A STUDY OF MECHANIZATION ALTERNATIVES IN FRUIT HARVESTING

BY

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A THESIS SUBMITTED IN PARTIAL FULFILMENT OF

THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF SCIENCE

in the Department

of

Agricultural Mechanics

We accept this thesis as conforming to the required standard

THE UNIVERSITY OF BRITISH COLUMBIA

September, 1970.

ABSTRACT

Fruit growers in the lower mainland of British Columbia are facing a potential labor shortage for hand harvesting of fruit. Prices paid to hand picking labor have increased by more than 100 percent in the last three years. These factors have prompted interest in mechanical harvesting methods.

The purpose of this research was to investigate the feasibility of introducing mechanical harvesting methods in raspberry production and to determine optimum machine parameters.

A review of methods used for determining the optimum size of agricultural equipment was conducted and the methods were summarized. Due to the nature of small fruit production some commonly used methods were not applicable and modifications were necessary.

A fruit yield function and a timeliness function were developed for Willamette raspberries. The fruit yield function based on actual yield data, was used for determining the potential income from a raspberry plantation. The timeliness function, based on the reduction of fruit quality due to variations in the length of the interval between subsequent harvests, was used to determine a suitable charge for untimeliness at any part of the harvest season.

An optimum fruit removal efficiency for mechanical harvesting of Willamette raspberries was determined by assessing the loss in potential income due to the removal of green fruit

and the production of over mature fruit. This was based on published results of mechanical harvesting trials.

Results indicated that the mechanical harvesting of raspberries could be potentially much more profitable than hand harvesting. A machine with a fruit removal efficiency of 80 percent and with an operating speed of 1.5 miles per hour, or greater, appeared to be optimum. At operating speeds above 1.5 miles per hour, the cost of mechanical harvesting was not significantly influenced by the purchase price of the harvester.

The cost of untimely operation was large. Extending the interval between subsequent harvests by one day resulted in an annual profit reduction of approximately 200 dollars per acre.

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NOMENCLATURE

A	area over which the operation is done annually, acres.
B	annual implement costs, dollars per year.
C	effective field capacity, acres per hour.
C_a	cost for a specific harvest, dollars per acre.
$C_{a \rightarrow b}$	hand picking cost, dollars per acre, for a specific three day period.
C_f	annual tractor cost for field operation, dollars per year.
C_h	machine operating cost, dollars per hour.
C_p	annual tractor cost for processing operation, dollars per year.
C_t	annual tractor cost for transport operation, dollars per year.
C_y	seasonal capacity of a machine, acres.
D	annual depreciation charge, dollars per year.
D_o	machine output, acres per hour.
E	field efficiency, percent.
F	fixed cost percentage.
G	energy requirement for processing operation, horsepower per ton
H	fuel cost, dollars per hour.
H_r	hour of operation, hours.
I	annual interest charge, dollars per year.
$I_{a \rightarrow b}$	gross income, dollars per acre, for a specific three day period.
J	gross income, dollars per acre.
K	timeliness factor per hour.

L	the estimated life of machine, years.
L_s	percent fruit loss, percent.
M	cost of labor, dollars per hour.
N	sample size.
O	cost of engine oil, dollars per hour.
P	purchase price of machine, dollars.
Q	tractor fixed cost charge, dollars per hour.
R	repair cost, dollars per hour.
R_1	fraction of grade number 1 fruit.
R_2	fraction of grade number 2 fruit.
R^2	coefficient of multiple determination.
S	salvage price of machine, dollars.
S_d	sum of years, digits (1 + 2 + 3....L)
SF	sinking fund, dollars.
S_y	standard error of the estimate.
T	harvest date, days.
V	the remaining value at anytime of machine, dollars.
V_n	value of the machine at the end of year n.
W	weight of material annually transported or processed, tons per year.
X	the ratio of the depreciation rate used to that of straight line method.
X_e	picking efficiency, percent.
Y	raspberry fruit yield, grams per plant for a specific harvest day.
Y_A	fruit yield at present day of picking, pounds per acre.
Y_B	fruit yield at previous closest picking date, pounds per acre.

Y_C	fruit yield at previous second closest picking date, pounds per acre.
Y_D	fruit yield at previous third closest picking date, pounds per acre.
Y_c	cumulative yield of raspberry, grams per plant.
Y_d	cumulative income reduction, dollars per acre.
$(Y_d)_a$	cumulative income reduction, dollars per acre, evaluated at date a.
$(Y_d)_{a \to b}$	income reduction, dollars per acre for a specific harvest period.
$(Y_d)_b$	cumulative income reduction, dollars per acre, evaluated at date b.
Y_i	gross income for specific harvest interval, dollars per acre.
Y_r	gross income reduction, dollars per acre per hour.
Y_4	the gross income reduction in dollars per acre per day for a four day picking interval as opposed to a three day interval.
Y_5	the gross income reduction in dollars per acre per day for a five day picking interval as opposed to a three day interval.
Y_6	the gross income reduction in dollars per acre per day for a six day picking interval as opposed to a three day interval.
Z	picking interval, days.
d	hauling distance, miles.
f	implement force factor, pound per foot of width.
h	tractor size, power take-off horsepower.
i	interest rate, percent.
j	a specific number of operations.
k	total number of annual transport operations.
m	total number of field operations of implement.

n	the age of the machine, years.
p	purchase price of implement, dollars per foot width.
q	total number of annual processing operation
s	speed, miles per hour.
t	timeliness charge, dollars per hour.
t_1	date of last picking.
t_2	date of present picking.
u	specific new tractor price per horsepower, dollars per horsepower.
v	crop value, dollars per bushel, ton, etc.
w	effective width, feet.
x_1	price per pound of number 1 raspberry fruit, dollars.
x_2	price per pound of number 2 raspberry fruit, dollars.

ACKNOWLEDGEMENTS

The author wishes to express his grateful appreciation to

Dr. E.O. Nyborg for his assistance and guidance in the preparation of this thesis.

Professor L.M. Staley for his supervision and chairmanship of the research committee.

Dr. G.W. Eaton, Dr. G.R. Winter and Dr. N.R. Bulley who served on the research committee and reviewed this paper.

This research was financed by the Canadian International Development Agency.

INTRODUCTION

Small Fruit Growing in the British Columbia Lower Mainland

The trend toward increased mechanization on fruit farms in British Columbia is the result of two quite distinct conditions. One is the economic drive for greater productivity which is expressed by a greater acreage of land per farm unit, while the other is a reduced farm labor supply.

Since hand harvesting is one of the most costly activities of fruit production and since the activity of hand labor is often acute during harvesting, the survival of some types of fruit production will depend upon the development of a mechanical harvester. This is especially true for the small fruit growing industry in the British Columbia lower mainland. In recent years, both the acreage and volume of raspberry production in the lower mainland has shown a steady increase. The raspberry acreage in the lower mainland increased from 1,300 acres in 1962 to over 2,100 acres in 1967 (8)*. Due to improved cultural practices, yields have steadily increased until, at present, average production is about 10,000 pounds per acre. As many as 10,000 hand pickers are needed for the month-long raspberry harvest season in the lower mainland. The need for improved harvesting techniques is urgent if small fruit growers are to remain in production.

Scope and Purpose of this Research

The topography of raspberry farms in the lower

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* Numbers in parentheses refer to the appended references.

mainland is ideal for mechanical harvesting. Since the land is generally flat and has enough large raspberry plantations mechanical harvesting is feasible (2). Recent attempts at developing a mechanical raspberry harvester (2, 4, 6, 17) have indicated that although the topography is ideal for mechanical harvesting, raspberries are not especially suitable for mechanical handling and a mechanical harvesting system must be a compromise among several factors.

Although the actual cost of mechanical harvesting may be less than that of hand harvesting, machine harvested fruit is of reduced quality (17).

The purpose of this research is to compare mechanical harvesting techniques with hand harvesting methods in order to determine the economic limits for machine cost, machine capacity and the quality of machine harvested fruit. Although raspberry production is used, the methods developed should be applicable to the selection of minimum cost harvesting equipment for any fruit growing enterprise.

REVIEW OF LITERATURE

Development of Mechanical Raspberry Harvesting Systems

Many recent attempts have been made at developing mechanical raspberry harvesting systems for the west coast region of Canada and the United States (2, 4, 6). Although the Willamette variety is very suitable for this region and has replaced most other varities, it is not especially suited to mechanical harvesting methods (17). Due to the high ratio of fruit retention force to stem strength, fruit must be more mature than for hand picking, before mechanical harvesting is possible. Similarly, fruit removal efficiency must be limited to prevent excessive plant damage. Although the requirements of mechanical harvesting systems to enable competition with hand harvesting methods have been suggested, (17) several factors were not considered and a more complete economic analysis appears to be necessary.

Field Machinery Selection

Since the introduction of high speed computers, several methods have been used for selecting machinery systems to suit specific farming enterprises (5, 10, 14). Simons (20) developed stored computer programs for solving problems of field machinery selection and cost analysis. Hunt (9) developed a Fortran program to select farm equipment on a least cost basis. This program, which is suited for large grain farming operations, is used to calculate the annual machinery cost for operations where the number and types of machines are known. It is arranged to calculate annual depreciation charges, trade-in value, interest on investment, fixed annual rates for repairs and lubrication charges and fuel consumption. In order to use this program, raw data on farm operations, machine data including the price and function of all machines and tractors, as well as specific horsepower requirements and fuel consumption must first be obtained.

For field machinery selections by size and capacity of all implements, the effective width of implements and the equivalent horsepower requirement of tractors is used. Implement size selection on a least cost basis (5,20) must be adjusted to meet timeliness and requirements for maximum profit. Power requirements must be equal to the maximum amount of power required by any single implement in order to complete its operations within an allotted time.

Cost Analysis

Depreciation may logically be divided into two elements, variable and fixed (18). The variable element may be termed wear-depreciation and the fixed element may be considered as time-depreciation. The latter relates to the maximum number of years or hours over which a machine may be profitably used before it becomes obsolete. The former relates to the maximum use in hours or acres that can be expected before the machine wears out in an economic sense.

Fixed Costs

Depreciation

Depreciation is defined as the reduction in value of a machine caused by natural wear while in use, obsolescence, weathering, accidental damage, rust and corrosion. An estimate of depreciation is necessary for the calculation of cost of operation and in determining the service life of the machine.

Naturally the parts of the machine become worn out with use and depend on the operator's skill, maintenance practices, operating conditions and the quality of the machine itself. All this will affect the performance of the machine. The development of more up-to-date machines, designed to give higher efficiency and to suit new cultural practices, results in a rapid rate of obsolescence of machines now on hand.

Methods of Estimating Depreciation

Four methods of estimating depreciation costs (13) are widely used. These are the straight-line method, the declining balance method, the sum of digits method and the sinking fund method. The widely used straight-line method reduces the value of a machine by an equal amount each year during its useful life. A machine depreciates less by this method for the first few years than its resale value would indicate, while the machine depreciation cost of performing a farm operation remains constant at all ages of the machine. It is generally assumed when using this method that the value of the machine at the end of its service life will be about ten percent of its original cost. The annual depreciation charge by the straight-line method is

$$D = \frac{P - S}{L} \qquad [1]$$

where D = annual depreciation charge

P = purchase price

S = salvage value

L = the estimated economic life in years.

The declining balance method is a constant percentage method. A uniform rate is applied each year to the remaining value (including salvage value) of the machine at the beginning of the year. The depreciation amount is different for each year of the machine's life. Depreciation by this method is

$$D = V_n - V_{n+1} \qquad [2]$$

where $V_n = P\,(1 - \frac{X}{L})^n$

$$V_{n+1} = P\,(1 - \frac{X}{L})^{n+1}$$

and D = the amount of depreciation charged for year n+1

n = the age of the machine, in years, at the beginning of the year in question

P = purchase price

V = the remaining value at any time

L = estimated service life in years

X = the ratio of the depreciation rate used to that of the straight-line method

The sum of the digits method permits a higher rate of depreciation during the early life of a machine. The digits of the estimated number of years of machine life are added together and this sum is divided into the number of years of life remaining for the machine including the year in question.

The fractional part of the difference between purchase price and the salvage value is the amount of depreciation charged each year. This method depreciates the value of a machine to zero at the end of its useful life. Using this method, annual depreciation is

$$D = \frac{L - n}{Sd} (P - S) \qquad [3]$$

where D = annual depreciation for year n

Sd = sum of years-digits (1 + 2 + 3 + ... + L)

n = the age of the machine in years at the beginning

L = estimated machine life, years

P = purchase price

S = salvage value

The sinking fund method considers depreciation cost as an investment which will draw compound interest. The accumulation of the fund by the time that a machine is fully depreciated, plus interest, is used to purchase another equivalent machine. The initial value of such a sinking fund is

$$SF = (P - S) \frac{i}{(1 + i)^L - 1} \qquad [4]$$

where SF = sinking fund

P = purchase price

S = salvage value

i = interest rate percent

L = estimated machine life, years

Its value at the end of year n is

$$V_n = (P - S)\left[\frac{(1 + i)^L - (1 + i)^n}{(1 + i)^L - 1}\right] + S \qquad [5]$$

where V_n = value at the end of year n

S = salvage value

P = purchase price

i = interest rate, percent

L = estimated machine life, year

Service Life

In determining the depreciation cost of a machine its service life must be estimated. The economic life (11) of a machine is a more pertinent measure of the period of time 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 to keep the machine operational. Unfortunately, the service life of an implement sometimes is terminated instantly due to an irreplaceable or irrepairable part failure. Economic life is defined as the length of time from purchase of the machine to that point where it is more economic to replace it with a new machine rather than to continue with the old machine.

A machinery schedule for the remaining value, the wear out life and accumulated repairs, for various farm machines is listed on page 282 of reference (1). The reported values are based on the actual performance records of numerous

TABLE I SERVICE LIFE OF FARM MACHINES

	Time to Obsolescence (Years)	Wear-out Life (Hours)	Yearly Usage for Wear-out Life to Equal Obsolescence Life (Hours)
Tillage			
Cultivator	12	2,500	208
Disk harrow	15	2,500	167
One-way disk	15	2,500	167
Disk plow	15	2,500	167
Moldboard plow	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			
Pull-type combine	10	2,000	200
Self-propelled combine	10	2,000	200
Cornpicker	10	2,000	200
Cotton picker	8	2,000	250
Cotton stripper	10	2,000	200
Forage harvester	10	2,000	200
Hay conditioner	12	2,500	250
Mower	12	2,000	
Side-delivery rake	12	2,500	208
Beet harvester	10	2,500	250
Self-propelled windrower	8	2,500	313
Tractor and Miscellaneous			
Track tractor	15	12,000	800
Wheel tractor	15	12,000	500
Wagon	15	5,000	333

agricultural implements and power units and are widely used for machinery cost calculations. Table I is a summary of some of the service life data included in this reference.

Interest on Investment

In estimating the cost of machine operation, interest on the investment in the farm machine must be included since money used in purchasing the machine cannot be used for another productive enterprise. An interest rate of six percent per year has been commonly used (1) and is included as one of the ownership costs.

When the straight line method of depreciation is used, it is more convenient to allocate similar interest charges for each year of machine life. On this basis, the annual interest charge is calculated on one-half the sum of the first cost of the machine and the trade-in value.

$$I = \left(\frac{P + S}{2}\right) i \qquad [6]$$

where I = annual interest

P = purchase price

S = trade-in value

i = annual interest rate, percent.

Taxes

The rate of tax charges on the overhead cost of operating farm machinery varies widely in different locations. A rate of two percent is commonly used (1).

Insurance

It is justified to charge one percent of initial cost of machine (1) for insurance against loss of the machine. Annual insurance rates for farm equipment vary from \$0.60 to \$1.20 per \$100 coverage. Most insurance companies will insure equipment to up to two-thirds of its replacement value.

Shelter

While the average total expected life is consistently greater for sheltered machines (11), the average annual estimated repair expenses are also consistently smaller with the observation that sheltering goes along with better care and management. Sheltering also aids in making repairs during idle periods. An average shelter charge of one percent of the initial cost of the machine is recommended (1).

Fixed Cost Percentage

Since all the items included in the annual fixed cost of a machine are constant with use, it is more convenient to combine them into one single constant that is related to the purchase price of the machine. This constant, called the fixed cost percentage, has been used by many researchers (10, 13, 14).

Hunt (10) calculated the fixed cost percentage by using the straight line method of depreciation as follows:

Using equation [1] and letting $S = 0.1P$, then for $L = 10$ years, the annual depreciation charge is, $D = 0.09P$. Using equation [6] with $i = 0.06$, the annual interest charge is, $I = 0.033P$. Considering annual tax charges as $0.020P$, insurance charges as $0.01P$ and annual shelter costs as $0.01P$

TABLE II. ANNUAL FIXED COST PERCENTAGES FOR FARM MACHINES

Machine	Fixed cost percentage
Tillage	
Cultivator	15% P*
Disk harrow	13% P
One-way disk	13% P
Disk plow	13% P
Moldboard plow	13% P
Spike-tooth harrow	12% P
Spring-tooth harrow	12% P
Planting	
Grain drill	12% P
Row crop planter	13% P
Harvesting	
Pull-type combine	16% P
Self-propelled combine	16% P
Corn picker	16% P
Cotton picker	18% P
Cotton stripper	16% P
Forage harvester	16% P
Hay conditioner	15% P
Mower	15% P
Rake side delivery	15% P
Beet harvester	16% P
Self-propelled windrower	18% P
Tractor and Miscellaneous	
Track tractor	13% P
Wheel tractor	13% P
Wagon	13% P

* P = The purchase price of a machine

and summing these five fixed costs, the annual fixed cost is 0.163P and the annual fixed cost percentage is 16 percent.

Using this method, the annual fixed cost percentage for all the machines shown in Table I has been calculated, based on the estimated life of the machines. These values are given in Table II.

Purchase Price of Tractors and Equipment

Specific price information for a particular machine often is not available. A reasonable estimate of the purchase price of machines may be made by using Table III. This table which is a compilation of data presented by Hunt (11) is based on 1964 selling prices of implements and expresses purchase price on a foot of width basis.

The specific price of tractors has been tabulated by Southwell (21). Some of this data, which is based on 1966 prices, is presented in Table IV and expresses the purchase price of tractors on a per-pound-basis and on a per-horsepower basis. The latter figure is based on Nebraska Test data.

