from 92 percent which is the estimated efficiency for hand harvest.

This value establishes the relationship between the selling price per ton and the harvesting efficiency of the machine.

(4) The low efficiency encountered when harvesting a high to medium-yielding crop of high value must be given consideration in the efficiencies become more critical as the value of the crop increases.

(5) Checking the machinery's efficiency when harvesting is very important. It should be estimated on basis of the tonnage delivered to the processing plant rather than evaluating the amount of grapes left on the vine and on the ground.

(6) With a basic price machine of 27,500, as of 1971 the efficiency of the machine plays a very important role in the break even point of the machine in acres per season. If the machine could reach the same degree of efficiency as the hand pickers, the price per ton of grapes would not make a difference for the break even point.

(7) As the acreage to be harvested increases the harvest cost with machine decreases.

(8) As the picking efficiency of the machine decreases the acreage requirement increases.

(9) As the picking efficiency of the machine decreases and the price per ton increases the acreage requirement becomes larger in number.

Finally, in addition to the economic factors considered in this study, other factors, mainly physical damage and defoliation of the vines by the machine should be taken into consideration.

TABLE XII

BREAK-EVEN POINT
(Acres Required Per Machine)

Yield (Ton/ Acre)	Cost of Hand Picking Per Ton	Price per Ton $54.20 Efficiency			Price per Ton $64.20 Efficiency			Price per Ton $74.20 Efficiency		
		83%	87%	92%	83%	87%	92%	83%	87%	92%
9.78	6.50	--	285	153	--	348	153	--	418	153
9.78	10.50	201	126	91	265	135	91	385	142	91
9.78	15.50	98	78	60	105	80	60	116	88	60
10.88	6.50	--	250	135	--	300	135	--	360	135
10.88	10.50	178	112	80	233	120	80	330	128	80
10.88	15.50	83	58	53	91	74	53	106	78	53
11.96	6.50	--	225	122	--	272	122	--	330	122
11.96	10.50	163	104	73	207	109	73	292	117	73
11.96	15.50	76	66	48	83	64	48	94	67	48

LITERATURE CITED

1. American Society of Agricultural Engineers, St. Joseph, Michigan: Agricultural Engineers Yearbook, pp. 227-233, (1963).

2. American Society of Agricultural Engineers, St. Joseph, Michigan: Agricultural Engineers Yearbook, (1968).

3. American Society of Agricultural Engineers, St. Joseph, Michigan: Agricultural Engineers Yearbook, pp. 279-284, (1970).

4. Baranek, Paul P., "Watch Delivered Total - Not Just Recovery." California Grape Grower Pilot, Issue 1, Vol. 1, No. 1., (1971).

5. Bombright, J. C., Valuation of Property, New York: McGraw-Hill Book Co., Inc., Chapter X, (1937).

6. Cargil, B. F. and Rossmiller, G. E., Fruit and Vegetable Harvest Mechanization Technological Implications, Michigan: Rural Man-Power Center, Michigan State University, pp. 569-621, (1967).

7. Claypool, L. L., The Present Status and Future Prospects of Mechanical Tree Fruit Harvest in the U. S. 1969. Paper presented to Euro Fruit at Ferrara, Italy, (1967).

8. Grant, Eugene Lodiwick, and Grant, Ireson W., Principle of Engineering Economy, 4th ed., New York: Ronald Press, (1960).

9. Hunt, D. R., Efficient Machinery Selection, Implement and Tractor. St. Joseph, Michigan: Transactions of ASAE, 16: (13) pp. 78-80, (1963).

10. Hunt, D. R., Farm Power and Machinery Management, Iowa: Iowa State University Press, 5th ed., (1968).

11. Hunt, D. R. and Patterson, R. E., Evaluating Timeliness in Field Operations. American Society of Agricultural Engineers Publication Proc-468 presented at Sherman House, Chicago, Illinois, pp. 18-21 (December 1968).

12. Lynn, Curtis D., Picking Your Picking Date, Farm and Home Advisors Office, (August 1968).

13. Moulton, Kirby S., "The Great California Grape Expansion, An Economic View." Wines and Vines, 2, pp. 24-28, (1972).

14. ___________, Nebraska Tractor Test Data 1971, University of Nebraska Department of Agricultural Engineering. Lincoln, Nebraska, pp. 17-25, (1971).

15. Peters, Dale R., Mechanical Grape Harvesting Observations and Comparisons in 1968 and 1969. Paper presented to American Society of Enologists at San Diego, California. (June 1970).