Variable Costs

Repair and Maintenance Costs

The costs of repairs, maintenance and lubrication are proportional to the amount of time a machine is operated. They are fairly low in the early life of a machine but increase as a machine gets older. Maintenance costs, the cost of maintenance labor and the cost of replacement parts all must be included in repair cost. Information about the exact rate of repair costs throughout the life of a machine

TABLE III. SPECIFIC PRICE OF NEW IMPLEMENTS

Implement	Price Range	
Tillage		
Cultivator	38 - 54	dollars/ft
Disk harrow	60 - 90	"
One-way disk	44 - 55	"
Disk plow	160 -250	dollars/disk
Moldboard plow	100 -250	dollars/bottom
Spike-tooth harrow	15	dollars/ft
Spring-tooth harrow	18 - 25	"
Planting		
Grain drill	55 - 65	"
Row-crop planter	100 -180	dollars/row
Harvesting		
Pull-type combine	300 -400	dollars/ft
Self-propelled combine	500 -650	"
Corn picker	1500-1700	dollars/row
Cotton picker	7300-10000	"
Cotton stripper	1000	"
Forage harvester	350 -625	dollars/ft
Hay conditioner	900	dollars
Mower	75 - 90	dollars/ft
Side-delivery rake	400 -500	dollars
Beet harvester	3000	dollars/row
Self-propelled windrower	300 -450	dollars/ft

TABLE IV SPECIFIC PRICE OF NEW TRACTORS

Specific Cost	Effect of Engine Type		Effect of Tractor Size	
	Gasoline Tractor	Diesel Tractor	Tractor over 50 PTO hp	Tractor under 50 PTO hp
Cost per pound				
average	90.0	95.0	92.0	95.0
range	72 - 123	74 - 136	72 - 136	72 - 120
Dollars per PTO horsepower				
average	91.4	99.8	94.9	98.1
range	75 - 108	79 - 134	75 - 120	82 - 134
Dollars per drawbar horse-power				
average	109.6	116.7	111.0	117.6
range	91 - 133	96 - 153	91 - 144	96 - 153

usually are not available. Curves of the accumulated repair cost of tractors and implements, as a function of retail price and hours of use, are given in the Agricultural Engineers Yearbook (1). Hunt (11) reports repair cost as an average constant percentage per hour of use over the life of the machine. Some of the data given by Hunt is included in Table V. The second column in Table V is the percentage of the purchase price of a machine which can be expected as repair cost per hour of machine usage. The third column is the total percentage of the purchase price of a machine which can be expected as repair cost if a machine is used until obsolete.

Fuel Costs

In determining the fuel consumption of a machine for a specific operation, the power consumption for that operation must be considered. An equivalent power take-off horsepower may be obtained by dividing the required drawbar horsepower by a traction-and-transmission coefficient. This equivalent power take-off horsepower may then be used to select the proper fuel consumption from Nebraska Tractor Test data for the particular tractor under consideration. A more convenient method of estimating fuel consumption is by the use of Figure 1. Figure 1 is taken from the Agricultural Engineers Yearbook (1) and is based on the averages of all Nebraska Tests from 1961 to 1965.

In order to use Figure 1, the equivalent power take-off horsepower must first be estimated, as was described

TABLE V REPAIR AND MAINTENANCE COST, PERCENT OF PURCHASE PRICE

Machine	Average per Hour of Use (percent of retail price)	Total During Wear-out Life (percent of retail price)
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		
Pull-type combine	0.045	90
Self-propelled combine	0.027	54
Corn picker	0.032	64
Cotton picker	0.026	52
Cotton stripper	0.020	40
Forage harvester	0.024	58
Hay conditioner	0.040	100
Mower	0.120	240
Side delivery rake	0.070	175
Beet harvester	0.025	63
Self-propelled windrower	0.040	100
Tractor and Miscellaneous		
Track tractor	0.008	78
Wheel tractor	0.012	120
Wagon	0.018	90

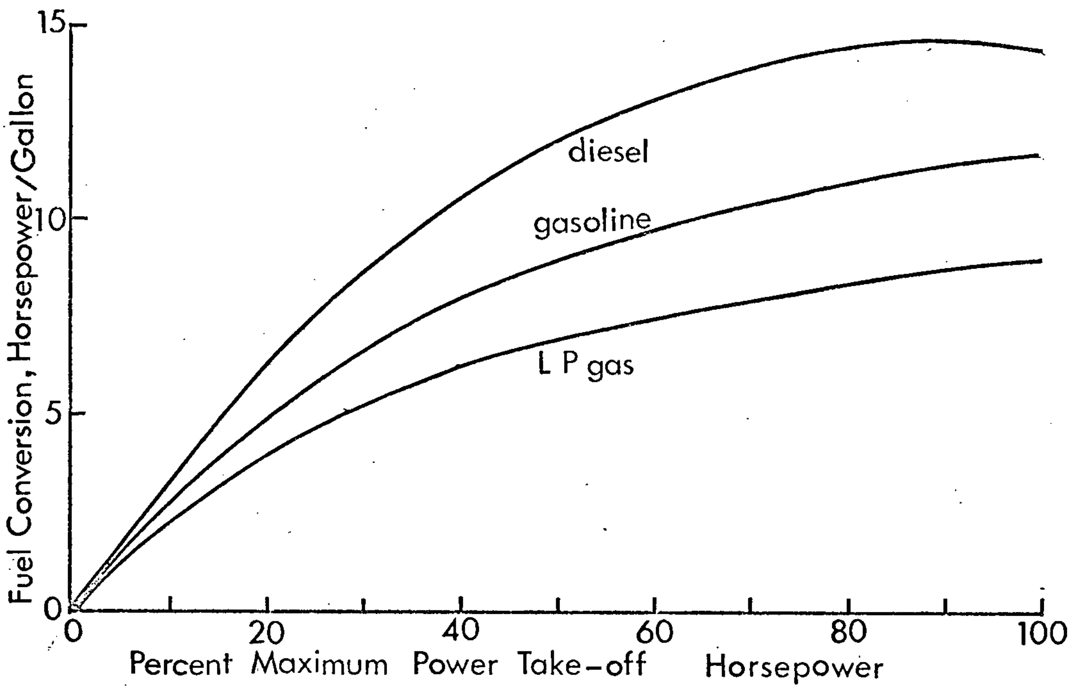

Figure 1. Graph for Estimating Tractor Fuel Consumption

above. A traction and transmission coefficient may be used to express the ratio between draw bar horsepower and power take-off horsepower. Table VI shows the traction and transmission coefficient calculated from the effects of tractor rolling resistance, drive wheel or track slippage, and losses in the power train between the engine and the axle, under various operating conditions. This table is taken from the Agricultural Engineers Yearbook (1)

TABLE VI. TRACTION AND TRANSMISSION COEFFICIENTS FOR WHEEL TRACTORS

Surface Condition	Traction and Transmission Coefficient: Light load (pull = 10% of weight)	Medium drawbar load	Moderately heavy drawbar load
Concrete	0.75	0.85	0.9
Firm, untilled field	0.6	0.75	0.8
Tilled, reasonably firm soil	0.4	0.6	0.65
Freshly plowed soil	0.25	0.4	0.45

Oil Costs

Oil consumption includes both the amount of oil consumed by an engine and the amount of oil required for regular oil changes. Consumption is defined as the total volume of new oil placed in an engine in a given time period. The recommendation of oil change period varies among manufacturers. Hunt (11) has determined average oil consumption figures based on Nebraska Tractor Test data and manufacturer recommendations on oil change periods. Some of this data is included in Table VII. Another method of estimating the cost of oil consumption is by considering it as fifteen percent of the cost of fuel (1).

TABLE VII 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
90	.016	.015	.023
over 90	.016	.015	.023

Power and Energy Considerations

Force Factor

A force factor is commonly used to determine the gross energy requirements of field operations (1, 11). Force factors usually are expressed as pounds of force per foot of effective width of a field machine, and are based on published draft and power requirements with the auxiliary rolling resistance, if any, included. Since the capacity of a field implement may be designated by its effective width, the power requirement of a machine may be determined from its force factor and its effective width. This also facilitates the determination of the necessary tractor horsepower capacity to operate a field machine.

Table VIII is taken from data presented by Hunt (11) and in the Agricultural Engineers Yearbook (1) and may be used to estimate the power requirements of field machines. Since much variation in power requirements may be expected due to field and crop conditions, the resulting power requirements are only rough estimates.

TABLE VIII TYPICAL FARM IMPLEMENT FORCE FACTORS

Machine	Force Factors, lbs per ft 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 planter	110
Harvesting	
Combine	375
Corn picker	650
Forage harvester	400
Hay conditioner	140
Mower	130
Side delivery rake	80

Field Efficiency

The efficiency of performing a field operation must also be considered in estimating the cost of operation.

Field efficiency may be defined as the ratio of the useful time used in performing a field operation to the total time (useful time plus lost time) used in performing the operation. Useful time includes only the productive time spent in actually performing the operation while lost time includes the time spent in turning at row ends, travelling to and from the field, filling seed and fertilizer etc. (14).

Typical field efficiencies, taken from the Agricultural Engineers Yearbook (1) are presented in Table IX.

TABLE IX. TYPICAL FIELD EFFICIENCIES

Operation	Field Efficiency %
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 of corn	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

Timeliness Charges for Field Operations

Timeliness factor

Hunt and Patterson (12) defined timeliness as the state of being opportune or optimum in field operations. They evaluated the economic benefit of timeliness by considering the cost of being untimely, that is, the cost experienced as a result of reductions in crop value due to yield losses or quality reduction.

Figure 1a shows one of the patterns of curves which may occur in operations where an optimum time exists and where a penalty occurs if an operation is premature or delayed, in accordance with the allowable number of working days. The slope of such a curve may be expressed as a decimal reduction in income per unit of time. For example, if the slope is known to be 0.5 bushels per acre per day of delay (or prematurity) of operation and the potential income is 100 bushels per acre the slope would be 0.0002 dollars per acre per hour, when considering a value of one dollar per bushel.

The slope of the timeliness curve allows a charge to be made for untimely operations. A further correction (12) must, however, be made. It has been shown (11) that there is a 95 percent probability that only forty percent of the total available time is actually used for an operation. Adjusting the value of the slope, on this basis, the timeliness charge in the previous example becomes 0.0005 dollars per acre per hour.

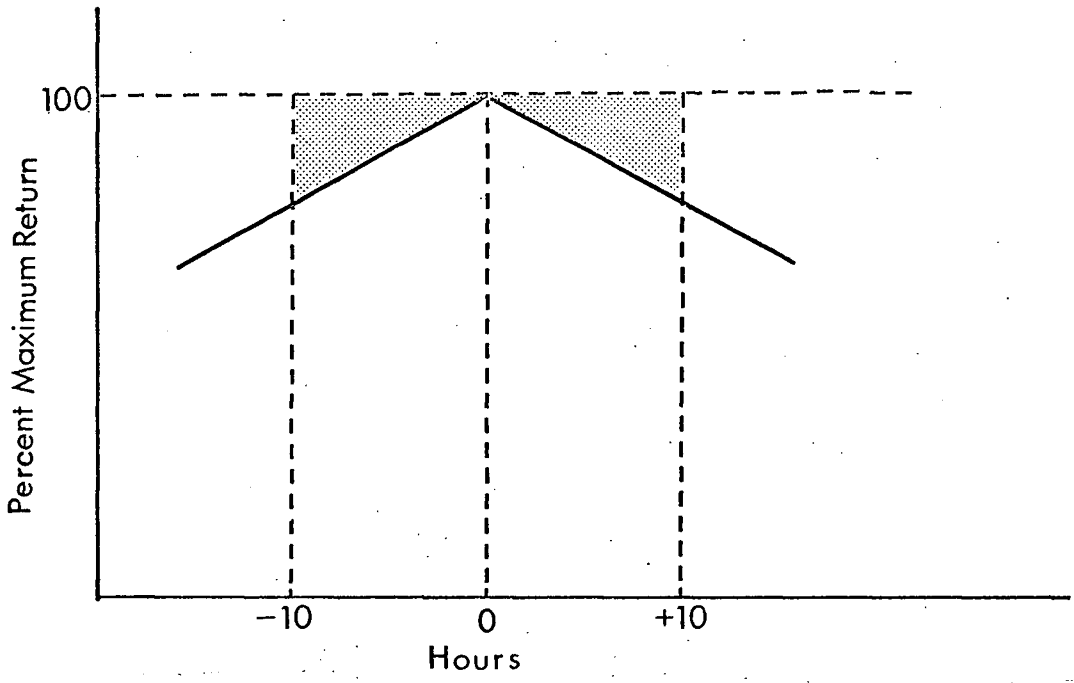

Figure 1a. Total Cost of Timeliness

TABLE X. 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

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

Determination of the Minimum Cost of a Machinery System

Hunt (9) in developing a Fortran program for determining a suitable system of machines for a farm enterprise, used a minimization procedure to select the economic size of implements and tractors. This was done by writing an expression for the total annual cost of using an implement or tractor, differentiating it with respect to the pertinent variable (the width of the implement or the horsepower of the tractor) equating it to zero and solving for the variable.

Implement Selection

The effective field capacity of an implement may be written as

$$C = (swE)/8.25 \qquad [7]$$

where C = effective field capacity, acres per hour

s = forward speed, miles per hour

w = effective width, feet

E = field efficiency, percent (Table IX)

Using equation [7], the annual cost of a specific implement may be expressed as

$$B = F\,p\,w + \sum_{j=1}^{m} \left(\frac{8.25\,A_j}{s_j\,w\,E_j}\,(R_j + M_j + O_j + H_j + Q_j + t_j)\right) \qquad [8]$$

where B = annual implement cost, dollars per year

F = implement fixed-cost percentage (Table II)

p = purchase price of implement, dollars per foot width (Table III)

w = effective width, feet

A = number of acres over which a specific operation is performed annually, acres

s = forward speed, miles per hour

E = field efficiency, percent (Table IX)

R = repair costs, dollars per hour (Table V)

M = cost of labor, dollars per hour

O = cost of engine oil, dollars per hour (Table VII)

H = fuel cost, dollars per hour (interpreted from Table VI and VIII and Figure 1)

Q = tractor fixed cost charge, dollars per hour (interpreted from Table II, purchase price and annual use)

t = timeliness charge (equation [9])

j = the specific implement operation

m = the total number of implement operations in one year

The timeliness charge, t, in equation [8] may be expressed as follows

$$t_j = K_j A_j y_j v_j \qquad [9]$$

where t = timeliness charge, dollars per hour

K = timeliness factor $(\text{hour})^{-1}$ (from Table XI)

A = number of acres over which a specific operation is annually performed, acres

y = potential crop yield, bushel, ton, etc. per acre

v = crop value, dollars per bushel, ton, etc.

To determine the optimum size of an implement, equation [8] may be differentiated with respect to the effective implement width. It should be noted that R, O, and H may be considered as proportional to the annual area of a field operation and will be constant, regardless of the size of field machine. Differentiating, equating to zero and solving for w, the optimum size of field machine is

$$w = \left[\frac{8.25}{F_p} \sum_{j=1}^{m} \left(\frac{A_j}{s_j E_j} (M_j + Q_j + t_j)\right)\right]^{1/2} \qquad [10]$$

where w = implement effective width for minimum cost and other symbols are as previously defined.

Tractor Selection

In selecting an optimum size tractor for a certain farm enterprise, Hunt (9) considered three specific tractor operations, field work (when the tractor is used to pull a field implement), transport work (when the tractor is used for transporting products such as grain, hay, etc.) and processing work (when the tractor is used for stationary operations such as feed grinding).

The annual fixed cost charge for a tractor is

$$C_a = F\,u\,h \qquad [11]$$

where C_a = annual fixed cost charge, dollars per year

F = fixed cost percentage (Table II)

u = specific price of new tractor, dollars per horsepower (Table IV)

h = tractor size, power take-off horsepower

As was previously discussed, the costs of repair, maintenance, fuel and oil are a direct function of acreage for field operations or of quantities handled for transport and processing operations. Hence, only timeliness costs and labor costs need be considered in selection of an optimum sized power unit.

The annual cost for tractor power used in field operations, when neglecting repair costs, fuel costs and oil costs is

$$C_f = \sum_{j=1}^{m} \left[\frac{0.022\ A_j f_j}{E_j\ h} (M_j + t_j)\right] \qquad [12]$$

where C_f = annual tractor cost for field operations, dollars per year

f = implement force factor, pounds per foot of width (Table VIII)

and other symbols are as previously defined

The annual cost for tractor power used for transport operations, when neglecting costs of repair, fuel and oil, may be written as

$$C_t = \sum_{j=1}^{k} \left[\frac{M_j}{h} (1.1\ d_j\ W_j)\right] \qquad [13]$$

where C_t = annual tractor cost for transportation, dollars per year

M = labor cost, dollars per hour

h = tractor size, power take-off horsepower

d = hauling distance, miles

W = weight of material annually transported, tons per year

1.1 = a constant (considering average rolling resistance as five percent of weight), horsepower-hour per ton-mile

j = a specific transport operation

k = the total number of annual transport operations

Finally, the annual tractor cost for stationary processing operations when neglecting repair, fuel and oil costs, is

$$C_p = \sum_{j=1}^{q} [G_j \; W_j] \qquad [14]$$

where C_p = annual tractor cost for processing

G = energy requirement for processing, horsepower-hour per ton (Reference (1))

W = weight of material annually processed, tons per year

j = a specific processing operation

q = the total number of annual processing operations

Adding [11], [12], [13] and [14], differentiating the sum with respect to tractor size (h) and solving for tractor size, the minimum cost size of tractor for a specific farm is

$$h = \left[\sum_{j=1}^{m} \frac{0.022 \; A_j f_j}{FuE_j}(M_j + t_j) + \sum_{j=1}^{k} \frac{1.1 \; M_j d_j W_j}{Fu} + \sum_{j=1}^{q} \frac{M_j G_j W_j}{Fu} \right]^{1/2} \qquad [15]$$

where h = optimum tractor size for a specific farm, power take-off horsepower

and other symbols are as previously defined.

By the method outlined above, it is possible to select implement sizes and tractor sizes to obtain a minimum cost machinery system for a specific farm.

ECONOMIC ANALYSIS OF RASPBERRY HARVESTING

Introductory Remarks

As it was previously mentioned raspberry harvesting will be used as an example of a fruit growing enterprise for studying mechanization alternatives. In the previous pages a minimum cost method, for the selection of implements and power units was considered. This method was originally developed for selecting machinery systems for large grain farming enterprises. The method needs modification before it can be adapted to a small fruit growing enterprise. For example, the method assumes that machinery width (equation [10]) is limited only by economic considerations whereas, in the case of raspberry growing, machinery width is determined by cultural practices since raspberries are grown in rows of a fixed spacing. The method also uses specific price data (Table III); however, since most fruit harvesting equipment is still in an experimental stage, such data does not exist. Finally, the method uses timeliness cost factors (Table X) based on once-over harvesting methods. Since raspberries must be harvested a number of times during a harvest season, this type of timeliness factor is not appropriate.

Marketing Conditions

The end product of the harvested fruit depends upon the available market for different grades of fruit. High quality fruit may be marketed fresh or frozen or may be processed prior to marketing. Fruit of lower quality must be processed as jam, canned fruit or frozen fruit to prevent deterioration. During the past decade, from 95 to 98 percent of the raspberry production in the lower mainland (8) has been sold for processing rather than for direct consumption. This indicates that even if a machine is incapable of harvesting fruit suitable for the fresh market, it can still serve 95 percent of the industry. The income to the producer will, however, be reduced as processing fruit demands a lower market price. Market prices in 1970 (19) ranged from 33 to 35 cents per pound for number 1 fruit (suitable for fresh fruit market) while prices for number 2 fruit (suitable for processing) ranged from 19 to 22 cents per pound.

Cultural Practices for Raspberry Growing

The most popular raspberry variety grown in the lower mainland is the Willamette variety. (Figure 4). Most of the experimental work on raspberry harvesting (2, 4, 17) has, therefore, been conducted on this variety.

The following description of cultural practices is a consolidation of that presented by Nyborg (17). Figures 3 to 5 were also obtained from this source.

The raspberry plant (Figure 2) has a perennial root system with biennial stalks. The plants begin to bear fruit in the second year after planting and are productive in the succeeding years, for twelve or more years, when it is necessary to destroy them and plant new root stock.

Raspberries are planted in parallel rows spaced at ten feet. Individual plants are spaced in the rows at a distance of two and one half feet, resulting in hedge rows (Figure 4) once the plants mature. A supporting system is necessary to prevent the plants from lodging due to rank growth, weak and flexible canes, weak root systems and a heavy load imposed on the canes by fruit and leaves. Most growers use a trellising system composed of wooden posts and steel support wires placed within the rows.

Raspberry fruit is an aggregate fruit composed of loosely bound drupelets attached to a central core (Figure 3). Raspberries mature unevenly over a thirty day period, with peak production occurring approximately midway in the harvest season. Picking is required at least once every three days throughout the harvest season to avoid overmature fruit. As the length of the picking interval is increased beyond three days, the quality of the resulting fruit is reduced. If the picking interval is extended beyond approximately six days, fruit loss occurs due to natural abscission.

Hand picking represents one of the largest costs associated with raspberry production. The price paid to hand pickers has increased from five cents per pound in 1967 to ten cents per pound, or more, in 1970. Additional expenses are also incurred. In recent years, to ensure the availability of picking labor, many growers have invested in buses for the transporation of pickers to and from the picking field. In addition, some growers supply living quarters on the farm for the pickers. The rising costs, associated with enticing picking labor and the difficulty in procuring suitable labor have directed efforts towards the use of mechanical harvesting methods.

Figure 2

Figure 3

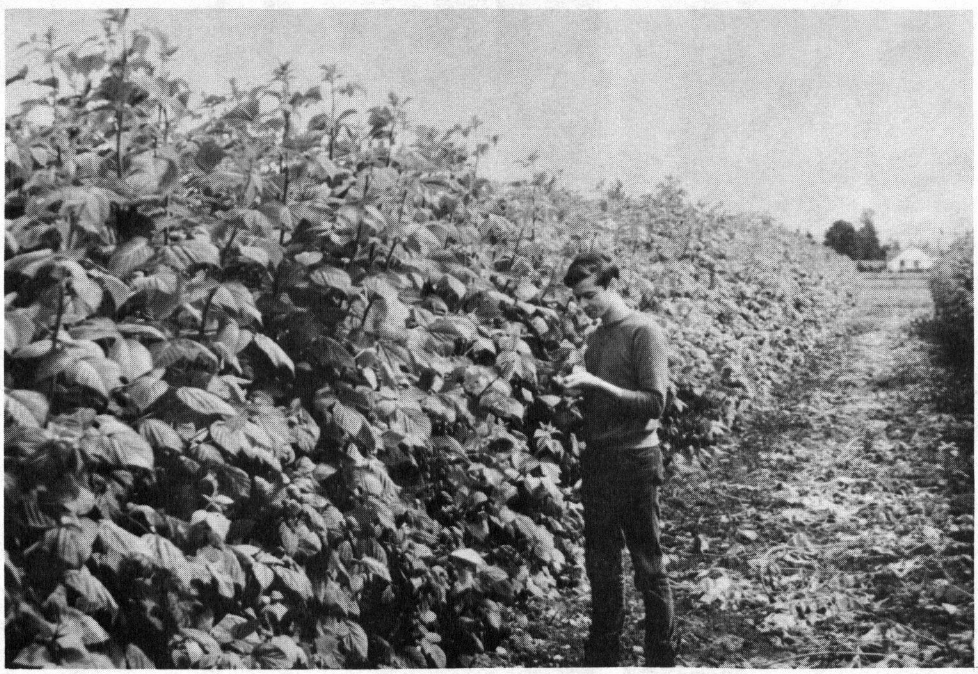

Figure 4

Scope of the Analysis

The machinery system required for establishing a raspberry plantation and for operating associated enterprises on a raspberry farm can be selected by the previously outlined minimization techniques. The costs involved for these enterprises should be similar for farms using hand picking methods and for farms using mechanical harvesting methods. The only difference in production costs should occur in the harvesting operation. For this reason, in the following analyses, only harvesting is considered

Determination of a Timeliness Function for Raspberry Harvesting

Timeliness Factor for once-over Operations

The values of the timeliness factors (Table X) were determined from the adjusted slopes of yield-timeliness curves (Figure 1a) for specific operations. On this basis, K represents a decimal reduction in income per acre for every hour of actual machine operation.

This method of determining a timeliness factor is suitable for once-over operations such as grain harvesting, hay harvesting and tillage but it is not suitable for multiple operations such as small fruit harvesting. For a crop such as raspberries, the field must be harvested a number of times during the season and timeliness becomes a function of several variables, as is described below.

Raspberry Yield

As a first step in determining a timeliness function,

TABLE XI. RASPBERRY YIELD DATA

Date (July, 1970)	Row	Plant	Fruit Yield[1] (gms/day)	Cumulative Fruit Yield (gms)
3	A	1	29.2	87.5
3	A	2	62.0	185.2
3	A	3	29.2	87.5
3	A	4	31.5	94.5
3	B	1	36.2	108.5
3	B	2	54.8	164.5
3	B	3	56.0	168.5
3	B	4	35.0	105.0
3	C	1	25.7	77.0
3	C	2	42.0	126.0
3	C	3	38.4	112.0
3	C	4	36.2	108.5
6	A	1	42.4	254.0
6	A	2	42.3	253.0
6	A	3	45.6	273.0
6	A	4	67.5	404.0
6	B	1	94.0	563.0
6	B	2	67.0	402.0
6	B	3	104.2	625.0
6	B	4	80.3	481.0
6	C	1	87.5	525.0
6	C	2	141.0	847.0
6	C	3	113.2	681.0
6	C	4	87.8	526.0

1 These values were obtained by dividing the actual fruit yield by the number of days between picking intervals. June 30 was considered as day zero.

TABLE XI (Continued)

Date (July, 1970)	Row	Plant	Fruit Yield (gms/day)	Cumulative Fruit Yield (gms)
9	A	1	160.0	736.0
9	A	2	101.0	556.0
9	A	3	101.0	576.0
9	A	4	139.0	821.0
9	B	1	177.0	1095.0
9	B	2	199.0	998.0
9	B	3	213.0	1262.0
9	B	4	187.5	1044.0
9	C	1	134.8	929.0
9	C	2	159.1	1325.0
9	C	3	197.5	1273.0
9	C	4	155.8	993.0
14	A	1	133.0	1401.0
14	A	2	81.5	963.0
14	A	3	90.5	1028.0
14	A	4	123.0	1436.0
14	B	1	138.2	1786.0
14	B	2	123.8	1617.0
14	B	3	164.5	2085.0
14	B	4	111.2	1601.0
14	C	1	123.5	1546.0
14	C	2	111.0	1880.0
14	C	3	166.5	2105.0
14	C	4	115.0	1567.0

TABLE XI (Continued)

Date (July, 1970)	Row	Plant	Fruit Yield (gms/day)	Cumulative Fruit Yield (gms)
17	A	1	126.1	1780.0
17	A	2	121.0	1326.0
17	A	3	107.6	1451.0
17	A	4	164.5	1927.0
17	B	1	117.2	2138.0
17	B	2	91.1	1890.0
17	B	3	145.5	2522.0
17	B	4	105.0	1917.0
17	C	1	131.2	1942.0
17	C	2	99.0	2177.0
17	C	3	132.1	2502.0
17	C	4	143.6	1998.0
22	A	1	72.0	2140.0
22	A	2	51.0	1611.0
22	A	3	62.8	1764.0
22	A	4	94.1	2397.0
22	B	1	79.7	2536.0
22	B	2	83.3	2307.0
22	B	3	109.6	3081.0
22	B	4	68.7	2260.0
22	C	1	139.0	2637.0
22	C	2	70.6	2530.0
22	C	3	135.0	3176.0
22	C	4	127.9	2638.0

TABLE XI (Continued)

Date (July, 1970)	Row	Plant	Fruit Yield (gms/day)	Cumulative Fruit Yield (gms)
27	A	1	49.2	2386.0
27	A	2	36.2	1792.0
27	A	3	63.1	2080.0
27	A	4	66.4	2729.0
27	B	1	47.4	2809.0
27	B	2	44.0	2527.0
27	B	3	72.5	3443.0
27	B	4	32.0	2420.0
27	C	1	120.0	3237.0
27	C	2	59.0	2827.0
27	C	3	86.0	3606.0
27	C	4	104.2	3160.0

for raspberry harvesting, a yield distribution function was determined by analyzing raspberry yield data for the 1970 harvest season. Table XI presents the yield data for twelve raspberry plants of the Willamette variety grown in three different rows at the Canada Department of Agriculture Small Fruit Substation, Abbotsford, British Columbia. (These data were obtained from P.A. Jolliffe, Plant Science Department, and E.O. Nyborg, Agricultural Engineering Department, U.B.C. and is data for the check plots in a field experiment).

Using the method of least squares and a stepwise regression procedure, the best fit polynomial of daily fruit yield versus harvest time was determined. The selected level of significance for inclusion or exclusion of independent variables was 0.01. The polynomial describing fruit yield was

$$Y = -8.54 + 20.16T - 0.07T^3 + 0.13 \times 10^{-3}\ T^5 - 0.24 \times 10^{-5}\ T^6 \qquad [16]$$

$$R^2 = 0.79,\ N = 108,\ Sy = 27.18$$

for the range $0 \leq T \leq 33$

where Y = fruit yield, grams per plant, for a specific harvest day

T = harvest time with July 1 considered as the first day.

Figure 5 is a plot of the raw data given in column 4 of Table XI and of equation [16].

By integrating the equation [16] with respect to time a cumulative yield function was obtained

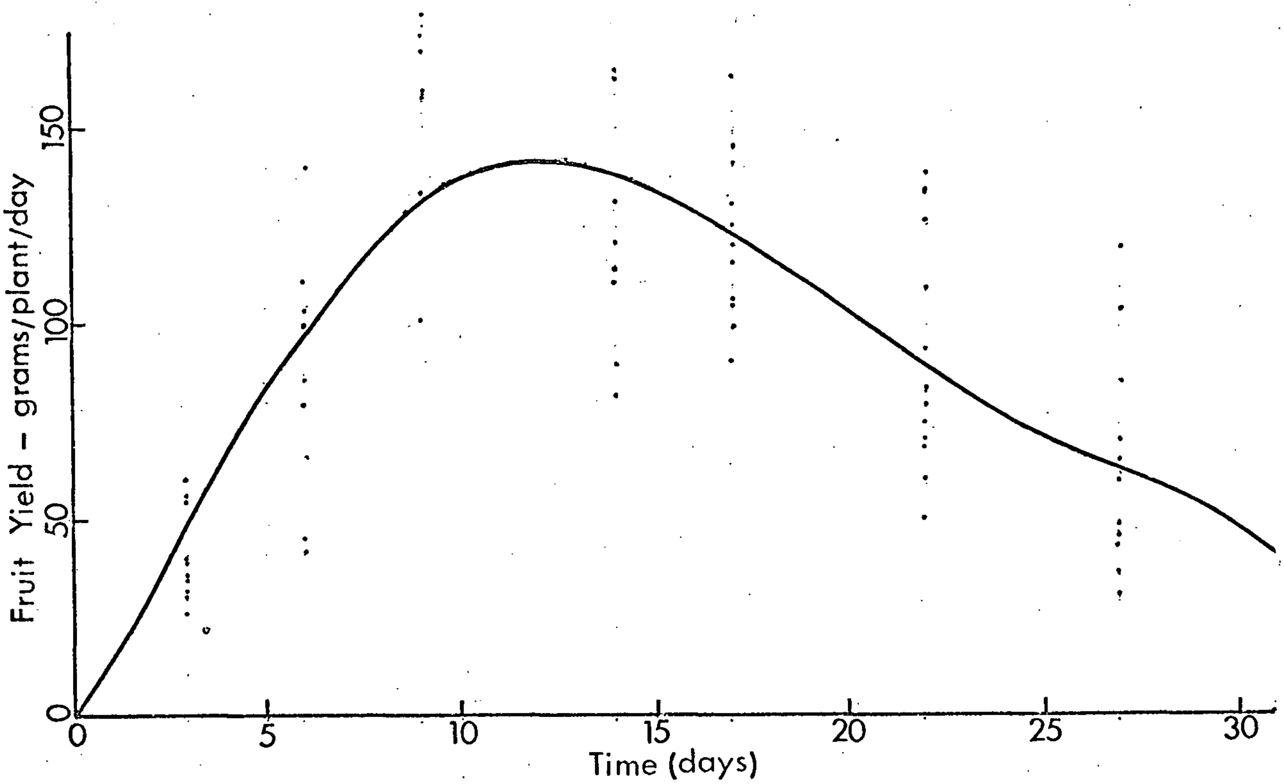

Figure 5. Daily fruit yield for Willamette raspberries

$$Yc = \int_{t_1}^{t_2} (Y)$$

$$= [-8.54\ T + 10.08\ T^2 - 0.17\ T^4 + 0.21 \times 10^{-4}\ T^6 - 0.35 \times 10^{-6}\ T^7]_{t_1}^{t_2} \qquad [17]$$

Where Yc = cumulative yield, grams per plant

T = harvest date, with July 1 considered as the first day.

By evaluating equation [17] between suitable limits of integration, the total yield for any harvest interval may be obtained. Figure 6 shows the cumulative yield function for the complete harvest season.

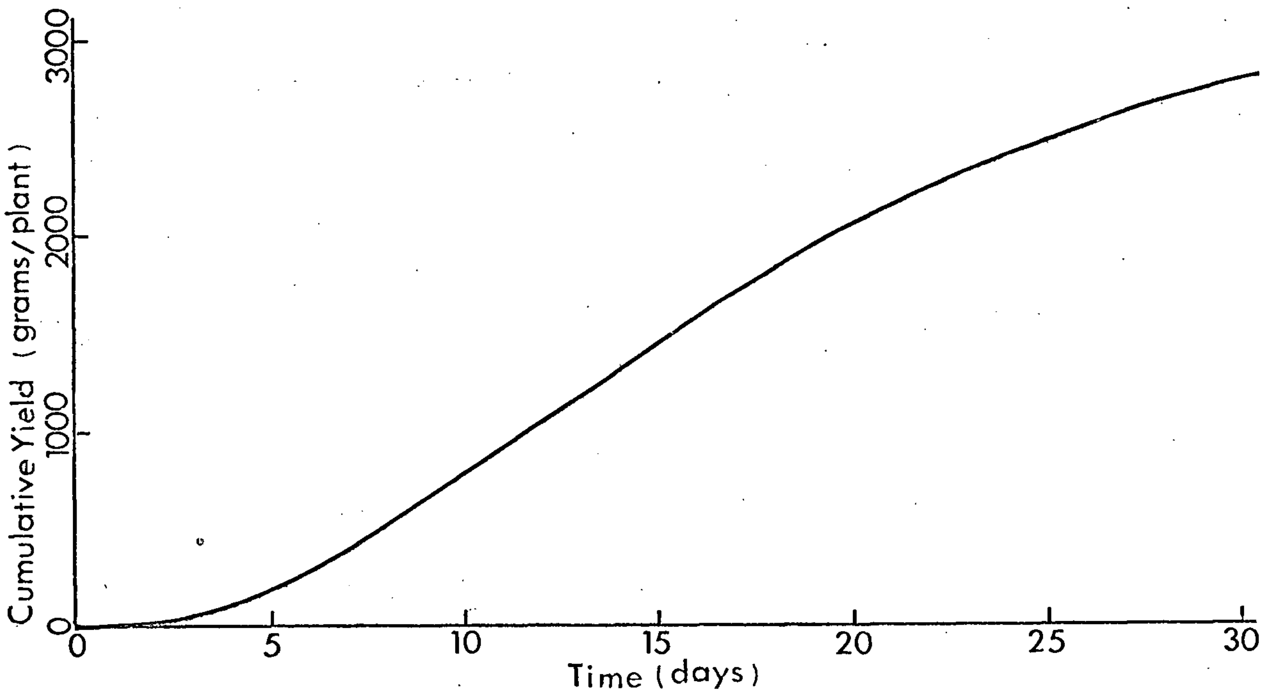

Figure 6. Cumulative yield for Willamette raspberries

<u>The Dependence of Fruit Quality on Time of Picking</u>

The quality of raspberries depends upon the stage of maturity at which the fruit is harvested. It has been shown (17) that in order to obtain top quality fruit, suitable for the fresh market, raspberry plants must be harvested at least once every three days. If the harvest interval is more than three days, a portion of the fruit becomes over-mature and is suitable only for processing. If the harvest interval is greater than six days fruit loss occurs due to natural abscission. Since the gross income received from a raspberry acreage during a certain harvest interval depends upon both the yield and the quality of harvested fruit, a timeliness function must be based on both these factors. The effect of picking interval on gross income is large since, at present, number 1 fruit has a selling price of 33 to 35 cents per pound (19) while number 2 fruit has a selling price of only 19 to 22 cents per pound.

The Timeliness Function

In determining a timeliness function for raspberry harvesting, it was assumed that if the picking interval were three days, only number 1 fruit would be obtained. If the picking interval were more than three days, it was assumed that the fruit yield obtained in the first three days of the picking interval would be number 1 fruit while the fruit yield obtained from the portion of the interval greater than three days would be number 2 fruit. In making this assumption, it was assumed that the processor has the capability of mechanically sorting fruit according to quality (17).

On this basis, using equation [17], the gross income of a specific harvest operation becomes

$$Yi = \left[\int_{t_1}^{t_{1+3}} (Y)\ (x_1) + \int_{t_{1+3}}^{t_2} (Y)\ (x_2) \right] \frac{1742}{454} \qquad [18]$$

where Yi = gross income for a specific harvest interval, dollars per acre

t_1 = date of last picking

t_2 = date of present picking

x_1 = price per lb. of number 1 fruit

x_2 = price per lb. of number 2 fruit

and $3 \leq (t_2 - t_1) \leq 6$

(The factor $(\frac{1742}{454})$ converts grams per plant to pounds per acre).

Figure 7 shows the cumulative gross income obtained from equation [18] for four different picking intervals using $x_1 = 34$ and $x_2 = 22$. The computer program used in determining figure 7 is shown in Appendix A.