16. Petrucci, V. J., and Cannatta, N., California State University at Fresno, California (Personal information).

17. Simons, M. D., Field Machinery Selection Using Stored Programs, Oklahoma State University Library, Stillwater Oklahoma. (1962) (M. S. thesis).

18. Shaulis, Nelson., Shepardson, E. S., and Jordan, T. D., The Geneva Double Curtain, Bulletin 811. New York State Agricultural Experiment Station, Geneva Cornell University, New York. pp. 19-21, (July 1967).

19. Southwell, P. H., An Analysis of Tractor Purchase Cost and Efficiencies. Canadian Agricultural Engineering, 10: (1) pp. 33-37, (May 1968).

20. Yomchinda, Vitawas., A Study of Mechanization Alternatives in Fruit Harvesting, University of British Columbia, Canada. (1970) (M. S. thesis).

21. Winkler, A. J., General Viticulture. University of California Press, Berkeley and Los Angeles, (1962).

APPENDIX A

Computer Program for the Optimun Acreage To Be Harvested in One Year Operation

```
      PROGRAM TWO
C     THE FC FACTOR COMES FROM THE VALUES FOR FIXED COST PERCENTAGE
C     THE T VALUE IS FOR THE USE OF TWO ADDITIONAL TRACTORS TO PULL THE
C     THE GONDOLAS
C     IN THE GRAPE HARVESTER THE WIDTH IS FIXED, TO 12 FT. BETWEEN
C     THE ROWS
      DIMENSION     A(1,3,4)
      S         =     1.00
      T         =     2.50
      W         =    12.00
      Y         =     9.00
      P         = 27500.00
      FC        =      .24
      FCP       = P*FC
      DO  2   K = 1,4
      DO  2   J = 1,3
      DO  2   I = 1,1
    2 A(I,J,K)  = 0
      DO  3   N = 1,12
    3 READ 4, I,J,K, A(I,J,K)
    4 FORMAT   ( 6X,I2,2X,I2,2X,I2,2X, F11.5 )
      DO  5   J = 1,3
      E         = A(1,J,1)
      PRINT 9
    9 FORMAT (1H1,//,17X,6H FIELD,9X,5H ACRE,7X,11H TIMELINESS,5X,
     110H OPERATORS,6X,6H PRICE,3X,6H IDEAL,/,33X,4H PER,/,15X,
     211H EFFICIENCY,7X,5H HOUR,9X,7H FACTOR,9X,6H WAGES,9X,4H TON,
     38X,8H ACREAGE,/,15X,83(1H-))
      DO  5   K = 1,3
      OW        = A(1,K,2)
      DO  5   L = 1,3
      XK        = A(1,L,3)
      DO  5   M = 1,3
      PPT       = A(1,M,4)
      A         =  (8.25*XK*Y*PPT)/(FCP*S*E)
      B         =  (8.25*(OW+T)/(FCP*S*E))
      C         = (W)**2
      D         = (B*B+4*A*C)
      AC        = (B+SQRT(D))/(2*A)
      ACH       =  (S*W*E)/8.25
      PRINT 7, E,ACH,XK,OW,PPT,AC
    7 FORMAT  (8X,3(8X,F7.5),3(8X,F7.2))
    5 CONTINUE
      END
```