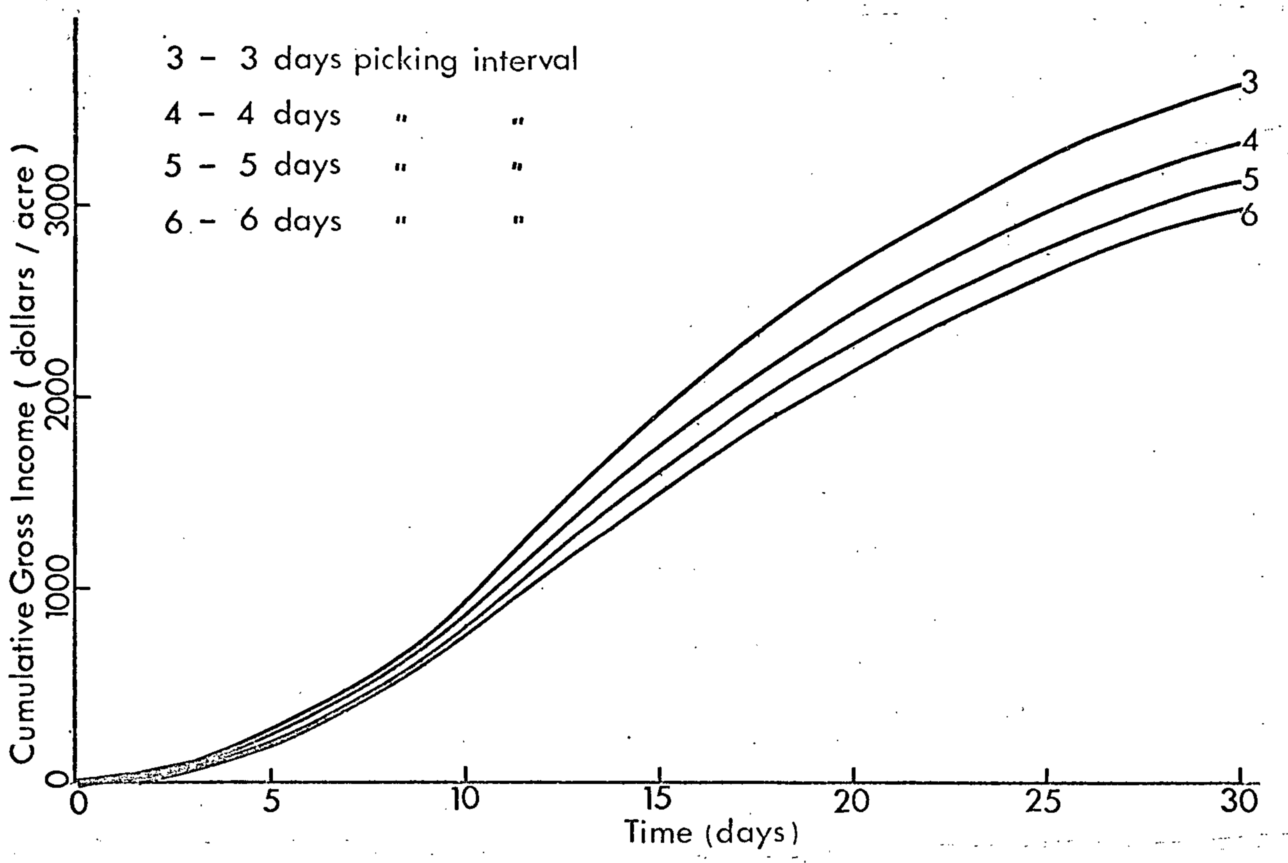

Figure 7. The effect of picking interval on the gross income from raspberries.

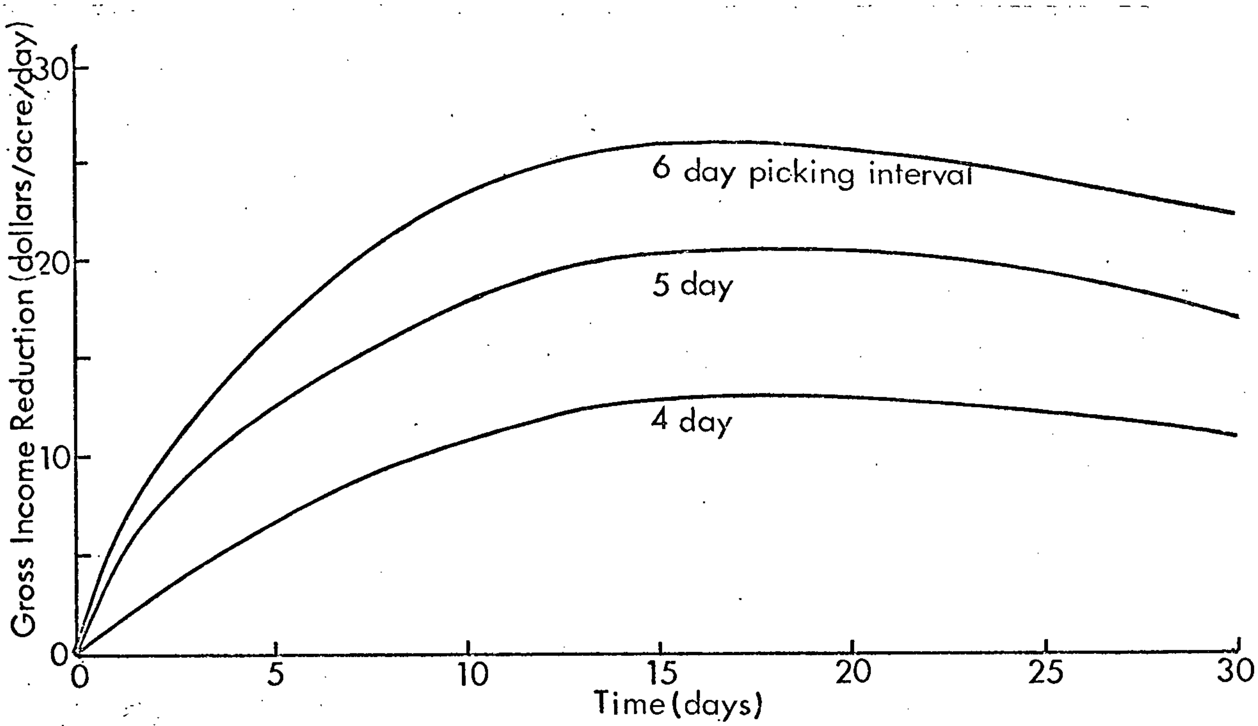

Figure 8. Gross income reduction due to delayed picking intervals.

As a further step in determining the timeliness function, the reduction in gross income due to the length of the picking interval was obtained by subtracting the ordinates of the 4-day, 5-day and 6-day gross income curves (Figure 7) from the ordinates of the 3-day curve and dividing each result by the harvest date. These data were then fitted using the method of least squares and a stepwise regression analysis procedure. The selected level of significance for inclusion or exclusion of an independent variable was 0.01. The resulting regression equation representing gross income reduction per day for a specific harvest date were:

$$Y_4 = 0.20 + 1.65\ T - 0.66 \times 10^{-1}\ T^2 + 0.76 \times 10^{-2}\ T^3 \qquad [19]$$

$$R^2 = 0.95$$

$$N = 33$$

$Sy = 0.72$

(for the interval $0 \leq T \leq 33$)

$$Y_5 = 4.06 + 1.95\ T - 0.58 \times 10^{-1}\ T^2 + 0.98 \times 10^{-8}\ T^6 \qquad [20]$$

$R^2 = 0.83$

$N = 33$

$Sy = 1.89$

(for the interval $0 \leq T \leq 33$)

$$Y_6 = 3.97 + 3.24\ T - 0.15\ T^2 + 0.21 \times 10^{-2}\ T^3 \qquad [21]$$

$R^2 = 0.87$

$N = 33$

$Sy = 1.99$

(for the interval $0 \leq T \leq 33$)

where Y_4 = the gross income reduction in dollars per acre per day for a four day picking interval as opposed to a three day interval

Y_5 = the gross income reduction in dollars per acre per day for a five day picking interval as opposed to a three day interval

Y_6 = the gross income reduction in dollars per acre per day for a six day picking interval as opposed to a three day interval

T = harvest date with July 1 considered as the first day.

As a final step in determining a timeliness function, the harvest time and picking interval were used as independent variables with gross income reduction as the dependent variable and the above data were analyzed using a stepwise multiple regression analysis procedure. The final expression for gross income reduction as a function of harvest time and picking interval was

$$Y_r = -1.47 + 0.11\,T - 0.49 \times 10^{-2}\,T^2 + 0.66 \times 10^{-4}\,T^3 + 0.32\,Z - 0.42 \times 10^{-5}\,Z^6 \qquad [22]$$

$R^2 = 0.97$

$N = 93$

$Sy = 0.05$

(for the interval $0 \leq T \leq 30$

$3 \leq Z \leq 6$)

where Y_r = gross income reduction, dollars per acre per hour

T = harvest date with July 1 considered as the first day

Z = picking interval, days.

$$Y_d = \left[-35.19\,T + 1.31\,T^2 - 0.04\,T^3 + 0.40 \times 10^{-3}\,T^4 + 7.79\,T\,(Z) - 0.10 \times 10^{-3}\,T\,(Z^6)\right]_{t_1}^{t_2} \qquad [23]$$

where Y_d = cumulative income reduction, dollars per acre

T = harvest time

Z = picking interval

t_1 = date of last picking

t_2 = date of present picking

Equation [23] is a timeliness function for raspberry harvesting. The reduction in income due to extended picking intervals (intervals greater than three days) at any time during the harvest season, may be approximated with this equation.

The Effect of Picking Efficiency on Gross Income

The ultimate goal in design of a harvesting machine is achieving a design with the maximum possible picking efficiency. It has however been shown, that for Willamette raspberries, due to a high ratio of fruit retention force to fruit stem strength, high picking efficiency may not be feasible. In mechanical harvesting trials (17), stem failure and green fruit removal occurred at picking efficiencies above fifty percent. This removal of green fruit would reduce yield in subsequent harvests, resulting in reduced income.

In tests using a mechanical harvester (17) no green fruit was removed when only fifty percent of the mature fruit was removed but ten percent of the harvested fruit sample was composed of green fruit when fruit removal efficiency was eighty percent. In order to estimate yield reduction due to green fruit removal, it was assumed that the relationship between green fruit removal and picking efficiency was linear. Considering a linear relationship and using the results reported in reference (17), green fruit removal is

$$L_s = (-16.7 + 33.3\ X_e)/100 \qquad [24]$$

(for the range $0.5 \leq X_e \leq 1.0$)

where L_s = the percentage of green fruit in a sample of mechanically harvested fruit

X_e = picking efficiency of the mechanical harvester, decimal quantity of the mature fruit on the plant at time of harvest.

In order to estimate the effect of fruit removal efficiency on gross income, for various lengths of picking intervals, equations [17] and [24] were combined in the following form

$$
\begin{aligned}
J = {} & (X_e)(x_1)(R_1)[(Y_A - Y_B) - (X_e)(L_s)(Y_B - Y_C)] \\
& + (X_e)(x_2)(R_2)[(Y_A - Y_B) - (X_e)(L_s)(Y_B - Y_C)] \\
& + (1 - X_e)(x_2)[(Y_B - Y_C) - (X_e)(L_s)(Y_C - Y_D)]
\end{aligned} \tag{25}
$$

where

J = gross income, dollars per acre

X_e = picking efficiency of the mechanical harvester, percent of yield

x_1 = price per lb. of number 1 fruit, dollars

x_2 = price per lb. of number 2 fruit, dollars

R_1 = fraction of grade number 1 fruit (i.e. when picking interval = 5, R_1 = 3/5)

R_2 = fraction of grade number 2 fruit (i.e. when picking interval = 5, R_2 = 2/5)

L_s = percent of green fruit in a sample of machine harvested fruit (from equation [24])

Y_A = cumulative fruit yield at present day of picking, pounds per acre (from equation [17])

Y_B = cumulative fruit yield at previous closest picking date, pounds per acre (from equation [17])

Y_C = fruit yield at previous secpnd closest picking date, pounds per acre (from equation [17])

Y_D = fruit yield at previous third closest picking date, pounds per acre (from equation [17]).

Several assumptions were made in formulating equation [25]. It was assumed that for a three day interval between picking, only number 1 fruit would be removed. For a picking interval of n days, for $3 \leq n \leq 6$, it was assumed that the fraction of number one fruit would be 3/n and the fraction of number 2 fruit would be (n-3)/n. This assumption appears to be reasonably valid on the basis of observations during the 1970 harvest. It was further assumed that for a fruit removal efficiency of x percent (1 - x) percent of the fruit would remain on the plants and would all be removed as number 2 fruit on the following harvest date. The percent of green fruit loss at one harvest date was subtracted from the gross yield on the following harvest date to account for the effect of green fruit removed on subsequent yields.

Results of this analysis, based on x_1 = 34 cents per pound and x_2 = 22 cents per pound, are presented in Table XII. The computer program used for calculating the values is given in Appendix B.

The effect of fruit removal efficiency on gross annual income is illustrated in Figure 9. It is seen that when fruit removal efficiency is one hundred percent of the mature fruit on the plants, gross income is not maximum due to the fact that the removal of immature fruit results in an overall yield reduction. Curves for 3-day, 4-day, 5-day and 6-day picking intervals all are maximum at approximately 80 percent picking efficiency. This indicates that for

Willamette raspberries, the fruit removal efficiency of a mechanical harvester should be approximately 80 percent in order to maximize gross income.

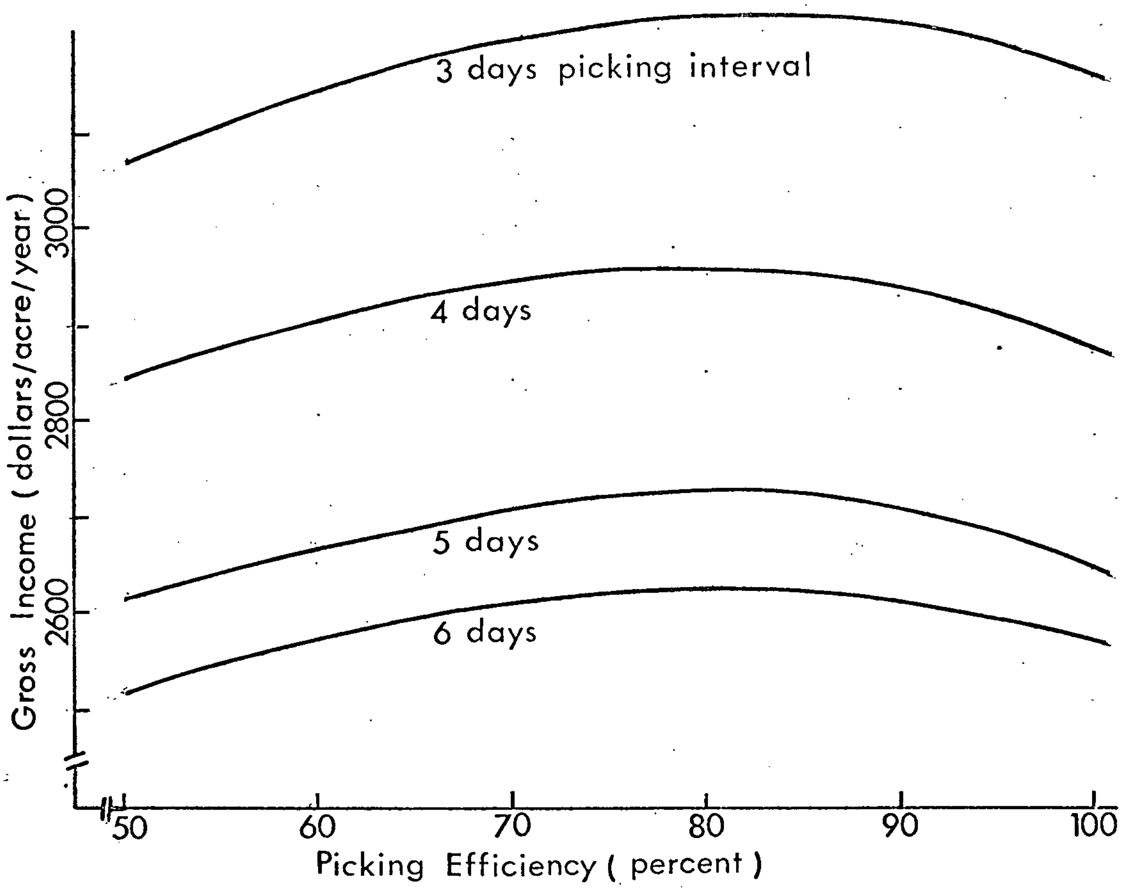

Figure 9. The effect of fruit removal efficiency on gross annual income for various picking intervals.

TABLE XII. THE EFFECT OF PICKING INTERVAL AND PICKING EFFICIENCY ON INCOME FROM RASPBERRIES.

Date		Picking Interval	Cumulative Income (dollars/acre)					
			Picking Efficiency (percent)					
			50	60	70	80	90	100
July	3	3 days	41.60	49.93	58.25	66.57	74.89	83.21
"	6	"	216.64	248.20	279.04	309.00	337.90	365.58
"	9	"	539.50	593.32	643.96	690.77	733.10	770.31
"	12	"	954.70	1025.82	1090.22	1146.72	1194.14	1231.31
"	15	"	1399.79	1481.70	1552.83	1611.52	1656.11	1684.93
"	18	"	1280.77	1907.33	1979.10	2034.03	2070.07	2085.16
"	21	"	2184.43	2271.55	2340.32	2388.43	2413.55	2413.33
"	24	"	2483.50	2569.93	2635.11	2676.53	2691.67	2678.01
"	27	"	2730.36	2816.98	2879.99	2916.74	2924.59	2900.89
"	30	"	2935.48	3022.05	3083.02	3115.64	3117.13	3084.71
Aug.	2	"	3066.09	3144.79	3196.27	3217.67	3206.09	3158.68
July	4	4 days	73.13	87.75	102.38	117.00	131.63	146.25
"	8	"	356.70	405.77	453.37	499.41	543.60	585.65
"	12	"	841.05	914.54	982.95	1045.28	1100.51	1147.63
"	16	"	1393.55	1476.52	1549.54	1610.98	1659.20	1692.59
"	20	"	1899.02	1979.19	2044.68	2093.46	2123.51	2132.79
"	24	"	2303.50	2376.43	2430.84	2464.55	2475.35	2461.04
"	28	"	2617.21	2685.18	2731.78	2754.76	2751.85	2720.81
Aug.	1	"	2845.79	2906.36	2943.30	2954.30	2937.03	2889.16
July	5	5 days	111.58	133.90	156.22	178.53	200.85	223.17
"	10	"	516.54	583.54	648.61	711.30	771.18	827.78
"	15	"	1147.31	1234.73	1315.00	1386.72	1448.50	1498.96
"	20	"	1772.44	1854.45	1923.54	1977.73	2015.03	2033.47
"	25	"	2262.18	2329.44	2379.19	2409.30	2417.65	2402.08
"	30	"	2619.07	2675.75	2711.78	2725.07	2713.52	2675.04

TABLE XII (Continued)

Date	Picking Interval	Cumulative Income (dollars/acre)					
		Picking Efficiency (percent)					
		50	60	70	80	90	100
July 6	6 days	156.24	187.49	218.74	249.98	281.23	312.48
" 12	"	686.91	771.45	853.27	931.77	1066.31	1076.28
" 18	"	1433.01	1526.82	1611.35	1684.84	1745.53	1791.64
" 24	"	2073.26	2146.04	2203.44	2243.30	2263.42	2261.62
" 30	"	2522.95	2576.85	2611.43	2624.61	2614.33	2578.51

Cost Analysis of Hand Harvesting of Raspberries

Cost of Hand Labor

The price paid to hand pickers in 1970 varied from 10 to 12 cents per pound of harvested fruit (19). As was previously discussed, the price paid to picking labor has increased by more than 100 percent in the last three years. An additional cost due to fruit loss must also be charged against hand picking as it has been shown (17) that the overall fruit removal efficiency for hand pickers is approximately 80 percent. In order to obtain fruit of the optimum maturity, each field must be picked at least once every three days. If the picking interval is greater than three days, income will be lowered due to reduced fruit quality. Appropriate corrections for income reduction over the harvest season, due to varying lengths between pickings, may be made by applying equation [23].

In the following cost analysis of hand picking, it was assumed that fruit removal efficiency was 80 percent; the price paid to hand pickers was 12 cents per pound; fields were picked once every three days, resulting in only number 1 fruit; the selling price of number 1 fruit was 34 cents per pound and the potential yield of a raspberry field was as given by equation [17].

Additional Costs Incurred in Hand Harvesting

As an incentive in maintaining hand picking labor, growers may provide daily transportation to the farm from the nearest town. Used buses are often purchased for this purpose. For lower mainland growers, daily one-way transportation distance could be up to 50 miles. In addition, a second vehicle, usually a pickup truck, is required to collect fruit in the field and transport it to a central location.

Assuming that the combined purchase price of both these vehicles is 7000 dollars and assuming a fixed cost percentage (Table II) of 15 percent, the annual fixed cost is 1050 dollars. Assuming a 30 day harvest season and an average farm size of 15 acres, the fixed cost is 2.34 dollars per acre per day.

The variable costs associated with these two vehicles may be determined as follows: Assuming that the bus is used 100 miles each day and that the truck is used 50 miles each day, that each averages 10 miles per gallon of fuel and that fuel costs 40 cents per gallon, daily fuel cost is 6 dollars. Assuming that a driver is employed 8 hours per day and is paid 2 dollars per hour, daily labor cost is 16 dollars. Assuming an hourly repair and maintenance cost of 0.012 percent of purchase price (Table V), daily repair and maintenance cost is 6.72 dollars. Finally, assuming an oil consumption of 0.016 gallons per hour (Table VI) and a cost of 2.50 dollars per gallon, daily oil cost is 0.32 dollars. Adding these daily costs and considering a farm size of 15 acres, the variable cost is 1.94 dollars per acre per day.

Adding fixed and variable costs, the total operating cost of these vehicles is 4.28 dollars per acre per day.

Income, Cost and Profit

Using equation [17] for cumulative yield and applying the previously mentioned assumptions, the gross income for a specific harvest is

$$I_{a \to b} = (Y_b - Y_a)\ (0.34)(0.80)(1742/454) \qquad [26]$$

where $I_{a \to b}$ = gross income, dollars per acre, for a specific three day period

Y_b = equation [17] evaluated at date b

Y_a = equation [17] evaluated at date a

and $(b-a)$ = 3.

The cost associated with this harvesting is

$$C_{a \to b} = (Y_b - Y_a)(0.12)(0.80)(1742/454) + (3)(4.28) \qquad [27]$$

where $C_{a \to b}$ = hand picking cost, dollars per acre, for a specific three day period

and all other symbols are as defined in equation [26].

The gross profit for a specific three day period from date a to date b is determined by subtracting $C_{a \to b}$ from $I_{a \to b}$. The computer program, used in evaluating the cost of hand picking over the whole harvest season, is given in Appendix C. Table XIII and Figure 10 give the results of this analysis for a 30 day harvest season with specific harvests spaced at 3 days.

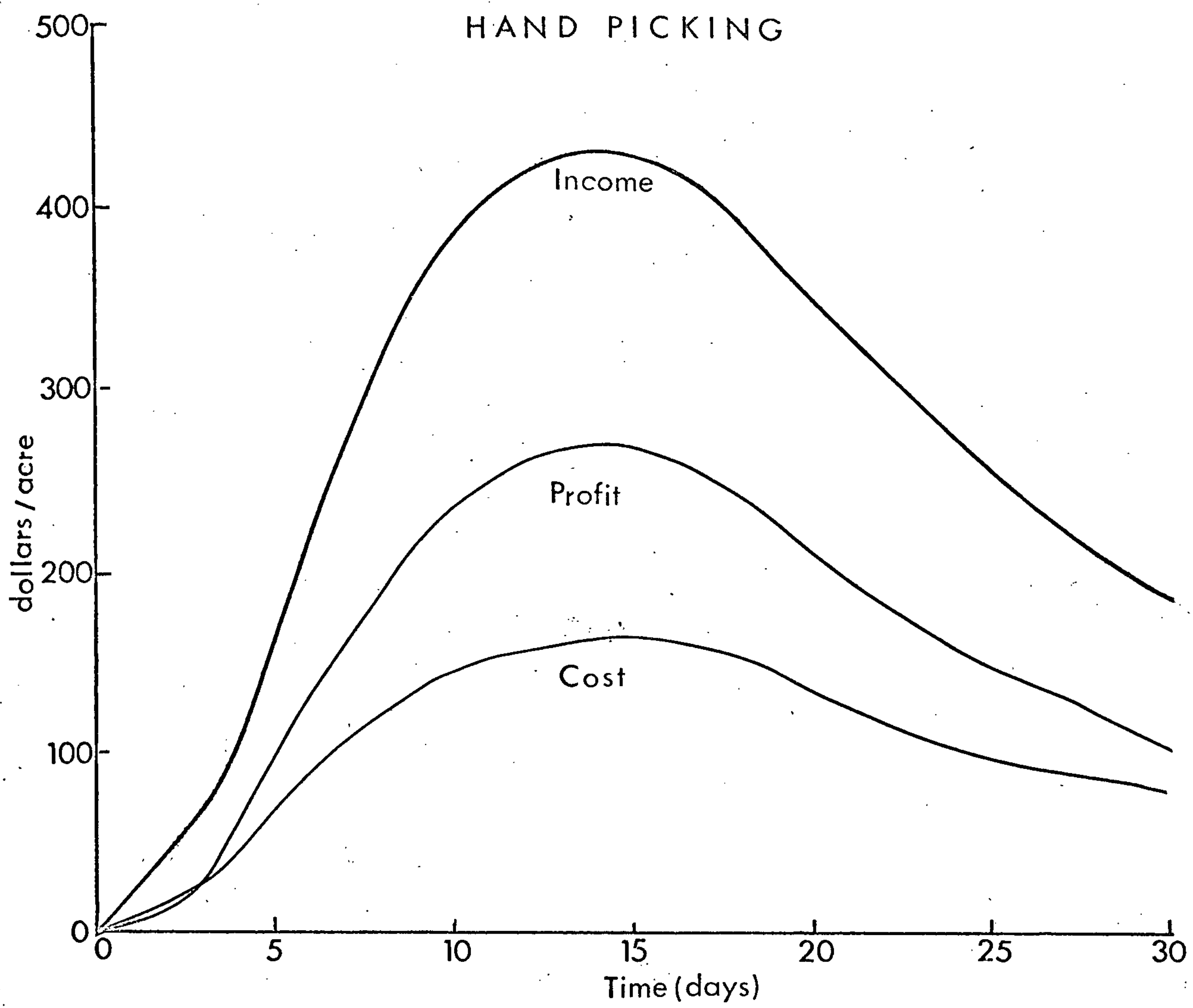

Figure 10. Cost Analysis of Hand Harvesting of Raspberries

TABLE XIII. COMPARISON OF HAND HARVESTING COST AND INCOME FROM A RASPBERRY PLANTATION

Harvest Date	Harvesting Cost (dollars/acre)	Income (dollars/acre)	Profit* (dollars/acre)
July 3	36.33	66.57	30.23
July 6	96.48	236.98	140.50
July 9	141.04	363.24	222.20
July 12	164.35	429.28	264.93
July 15	166.15	434.37	268.22
July 18	151.37	392.51	241.14
July 21	128.57	327.89	199.33
July 24	106.84	266.33	159.49
July 27	91.42	222.65	131.23
July 30	77.83	184.12	106.30
TOTAL:	1,160.38	2,923.94	1,763.57

* The values in this column are the differences between income and hand harvesting costs. They do not include the other costs involved in maintaining a raspberry plantation. Since the other costs are assumed to be constant for both mechanical harvesting methods and hand harvesting methods, these values may be used comparing harvesting methods. Similar values for mechanical harvesting are presented later.

Cost Analysis of Mechanical Raspberry Harvesting

Since mechanical harvesters are still in an experimental stage, the purchase price and capacity of such machines is not known. In order to compare the costs of mechanical harvesting and hand harvesting, ranges of purchase prices and capacities were investigated in an attempt to determine a suitable machine and machine capacity.

Fixed Costs

Using a fixed cost percentage (Table II) of 16 percent, the annual fixed cost is 0.16P, where P is the machine purchase price. Considering a 30 day harvest season, the daily fixed cost is 0.00533P dollars per day.

Operating Costs

Hourly operating costs may be estimated as follows:

Repair and maintenance (Table V)	=	.00025P	dollars/hour
Labor (assume 2 men at 2.00 dollars/hour)	=	4.00	"
Fuel (assume 3 gallons/hour at 30 cents per gallon)	=	0.90	"
Oil (assume 0.01 gallons/hour (Table VII) at 2.00 dollars/gallon))	=	0.02	"

In analyzing the cost of hand harvesting, it was assumed that a truck was necessary to transport fruit picked by hand pickers to a central location. A similar charge is not applied against the mechanical harvester, since it is assumed that it has sufficient storage capacity to eliminate this handling problem. Loss of operating time due to unloading fruit will be included in the field efficiency factor for the harvester.

Summing the above costs, the total hourly operating cost of a mechanical harvester is

$$C_h = 0.00533P/H_r + 0.00025P + 4.92 \qquad [28]$$

where C_h = machine operating cost, dollars per hour

P = machine purchase price, dollars

H_r = daily operating time, hours.

Machine Capacity

Since raspberry rows are spaced at 10 feet, the output for a single row machine is 1.21s acres per hour, where s is the forward speed in miles per hour. Assuming 75 percent field efficiency (Table IX), the output of a machine is

$$D_o = 0.907\ s \qquad [29]$$

where D_o = machine output, acres per hour

s = forward speed, miles per hour.

Similarly, the seasonal capacity of a mechanical harvester is

$$C_y = 0.907\ (s)\ (H_r)\ (Z) \qquad [30]$$

where C_y = seasonal capacity of a machine, acres

s = forward speed, miles per hour

H_r = operating time, hours per day

Z = picking interval between subsequent harvests, days.

Combining equations [28] and [29], the cost of mechanical picking, for each specific harvest, is

$$C_a = (0.00533P/H_r + 0.00025P + 4.92)/0.907s \qquad [31]$$

where C_a = cost for a specific harvest, dollars per acre and all other symbols are as previously defined.

Method of Calculation

A computer program (Appendix C) was developed to calculate the cost of mechanical harvesting gross income and the resulting gross profit, in order that mechanical harvesting could be compared to hand harvesting. Machine purchase price was varied from 1000 to 15,000 dollars while machine speed was varied from 0.5 to 3 miles per hour to determine the effect of machine cost and machine capacity on operating costs.

Fruit removal efficiency was assumed to be 80 percent, while picking interval length was varied from 3 to 6 days and the daily length of operation was varied from 8 to 10 hours.

Gross income for a specific harvest date was determined using equation [26] with the modification that $3 \leq (b - a) \leq 6$, to account for varying lengths of picking intervals.

Operating cost for each picking was determined using equation [31]. The length of picking interval does not affect the cost for each specific harvest but does affect the cumulative cost for the whole harvest season as with a larger picking interval, a machine will be used a fewer number of times on each acre.

For picking intervals of length greater than three days the timeliness factor (equation [23]) was used to determine the cost of reduced fruit quality. This equation was evaluated between the same limits as used for the gross income equation in order that timeliness costs applied to the same interval.

$$(Y_d)_{a \to b} = (Y_d)_b - (Y_d)_a \qquad [32]$$

where $(Y_d)_{a \to b}$ = income reduction, dollars per acre for a specific harvest period

$(Y_d)_b$ = equation [23] evaluated at date b

$(Y_d)_a$ = equation [23] evaluated at date a

and $3 \leq (b - a) \leq 6$.

Gross profit for a specific harvest was determined by subtracting the operating cost and timeliness cost for that harvest from the gross income. Cumulative gross profit for the whole harvest season was determined by summing the profits for each specific harvest.

Machine Cost and Gross Profit Variation over the Harvest Season

Figures 11, 12, 13 and 14 show the variations in gross income, operating cost, timeliness cost and gross profit over the harvest season for 3, 4, 5 and 6 day harvest intervals respectively. These figures are based on a machine purchase price of 5,000 dollars, a machine speed of 1.5 miles per hour and an 8 hour working day. Since the gross profit curves are based on only operating costs, and do not consider the costs of establishing and maintaining a raspberry plantation, these profit curves may be directly compared to the gross profit curves for hand picking (Figure 10). Comparison to Figure 10

TABLE XIV. COST AND PROFIT (DOLLARS PER ACRE PER YEAR) OF RASPBERRY MACHINE PICKING PER ACRE 8 HOURS PER DAY.

Speed	Acre per	Capacity	PURCHASE PRICE (dollars)							
			1,000		5,000		9,000		13,000	
mph.	hour	(acres)	Cost	Profit	Cost	Profit	Cost	Profit	Cost	Profit
3 DAY PICKING INTERVAL										
0.5	0.45	10.88	128.69	2795.25	209.51	2714.44	290.32	2633.62	371.14	2552.80
1.5	1.36	32.65	42.90	2881.05	69.84	2854.11	96.78	2827.17	123.71	2800.23
3.0	2.72	65.30	21.45	2902.50	34.92	2889.03	48.39	2875.56	61.86	2862.09
4 DAY PICKING INTERVAL										
0.5	0.45	10.88	96.52	2517.10	157.13	2456.49	217.74	2395.88	278.36	2335.27
1.5	1.36	32.65	32.17	2581.45	52.38	2561.25	108.87	2541.04	92.79	2520.84
3.0	2.72	65.30	16.09	2597.54	26.19	2587.44	26.29	2577.33	46.39	2567.23
5 DAY PICKING INTERVAL										
0.5	0.45	10.88	77.22	2337.72	125.71	2289.23	174.19	2240.74	222.68	2192.25
1.5	1.36	32.65	25.74	2389.20	41.90	2373.03	58.07	2356.87	74.23	2340.71
3.0	2.72	65.30	12.87	2402.07	20.95	2393.98	29.03	2385.90	37.11	2377.82
6 DAY PICKING INTERVAL										
0.5	0.45	10.88	64.35	2211.27	104.75	2170.86	145.16	2130.45	185.57	2090.04
1.5	1.36	32.65	21.45	2254.17	34.92	2240.70	48.39	2227.23	61.86	2213.76
3.0	2.72	65.30	10.72	2264.89	17.46	2258.16	24.19	2251.42	30.93	2244.69

TABLE XV. COST AND PROFIT (DOLLARS PER ACRE PER YEAR) OF RASPBERRY MACHINE PICKING PER ACRE 10 HOURS PER DAY

Speed mph.	Acre per hour	Capacity (acres)	PURCHASE PRICE (dollars) 1,000 Cost	1,000 Profit	5,000 Cost	5,000 Profit	9,000 Cost	9,000 Profit	13,000 Cost	13,000 Profit
0.5	0.45	13.60	125.76	2798.19	194.82	2729.13	263.88	2660.07	332.94	2591.00
1.5	1.36	40.81	41.92	2882.03	64.94	2859.01	87.96	2835.99	110.98	2812.97
3.0	2.72	81.63	20.96	2902.99	32.47	2891.48	43.98	2879.97	55.49	2868.46
4 DAY PICKING INTERVAL										
0.5	0.45	13.60	94.32	2519.31	146.11	2467.51	197.91	2415.71	249.71	2363.91
1.5	1.36	40.81	31.44	2582.18	48.70	2564.92	65.97	2547.65	83.24	2530.39
3.0	2.72	81.63	15.72	2597.90	24.35	2589.27	32.99	2580.64	41.62	2572.01
5 DAY PICKING INTERVAL										
0.5	0.45	13.60	75.45	2339.48	116.89	2298.04	158.33	2256.61	199.77	2215.17
1.5	1.36	40.81	25.15	2389.79	38.96	2375.97	52.78	2362.16	66.59	2348.35
3.0	2.72	81.63	12.58	2402.36	19.48	2395.45	26.39	2388.55	33.29	2381.64
6 DAY PICKING INTERVAL										
0.5	0.45	13.60	62.88	2212.79	97.41	2178.21	131.94	2143.67	166.47	2109.14
1.5	1.36	40.81	20.96	2254.66	32.47	2243.15	43.98	2231.63	55.49	2220.12
3.0	2.72	81.63	10.48	2265.14	16.23	2259.38	21.99	2253.62	27.75	2247.87

indicates that for 3, 4 and 5 day picking intervals, the profit curves for machine harvesting are higher than for hand harvesting, at all stages of the harvest season. Comparison of Figures 10 and 14 indicate that the gross profit from hand picking and machine picking, for a 6 day picking interval, are similar at the first and last of the harvest season but at the peak of the harvest season, gross profit from hand harvesting is only 80 percent of that from machine harvesting. The above comparisons indicate, that for all the combinations considered, machine harvesting is more profitable than hand harvesting.

Machine Capacity and Purchase Price

In order to determine the effects of machine purchase price and machine speed on harvesting costs and subsequent profits, the total costs and profits for each season were calculated by summing the costs and profits of the individual harvest operations. The results of the complete analysis are tabulated in Appendix D, while results are summarized in Table XIV and Table XV. Results are reported for machine purchase price variations from 1,000 to 15,000 dollars, for machine speed variations from 0.5 to 3 miles per hour, for picking interval variations from 3 to 6 days and for daily operating times of 8 hours (Table XIV) and 10 hours (Table XV).

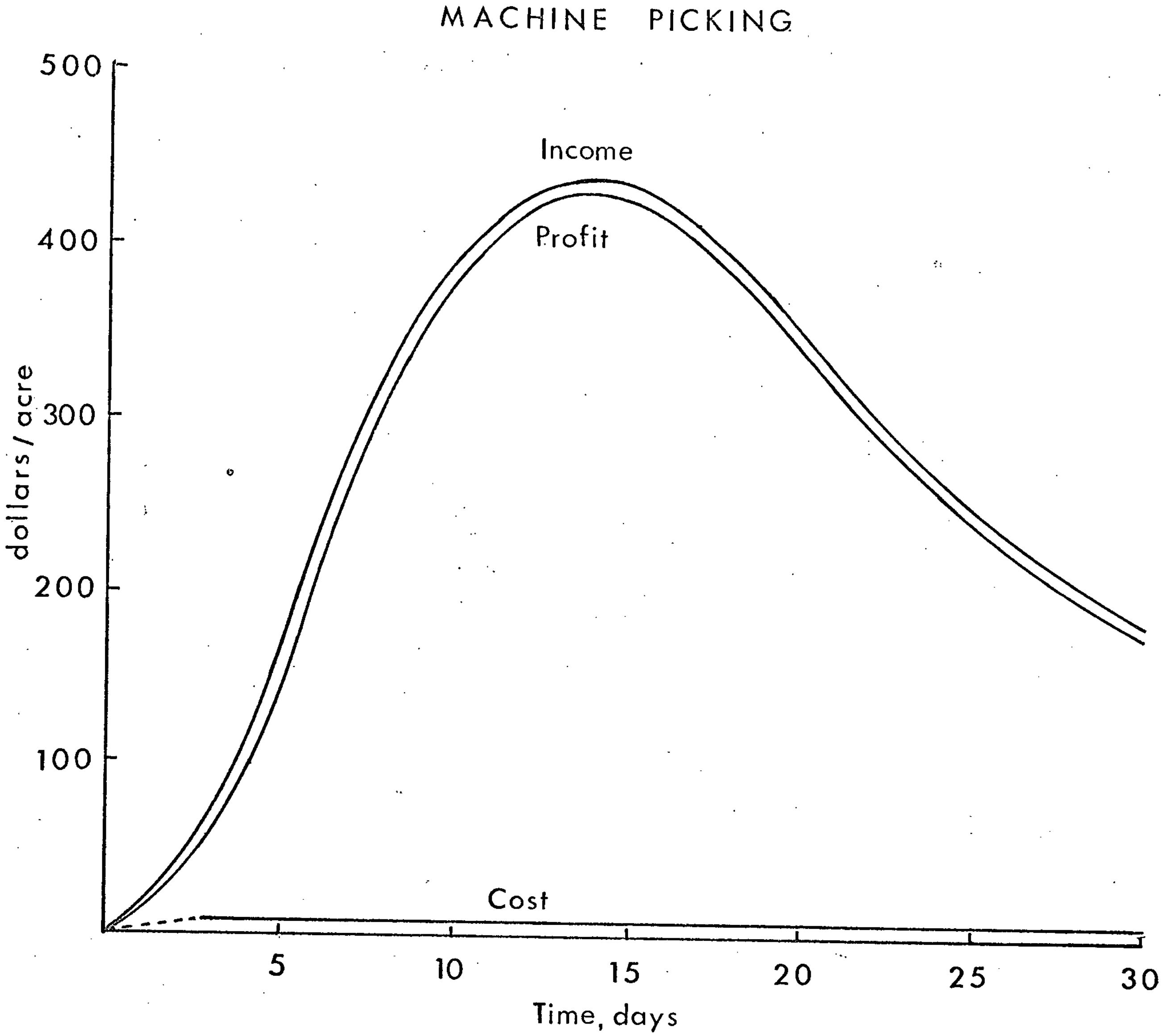

Figure 11. Graph of cost, income, profit and yield reduction of raspberry machine picking operating 8 hours per day purchase price $5,000, speed: 1.5 mph, with 3 day picking interval.