APPENDIX B

Computer Program for the Cost Analysis of Mechanical Harvesting Versus Hand Harvesting

```
                              MS FORTRAN (4.2)/MSOS                    05/25/72
      PROGRAM THOMPSON
      ANALYSIS OF THE OPERETIONAL COST OF THE GRAPE HARVESTERHARVESTER O
      ON THOMPSON GRAPES
      IF DIFFERENT VARIETY IS TO BE ANALYSE THE VARIABLES SHOULD BE.
      CHANGE WITH OTHERS THAT CORRESPONDS TO THEI PARTICULAR VARIETY
      DIMENSION     A(1,3,4)
      P        = 27500.00
      XL       =  5000.00
      TA       =  P * 0.04
      COP      =   352.00
      TI       =  P * 0.01
       W        =     12.00
      W        =     12.00
      RML      =     11.01
      XN       =      5.00
      Y        =  10.00
      TO       =  Y * .92
      SP       =      1.00
      E        =       .75
      G        =       .46
      XI       =       .09
      S        =  P * 0.01
          ACH          = (50*W*E)/(8.25)
      AC       =  CH   = OW   = EFF   = CR   = 0
      DO  1    J = 1,3
      DO  1    I = 1,1
      DO  1    K = 1,4
    1 A(I,J,K)  =       0.00
      DO  2    N = 1,12
    2 READ 3,  I,J,K,  A(I,J,K)
    3 FORMAT    (6X,I2,2X,I2,2X,I2,2X,F10.2)
      DO  4    J = 1,3
      PPT          = A(1,J,1)
      DO  4    K = 1,3
      CH           = A(1,K,2)
      DO  4    L = 1,3
      OW           = A(1,L,3)
      PRINT 6
```

```
6 FORMAT (1H1,//,10X,7H ACRES ,6X,7H PRICE ,5X,7H HAND H,4X,
 110H OPERATORS,2X,8H PICKING,4X,7H PROFIT,5X,7H PROFIT,/,24X,
 24H TON, 8X,5H COST,6X,6H WAGES,4X,11H EFFICIENCY,2X,8H HAND H.,3X,
 311H MACHINE H.,/,95(1H-))
  DO  4    M = 1,3
  EFF        = A(1,M,4)
  DO   4  N =  50,720,50
  AC         = N
  CR         = ((P-XL)*(XI)*((1+XI)**XN))/(((1+XI)**XN)-1)
  CR         = CR + (XL*XI)
  TIS        = TA+TI+S
  PE         = Y * EFF
  CAH        = (((CR+TIS)/AC)+(OW/ACH)+G)/PE
  COPT1      = (COP/TO)+CH
  COPT2      = (COP/PE)+CAH
  GPTH       = (PPT-COPT1)*TO
  GPTM       = (PPT-COPT2)*PE
  PRINT 7, AC,PPT,C1,OW,EFF,GPTH,GPTM
7 FORMAT (5X,7(5X,F7.2))
4 CONTINUE
  STOP
  END
```

FRESNO STATE COLLEGE
Fresno, California 93710

APPENDIX C

All figures should be based on a single-machine basis. Please do not place your name or address on this questionnaire. Answers can be written on the back of the page if there is not sufficient space. (Please just leave blank any questions not applicable to your operation.)

1. What is the make of machine? ____________________

2. What is the model and year purchased? ____________________

3. Purchasing costs:

   a. Machine only $__________

   b. Insurance (if any) $__________

   c. Taxes $__________

4. Any other attachments used (check what you have).

   a. Cutter bar hedger $__________ (Price)

   b. Sprayer $__________ "

   c. Stake presser $__________ "

   d. Others $__________ "

5. Approximate yearly use (acres or hours, please specify which)

	Acres	Hours
a. Harvesting operation		
b. Cutter bar hedging		
c. Spraying		
d. Stake pressing		
e. Others		

6. How many hours used per year?

   a. Harvesting __________ hours

   b. Others __________ hours

7. Operational costs per year:

   a. Maintenance $__________

   b. Lubrication $__________

   c. Repairs $__________

   d. Fuel cost per gallon $__________ (diesel) or $__________ (gas)

   e. How much operator paid per hour$__________

8. In what particular areas were mechanical difficulties experienced (i.e., shakers, conveyors, etc.)? ______________________________

____

9. Are you satisfied with the results of this machine over hand harvesting?

_______ yes _________no

10. Will you buy this same make machine again if the opportunity arises?_____

11. Give reasons for your reply to No. 10. ______________________________

____

12. Will you continue to use mechanical harvesting over hand harvesting, even if you do not own the machine and must have the harvesting contracted?

Yes _____ No _____ Why?______________________________

____

13. What means do you utilize to get grapes out of the field (Chisolm Rýder Tote-lift, bin trailers, etc.)? ______________________________

14. Before mechanical harvesting, what did you pay or charge for hand harvesting?

Varieties	Hand Picked Per Ton	Hand Picked Per Hour
Thompson	$	$

15. Do you custom harvest? ______________

16. If yes, how much do you charge (per hour, ton, or per acre)? $__________

17. Tonnage harvested per year of operation ______________

18. Speed of machine when harvesting ______________

19. Present labor cost per ton in your area $______________

20. What is average breakdown time during harvest per season of operation?_______

21. Cost of the change to new trellis system per acre specially made for

machine harvest $______________

22. Tractor hours other than harvester (tractors used to haul grapes out of field per year, per tractor) ______________

23. Number of persons involved in harvesting operation by machine ___________

24. How much do you pay tractor drivers to haul grapes out of field?

$__________ per hour