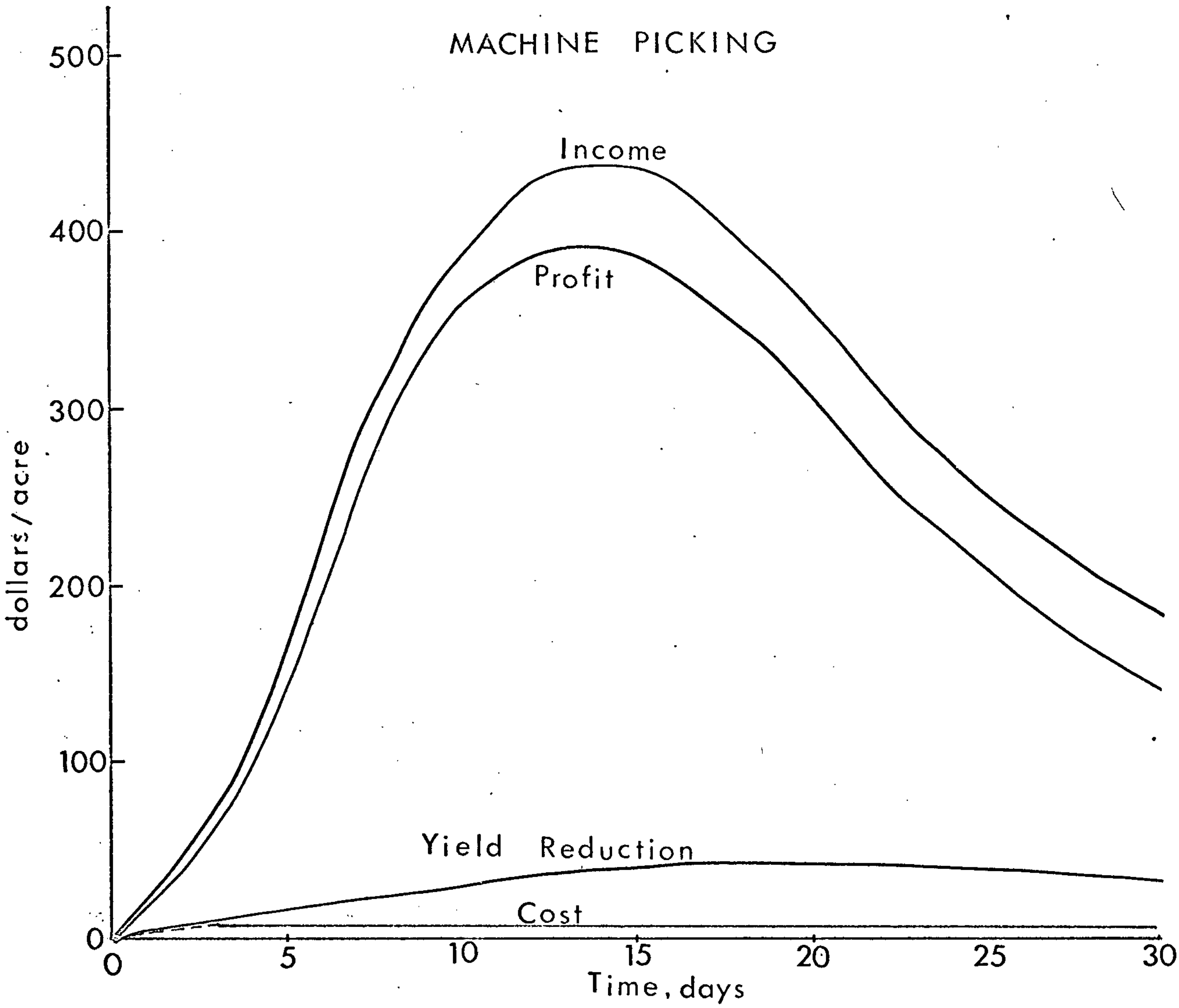

Figure 12. Graph of cost, income, profit and yield reduction of raspberry machine picking operating 8 hours per day purchase price $5,000, speed: 1.5 mph, with 4 day picking interval.

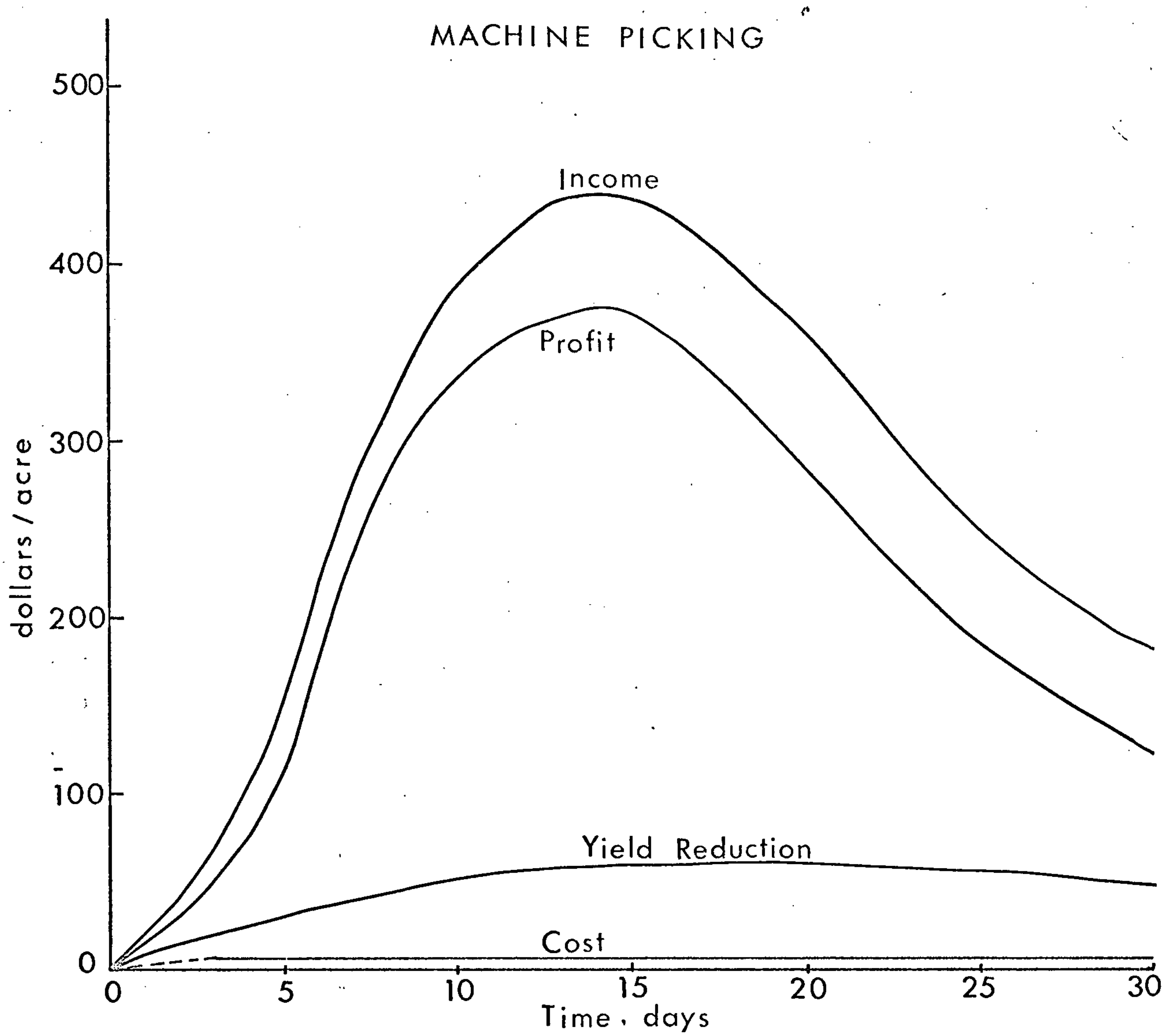

Figure 13. Graph of cost, income, profit and yield reduction of raspberry machine picking operating 8 hours per day purchase price $5,000, speed: 1.5 mph, with 5 day picking interval.

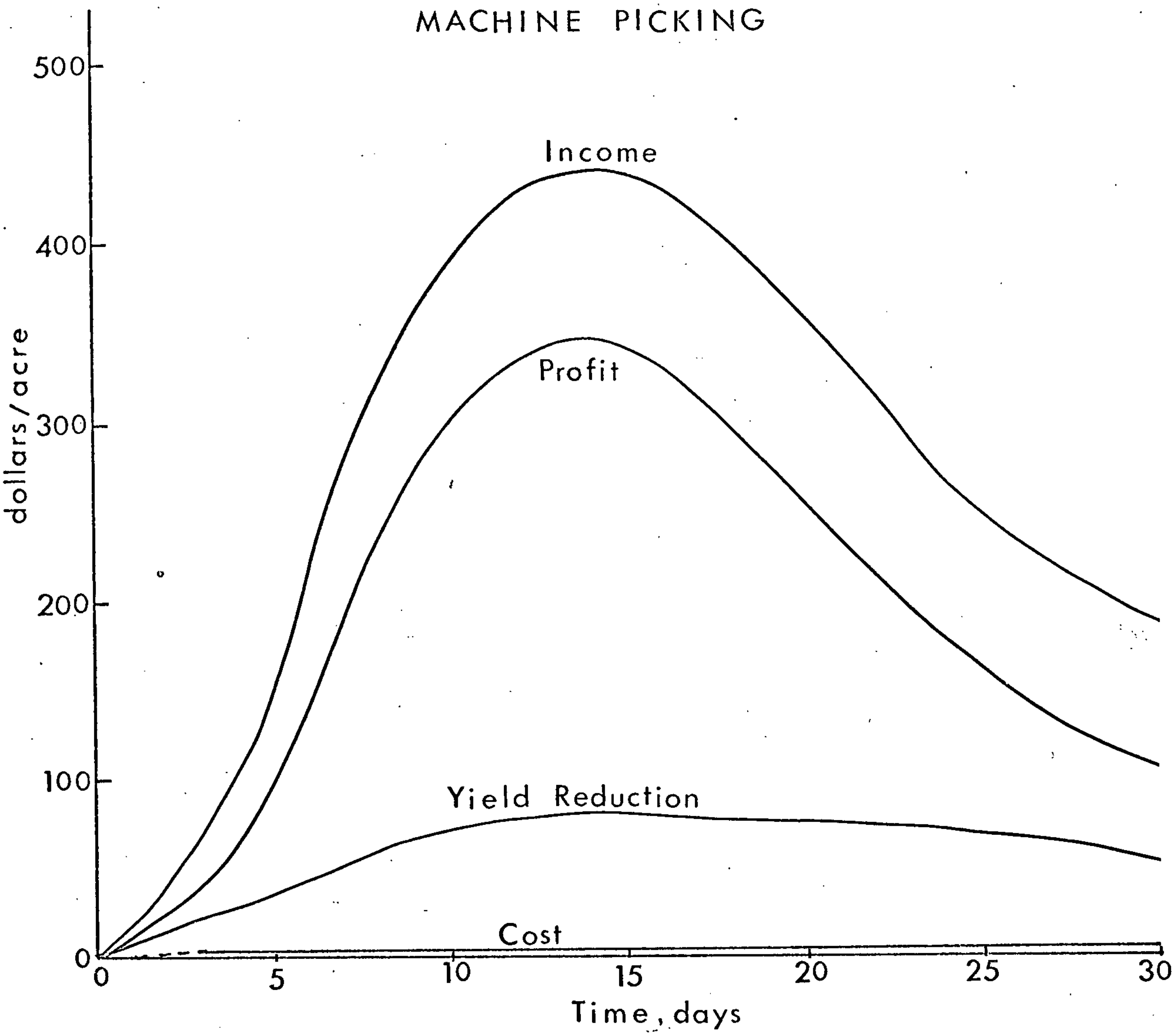

Figure 14. Graph of cost, income, profit and yield reduction of raspberry machine picking operating 8 hours per day purchase price $5,000, speed: 1.5 mph, with 6 day picking interval.

Figure 15 shows the effect of machine purchase price and machine speed on annual profit for a three day picking interval while Figure 16 shows the effect of machine purchase price and machine speed on annual profit for a five day picking interval. From the figures it is apparent that gross annual profit is not greatly influenced by machine purchase price, if operating speed is 1.5 miles per hour, or greater. On this basis an optimum machine speed for mechanical raspberry harvesting should be at least 1.5 miles per hour. This indicates that machine capacity will be 1.36 acres per hour and daily output will be 10.9 acres. The annual capacity of such a machine would be 32.7, 43.5, 54.4 and 65.3 acres per year for 3, 4, 5 and 6 day picking intervals respectively.

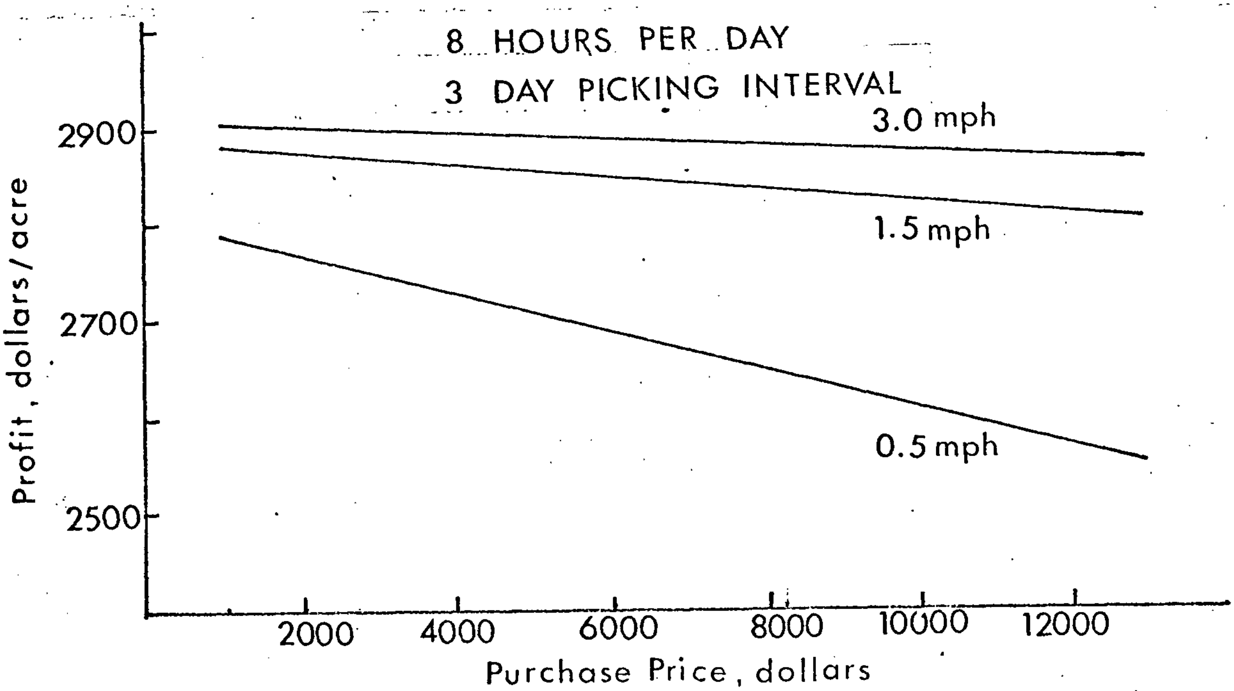

Figure 15. The effect of machine purchase price and machine speed on gross annual profit.

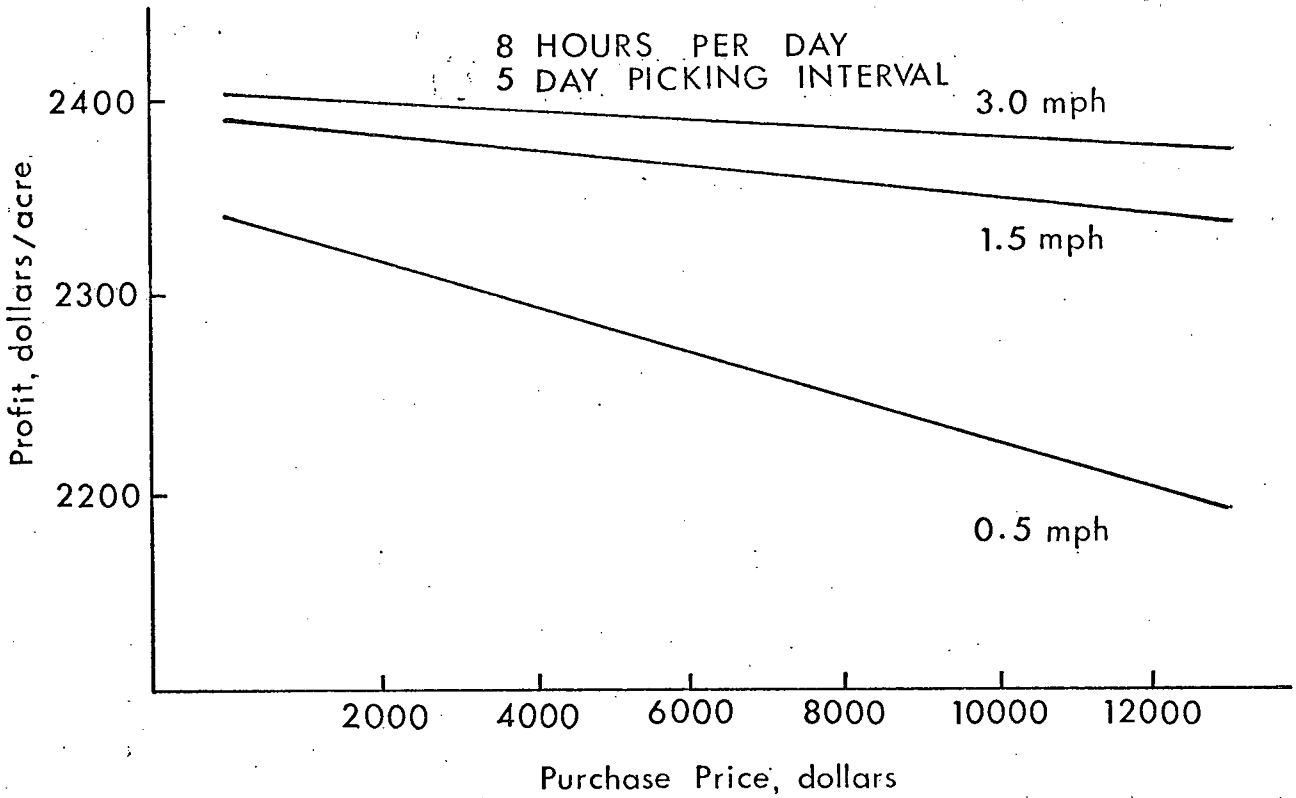

Figure 16. The effect of machine purchase price and machine speed on gross annual profit.

Effect of Picking Interval on Gross Profit

Figures 17, 18 and 19 show the effect of picking interval and machine speed on gross annual profit for machine purchase prices of 5,000, 9,000 and 13,000 dollars respectively. As is seen, in all cases, the effect of machine purchase price is not significant at machine speeds of 1.5 miles per hour, or greater. At this operating speed the relationship between gross annual profit and picking interval is nearly linear and the gross annual profit decreases by approximately 200 dollars per acre each time the picking interval is lengthened by one day. This, of course, is not necessarily applicable if the picking interval is extended beyond 6 days.

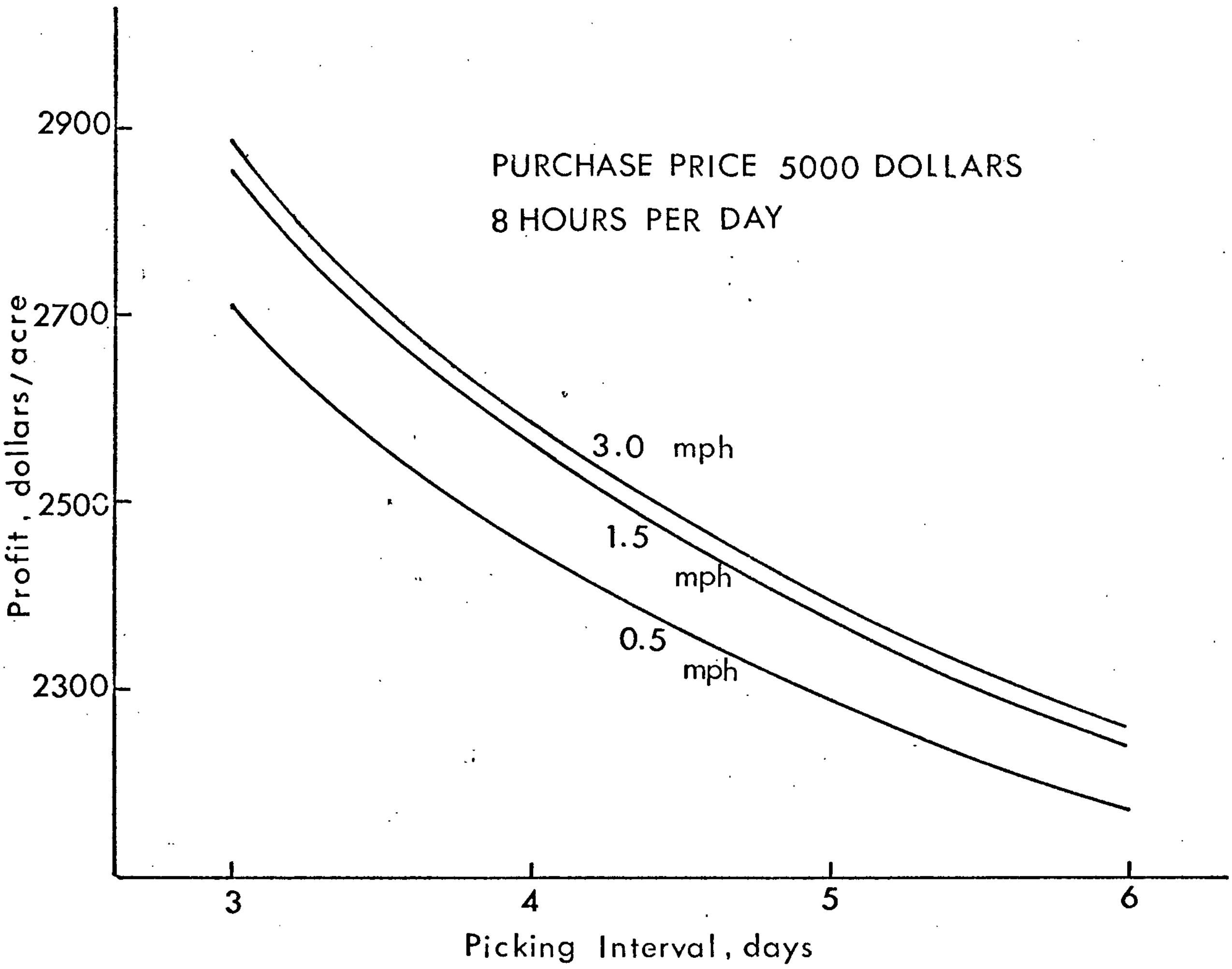

Figure 17. Gross annual profit of raspberry machine picking versus picking interval for different speeds of operation.

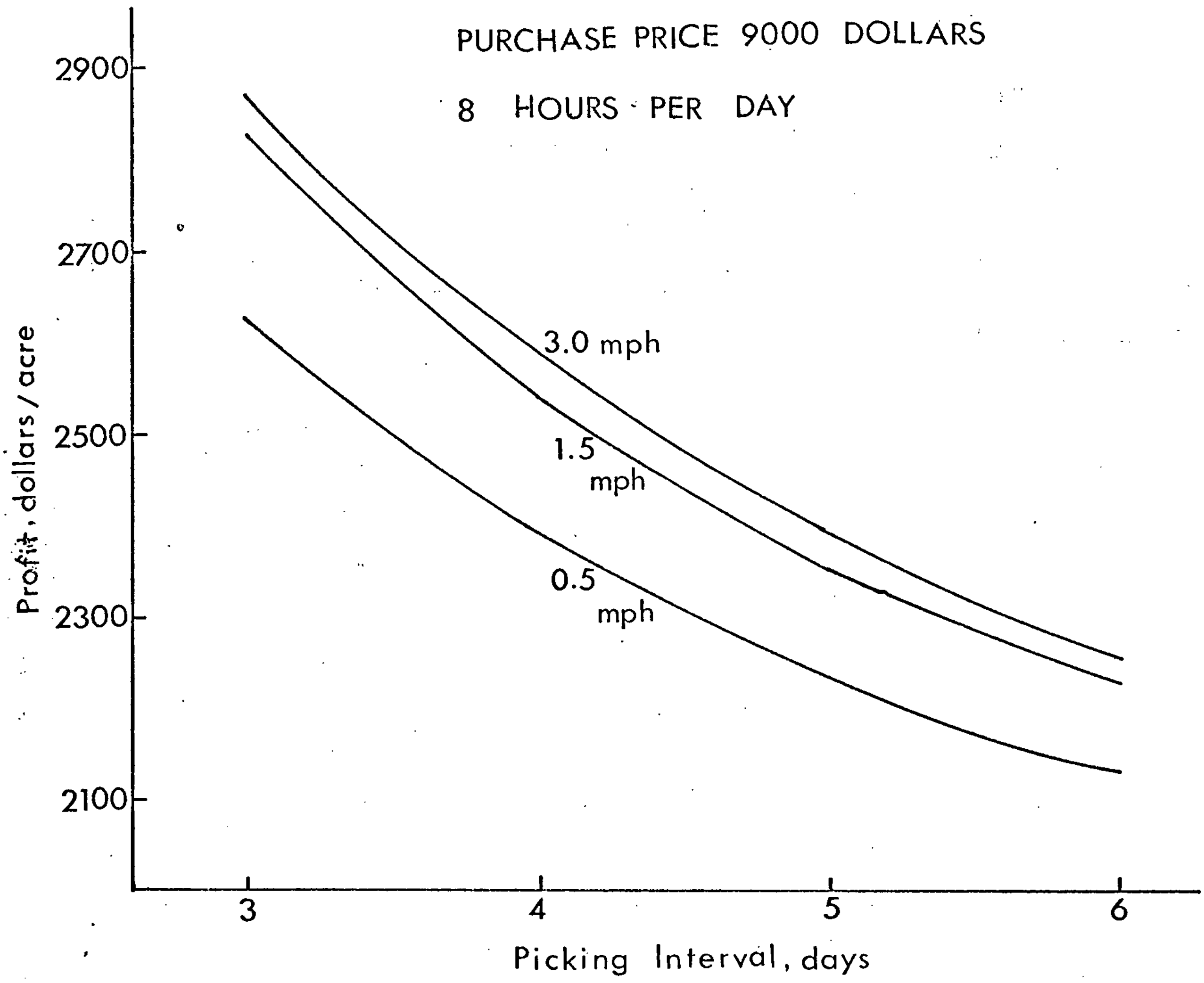

Figure 18. Gross annual profit of raspberry machine picking versus picking interval for different speeds of operation.

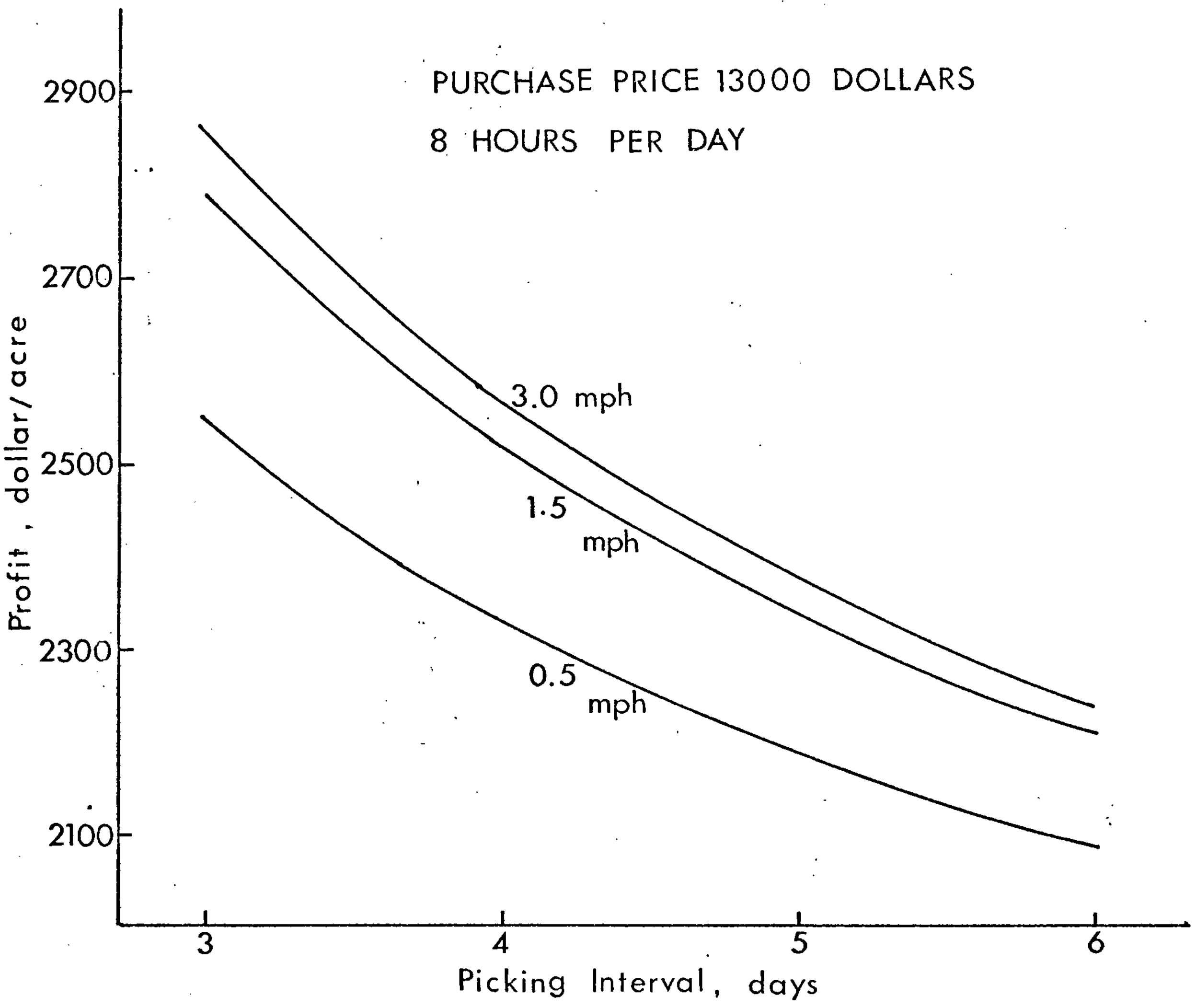

Figure 19. Gross annual profit of raspberry machine picking versus picking interval for different speeds of operation.

Comparison of Hand Picking to Machine Picking

Summing the profit column in Table XIII, the gross annual profit for hand harvesting is 1764 dollars per acre. Similar gross annual profits for mechanical harvesting (Appendix D) varied from maximum of 2903 to a minimum of 2069 dollars per acre. This indicates that any of the combinations of machine purchase price, machine speed and picking interval used in the mechanical harvesting analysis are more profitable than hand picking methods.

Considering a machine purchase price of 5,000 dollars as a reasonable price, and using a forward speed of 1.5 miles per hour, as discussed previously, and an 8 hour working day, the gross annual profit for machine harvesting was 2854, 2561, 2373 and 2241 dollars for 3, 4, 5 and 6 day picking intervals, respectively. On this basis, the annual increased profits due to mechanical harvesting are 1090, 798, 609 and 477 dollars per acre for 3, 4, 5 and 6 day picking intervals, respectively.

SUMMARY AND CONCLUSIONS

Methods for analyzing the costs of agricultural machinery systems and methods for determining optimum sizes of implements and power units were reviewed and summarized. As commonly used methods for determining least cost machinery systems for agricultural enterprises were not directly applicable to fruit growing, procedures were modified.

The mechanization of raspberry harvesting was used as an example for a cost analysis study and the modified procedures were used to determine suitable limits for machine size and capacity and were used to compare present harvesting practices with a proposed mechanical harvesting system. Methods and results may be summarized as follows:

(1) A description of fruit yield through the harvest season was obtained by analyzing actual yield data based on hand picking of several test plots of Willamette raspberries. The resulting fruit yield function was used as a basis for analyzing both hand harvesting and mechanical harvesting.

(2) A timeliness function, expressing the reduction in fruit value as a function of the length of time between subsequent harvests and as a function of specific harvest date, was obtained for Willamette raspberries. The timeliness function was used to determine a suitable timeliness charge against mechanical harvesting.

(3) An optimum fruit removal efficiency for mechanical raspberry harvesting was determined by investigating both timeliness costs and fruit yield reduction due to the

removal of immature fruit. Results indicated that a fruit removal efficiency of 80 percent is optimum for picking intervals ranging from 3 to 6 days.

(4) The costs of hand harvesting were investigated over the harvest season, based on current prices. Gross annual profit, defined as the difference between the income from the sale of fruit and the costs of harvesting, was used as a parameter for comparing hand harvesting costs to machine harvesting costs. The gross annual profit for hand harvesting was 1764 dollars per acre.

(5) Cost analysis of mechanical harvesting was conducted by considering fixed costs, variable costs and timeliness charges for a range of machine prices and machine speeds. Results indicated that for operating speeds of 1.5 miles per hour, or greater, gross annual profit was not significantly influenced by machine speed. A machine speed of 1.5 miles per hour was therefore considered as an optimum machine speed. On this basis, a single row machine will have a capacity of 1.36 acres per hour and will have a daily output of 10.9 acres. The annual capacity of such a machine would vary from 32.7 to 65.3 acres per year for picking intervals from 3 to 6 days, respectively.

(6) The effect of the length between subsequent harvests on gross annual profit from machine picking indicated the the gross annual profit decreased by approximately 200 dollars

per acre each time the interval between subsequent harvests was increased by one day. This applies for a range of picking intervals from 3 to 6 days.

(7) Comparison of gross annual profits from both methods of harvesting indicated that profits from hand picking were substantially less than those from machine picking. Using a machine with a purchase price of 5,000 dollars, with a fruit removal efficiency of 80 percent, with a forward speed of 1.5 miles per hour and an 8 hour working day, gross annual profits varied from 2854 to 2241 dollars per acre for picking intervals from 3 to 6 days, respectively. Comparing these values to the gross annual profit of 1764 dollars per acre for hand picking, it is seen that increased annual profits due to mechanical picking varied from 1090 to 477 dollars per acre.

SUGGESTIONS FOR FURTHER STUDY

The methods used should be applicable to other types of fruit harvesting enterprises. Since yield data, the variation of yield over the harvest season and the effect of untimeliness on reduced quality are not known, such data are required for other crops before analysis may be conducted.

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APPENDIX A

COMPUTER PROGRAM FOR THE EFFECT OF PICKING INTERVAL ON INCOME

```
      YLD(T)=(-8.5414*T+10.07765*T**2-0.01685*T**4+0.000020916*T**6-
     10.00000034814*T**7)*(1742.0/453.59)
      P1=0.34
      P2=0.22
      D=0.0
4     A=3.0
      SUM=0.0
5     B=A-3.0
      C=A+D
      GI=(YLD(A)-YLD(B))*P1+(YLD(C)-YLD(A))*P2
      SUM=SUM+GI
      WRITE (6,3) A, B, C, D, GI, SUM
3     FORMAT (10X,4F7.2,2F12.2)
      A=C+3.0
      IF (A.LE.33.0) GO TO 5
      D=D+1.0
      IF (D.LE.3.0) GO TO 4
99    STOP
      END
```

APPENDIX B

COMPUTER PROGRAM FOR THE EFFECT OF PICKING INTERVAL AND PICKING EFFICIENCY ON INCOME FROM RASPBERRIES.

```
      YLD(T)=(-8.5414*T+10.07765*T**2-0.01685*T**4+0.000020916*T**6-0.0
     10000034814*T**7)*(1742.0/453.59)
      XL(A)=(-16.650+33.3*A)/100.0
      R(A)=3.0/(3.0+A)
      S(A)=A/(3.0+A)
      SUM=0.0
      P1=0.34
      P2=0.22
      D=0.0
4     X=0.50
3     Y=1.0-X
      A=3.0+D
2     B=A-3.0-D
      C=A-2.0*(3.0+D)
      IF(C.LT.0.0) C=0.0
      E=A-3.0*(3.0+D)
      IF (E.LT.0.0) E=0.0
      GI=X*P1*R(D)*((YLD(A)-YLD(B))-X*XL(X)*(YLD(B)-YLD(C)))
     1+X*P2*S(D)*((YLD(A)-YLD(B))-X*XL(X)*(YLD(B)-YLD(C)))
     2+Y*P2*((YLD(B)-YLD(C))-X*XL(X)*(YLD(C)-YLD(E)))
      SUM=SUM+GI
      P=XL(X)
      Q=R(D)
      RA=S(D)
      WRITE (6,5) A,B,C,E,D,X,Y,P,Q,RA,GI,SUM
5     FORMAT(5X,12F10.3)
      A=A+3.0+D
      IF(A.LE.33.0) GO TO 2
      SUM=0.0
      X=X+.10
      IF(X.LE.1.0) GO TO 3
      D=D+1.0
      IF(D.LE.3.0) GO TO 4
99    STOP
      END
```

APPENDIX C.

Computer Program for Cost Analysis of Mechanical Harvesting

```
      DIMENSION C(10),D(10),E(10)
      YL(T)=(-8.5414*T+10.07765*T**2-0.01685*T**4+0.000020916*T**6-
     10.00000034814*T**7)*(1742.0/453.59)
      YR(T,P)=-35.1936*T+1.3104*T**2-0.039112*T**3+0.00039522*T**4
     1+7.7928*T*P-0.000101472*T*P**6
      CST(P,H,S)=(0.00533*P/H+4.92+0.00025*P)/(0.907*S)
      T(S)=0.907*S
      DA(S,H)=0.907*S*H
      CP(S,H,P )=0.907*S*H*P
      I=1
      A=0.0
      B=3.0
    1 C(I)=(YL(B)-YL(A))*0.12*0.80 +3.0*4.28
      D(I)=(YL(B)-YL(A))*0.34*0.80
      E(I)=D(I)-C(I)
      I=I+1
      A=A+3.0
      B=B+3.0
      IF (B.LE.30.0) GO TO 1
      WRITE(6,2)
    2 FORMAT(20X,'HAND PICKING'///10X,'COST',10X,'INCOME',10X,'PROFIT')
      DO 3 I=1,10
    3 WRITE(6,4) I,C(I),D(I),E(I)
    4 FORMAT(5X,I2,2X,3(F9.3,6X))
      WRITE(6,5)
    5 FORMAT(20X,'MACHINE PICKING',///)
      DO 10 I=3,6
      WRITE(6,6) I
    6 FORMAT(20X,I2,2X,'DAY PICKING INTERVAL',/)
      X=I
      DO 10 II=1000,15000,2000
      P=II
      WRITE(6,8) P
    8 FORMAT(20X,'PURCHASE PRICE =',F9.2,/)
      DO 10 J=8,10,2
      H=J
      WRITE(6,9) J
    9 FORMAT(40X,I2,2X,'HOURS PER DAY'/12X,'SPEED',2X,'ACRE/HOUR',3X,
     1'ACRE/DAY',4X,'CAPACITY',6X,'COST',6X,'INCOME',4X,'YLD RED',4X,
     2'PROFIT')
      DO 10 K=1,6
      XX=0.0
      YY=0.0
      ZZ=0.0
      WW=0.0
      R=K
      S=R/2.0
      A=0.0
      B=3.0
```

APPENDIX C (Continued)

```
 15     CA=(YL(B)-YL(A))*0.34*0.80
        DE=CST(P,H,S)*(3.0/X)
        IF (X.LE.3.0) GO TO 12
        EA=YR(B,X)-YR(A,X)
        GO TO 13
 12     EA=0.0
 13     G=T(S)
        HE=DA(S,H)
        R=CP(S,H,X)
        F=CA-DE-EA
        XX=XX+CA
        YY=YY+DE
        ZZ=ZZ+EA
        WW=WW+F
        A=A+3.0
        B=B+3.0
        IF(B.LE.30.0) GO TO 15
        WRITE(6,14) S,G,HE,R,YY,XX,ZZ,WW
 14     FORMAT(10X,F6.2,3X,F6.2,5X,F8.2,5X,F8.2,4(2X,F9.2))
 10     CONTINUE
 99     STOP
        END
```

APPENDIX D · COST ANALYSIS OF MECHANICAL HARVESTING

3 DAY PICKING INTERVAL

PURCHASE PRICE = 1000.00

8 HOURS PER DAY

SPEED	ACRE/HOUR	ACRE/DAY	CAPACITY	COST	INCOME	YLD RED	PROFIT
0.50	0.45	3.63	10.88	128.69	2923.95	0.0	2795.25
1.00	0.91	7.26	21.77	64.35	2923.95	0.0	2859.60
1.50	1.36	10.88	32.65	42.90	2923.95	0.0	2881.05
2.00	1.81	14.51	43.54	32.17	2923.95	0.0	2891.77
2.50	2.27	18.14	54.42	25.74	2923.95	0.0	2898.21
3.00	2.72	21.77	65.30	21.45	2923.95	0.0	2902.50

10 HOURS PER DAY

SPEED	ACRE/HOUR	ACRE/DAY	CAPACITY	COST	INCOME	YLD RED	PROFIT
0.50	0.45	4.53	13.60	125.76	2923.95	0.0	2798.19
1.00	0.91	9.07	27.21	62.88	2923.95	0.0	2861.07
1.50	1.36	13.60	40.81	41.92	2923.95	0.0	2882.03
2.00	1.81	18.14	54.42	31.44	2923.95	0.0	2892.51
2.50	2.27	22.67	68.02	25.15	2923.95	0.0	2898.80
3.00	2.72	27.21	81.63	20.96	2923.95	0.0	2902.99

PURCHASE PRICE = 3000.00

8 HOURS PER DAY

SPEED	ACRE/HOUR	ACRE/DAY	CAPACITY	COST	INCOME	YLD RED	PROFIT
0.50	0.45	3.63	10.88	169.10	2923.95	0.0	2754.85
1.00	0.91	7.26	21.77	84.55	2923.95	0.0	2839.40
1.50	1.36	10.88	32.65	56.37	2923.95	0.0	2867.58
2.00	1.81	14.51	43.54	42.28	2923.95	0.0	2881.67
2.50	2.27	18.14	54.42	33.82	2923.95	0.0	2890.13
3.00	2.72	21.77	65.30	28.18	2923.95	0.0	2895.76

10 HOURS PER DAY

SPEED	ACRE/HOUR	ACRE/DAY	CAPACITY	COST	INCOME	YLD RED	PROFIT
0.50	0.45	4.53	13.60	160.29	2923.95	0.0	2763.66
1.00	0.91	9.07	27.21	80.14	2923.95	0.0	2843.80
1.50	1.36	13.60	40.81	53.43	2923.95	0.0	2870.52
2.00	1.81	18.14	54.42	40.07	2923.95	0.0	2883.87
2.50	2.27	22.67	68.02	32.06	2923.95	0.0	2891.89
3.00	2.72	27.21	81.63	26.71	2923.95	0.0	2897.23

APPENDIX D (Continued)

PURCHASE PRICE = 5000.00

8 HOURS PER DAY

SPEED	ACRE/HOUR	ACRE/DAY	CAPACITY	COST	INCOME	YLD RED	PROFIT
0.50	0.45	3.63	10.88	209.51	2923.95	0.0	2714.44
1.00	0.91	7.26	21.77	104.75	2923.95	0.0	2819.19
1.50	1.36	10.88	32.65	69.84	2923.95	0.0	2854.11
2.00	1.81	14.51	43.54	52.38	2923.95	0.0	2871.57
2.50	2.27	18.14	54.42	41.90	2923.95	0.0	2882.05
3.00	2.72	21.77	65.30	34.92	2923.95	0.0	2889.03

10 HOURS PER DAY

SPEED	ACRE/HOUR	ACRE/DAY	CAPACITY	COST	INCOME	YLD RED	PROFIT
0.50	0.45	4.53	13.60	194.82	2923.95	0.0	2729.13
1.00	0.91	9.07	27.21	97.41	2923.95	0.0	2826.54
1.50	1.36	13.60	40.81	64.94	2923.95	0.0	2859.01
2.00	1.81	18.14	54.42	48.70	2923.95	0.0	2875.24
2.50	2.27	22.67	68.02	38.96	2923.95	0.0	2884.98
3.00	2.72	27.21	81.63	32.47	2923.95	0.0	2891.48

PURCHASE PRICE = 7000.00

8 HOURS PER DAY

SPEED	ACRE/HOUR	ACRE/DAY	CAPACITY	COST	INCOME	YLD RED	PROFIT
0.50	0.45	3.63	10.88	249.92	2923.95	0.0	2674.03
1.00	0.91	7.26	21.77	124.96	2923.95	0.0	2798.99
1.50	1.36	10.88	32.65	83.31	2923.95	0.0	2840.64
2.00	1.81	14.51	43.54	62.48	2923.95	0.0	2861.47
2.50	2.27	18.14	54.42	49.98	2923.95	0.0	2873.96
3.00	2.72	21.77	65.30	41.65	2923.95	0.0	2882.29

10 HOURS PER DAY

SPEED	ACRE/HOUR	ACRE/DAY	CAPACITY	COST	INCOME	YLD RED	PROFIT
0.50	0.45	4.53	13.60	229.35	2923.95	0.0	2694.60
1.00	0.91	9.07	27.21	114.67	2923.95	0.0	2809.27
1.50	1.36	13.60	40.81	76.45	2923.95	0.0	2847.50
2.00	1.81	18.14	54.42	57.34	2923.95	0.0	2866.61
2.50	2.27	22.67	68.02	45.87	2923.95	0.0	2878.08
3.00	2.72	27.21	81.63	38.22	2923.95	0.0	2885.72

APPENDIX D (Continued)

PURCHASE PRICE = 9000.00

8 HOURS PER DAY

SPEED	ACRE/HOUR	ACRE/DAY	CAPACITY	COST	INCOME	YLD RED	PROFIT
0.50	0.45	3.63	10.88	290.32	2923.95	0.0	2633.62
1.00	0.91	7.26	21.77	145.16	2923.95	0.0	2778.78
1.50	1.36	10.88	32.65	96.78	2923.95	0.0	2827.17
2.00	1.81	14.51	43.54	72.58	2923.95	0.0	2851.36
2.50	2.27	18.14	54.42	58.07	2923.95	0.0	2865.88
3.00	2.72	21.77	65.30	48.39	2923.95	0.0	2875.56

10 HOURS PER DAY

SPEED	ACRE/HOUR	ACRE/DAY	CAPACITY	COST	INCOME	YLD RED	PROFIT
0.50	0.45	4.53	13.60	263.88	2923.95	0.0	2660.07
1.00	0.91	9.07	27.21	131.94	2923.95	0.0	2792.01
1.50	1.36	13.60	40.81	87.96	2923.95	0.0	2835.99
2.00	1.81	18.14	54.42	65.97	2923.95	0.0	2857.98
2.50	2.27	22.67	68.02	52.78	2923.95	0.0	2871.17
3.00	2.72	27.21	81.63	43.98	2923.95	0.0	2879.97

PURCHASE PRICE = 11000.00

8 HOURS PER DAY

SPEED	ACRE/HOUR	ACRE/DAY	CAPACITY	COST	INCOME	YLD RED	PROFIT
0.50	0.45	3.63	10.88	330.73	2923.95	0.0	2593.21
1.00	0.91	7.26	21.77	165.37	2923.95	0.0	2758.58
1.50	1.36	10.88	32.65	110.24	2923.95	0.0	2813.70
2.00	1.81	14.51	43.54	82.68	2923.95	0.0	2841.26
2.50	2.27	18.14	54.42	66.15	2923.95	0.0	2857.80
3.00	2.72	21.77	65.30	55.12	2923.95	0.0	2868.82

10 HOURS PER DAY

SPEED	ACRE/HOUR	ACRE/DAY	CAPACITY	COST	INCOME	YLD RED	PROFIT
0.50	0.45	4.53	13.60	298.41	2923.95	0.0	2625.53
1.00	0.91	9.07	27.21	149.21	2923.95	0.0	2774.74
1.50	1.36	13.60	40.81	99.47	2923.95	0.0	2824.47
2.00	1.81	18.14	54.42	74.60	2923.95	0.0	2849.34
2.50	2.27	22.67	68.02	59.68	2923.95	0.0	2864.26
3.00	2.72	27.21	81.63	49.74	2923.95	0.0	2874.21

APPENDIX D (Continued)

PURCHASE PRICE = 13000.00

8 HOURS PER DAY

SPEED	ACRE/HOUR	ACRE/DAY	CAPACITY	COST	INCOME	YLD RED	PROFIT
0.50	0.45	3.63	10.88	371.14	2923.95	0.0	2552.80
1.00	0.91	7.26	21.77	185.57	2923.95	0.0	2738.38
1.50	1.36	10.88	32.65	123.71	2923.95	0.0	2800.23
2.00	1.81	14.51	43.54	92.79	2923.95	0.0	2831.16
2.50	2.27	18.14	54.42	74.23	2923.95	0.0	2849.72
3.00	2.72	21.77	65.30	61.86	2923.95	0.0	2862.09

10 HOURS PER DAY

SPEED	ACRE/HOUR	ACRE/DAY	CAPACITY	COST	INCOME	YLD RED	PROFIT
0.50	0.45	4.53	13.60	332.94	2923.95	0.0	2591.00
1.00	0.91	9.07	27.21	166.47	2923.95	0.0	2757.48
1.50	1.36	13.60	40.81	110.98	2923.95	0.0	2812.97
2.00	1.81	18.14	54.42	83.24	2923.95	0.0	2840.71
2.50	2.27	22.67	68.02	66.59	2923.95	0.0	2857.36
3.00	2.72	27.21	81.63	55.49	2923.95	0.0	2868.46

PURCHASE PRICE = 15000.00

8 HOURS PER DAY

SPEED	ACRE/HOUR	ACRE/DAY	CAPACITY	COST	INCOME	YLD RED	PROFIT
0.50	0.45	3.63	10.88	411.55	2923.95	0.0	2512.40
1.00	0.91	7.26	21.77	205.77	2923.95	0.0	2718.17
1.50	1.36	10.88	32.65	137.18	2923.95	0.0	2786.76
2.00	1.81	14.51	43.54	102.89	2923.95	0.0	2821.06
2.50	2.27	18.14	54.42	82.31	2923.95	0.0	2841.64
3.00	2.72	21.77	65.30	68.59	2923.95	0.0	2855.36

10 HOURS PER DAY

SPEED	ACRE/HOUR	ACRE/DAY	CAPACITY	COST	INCOME	YLD RED	PROFIT
0.50	0.45	4.53	13.60	367.47	2923.95	0.0	2556.47
1.00	0.91	9.07	27.21	183.74	2923.95	0.0	2740.21
1.50	1.36	13.60	40.81	122.49	2923.95	0.0	2801.45
2.00	1.81	18.14	54.42	91.87	2923.95	0.0	2832.08
2.50	2.27	22.67	68.02	73.49	2923.95	0.0	2850.45
3.00	2.72	27.21	81.63	61.25	2923.95	0.0	2862.70

4 DAY PICKING INTERVAL

PURCHASE PRICE = 1000.00

8 HOURS PER DAY

SPEED	ACRE/HOUR	ACRE/DAY	CAPACITY	COST	INCOME	YLD RED	PROFIT
0.50	0.45	3.63	14.51	96.52	2923.95	310.32	2517.10
1.00	0.91	7.26	29.02	48.26	2923.95	310.32	2565.36
1.50	1.36	10.88	43.54	32.17	2923.95	310.32	2581.45
2.00	1.81	14.51	58.05	24.13	2923.95	310.32	2589.49
2.50	2.27	18.14	72.56	19.30	2923.95	310.32	2594.32
3.00	2.72	21.77	87.07	16.09	2923.95	310.32	2597.54

10 HOURS PER DAY

SPEED	ACRE/HOUR	ACRE/DAY	CAPACITY	COST	INCOME	YLD RED	PROFIT
0.50	0.45	4.53	18.14	94.32	2923.95	310.32	2519.31
1.00	0.91	9.07	36.28	47.16	2923.95	310.32	2566.47
1.50	1.36	13.60	54.42	31.44	2923.95	310.32	2582.18
2.00	1.81	18.14	72.56	23.58	2923.95	310.32	2590.04
2.50	2.27	22.67	90.70	18.86	2923.95	310.32	2594.76
3.00	2.72	27.21	108.84	15.72	2923.95	310.32	2597.90

PURCHASE PRICE = 3000.00

8 HOURS PER DAY

SPEED	ACRE/HOUR	ACRE/DAY	CAPACITY	COST	INCOME	YLD RED	PROFIT
0.50	0.45	3.63	14.51	126.83	2923.95	310.32	2486.80
1.00	0.91	7.26	29.02	63.41	2923.95	310.32	2550.21
1.50	1.36	10.88	43.54	42.28	2923.95	310.32	2571.35
2.00	1.81	14.51	58.05	31.71	2923.95	310.32	2581.92
2.50	2.27	18.14	72.56	25.37	2923.95	310.32	2588.26
3.00	2.72	21.77	87.07	21.14	2923.95	310.32	2592.49

10 HOURS PER DAY

SPEED	ACRE/HOUR	ACRE/DAY	CAPACITY	COST	INCOME	YLD RED	PROFIT
0.50	0.45	4.53	18.14	120.21	2923.95	310.32	2493.41
1.00	0.91	9.07	36.28	60.11	2923.95	310.32	2553.52
1.50	1.36	13.60	54.42	40.07	2923.95	310.32	2573.55
2.00	1.81	18.14	72.56	30.05	2923.95	310.32	2583.57
2.50	2.27	22.67	90.70	24.04	2923.95	310.32	2589.58
3.00	2.72	27.21	108.84	20.04	2923.95	310.32	2593.59

APPENDIX D (Continued)

PURCHASE PRICE = 5000.00

8 HOURS PER DAY

SPEED	ACRE/HOUR	ACRE/DAY	CAPACITY	COST	INCOME	YLD RED	PROFIT
0.50	0.45	3.63	14.51	157.13	2923.95	310.32	2456.49
1.00	0.91	7.26	29.02	78.57	2923.95	310.32	2535.06
1.50	1.36	10.88	43.54	52.38	2923.95	310.32	2561.25
2.00	1.81	14.51	58.05	39.28	2923.95	310.32	2574.34
2.50	2.27	18.14	72.56	31.43	2923.95	310.32	2582.20
3.00	2.72	21.77	87.07	26.19	2923.95	310.32	2587.44

10 HOURS PER DAY

SPEED	ACRE/HOUR	ACRE/DAY	CAPACITY	COST	INCOME	YLD RED	PROFIT
0.50	0.45	4.53	18.14	146.11	2923.95	310.32	2467.51
1.00	0.91	9.07	36.28	73.06	2923.95	310.32	2540.57
1.50	1.36	13.60	54.42	48.70	2923.95	310.32	2564.92
2.00	1.81	18.14	72.56	36.53	2923.95	310.32	2577.10
2.50	2.27	22.67	90.70	29.22	2923.95	310.32	2584.40
3.00	2.72	27.21	108.84	24.35	2923.95	310.32	2589.27

PURCHASE PRICE = 7000.00

8 HOURS PER DAY

SPEED	ACRE/HOUR	ACRE/DAY	CAPACITY	COST	INCOME	YLD RED	PROFIT
0.50	0.45	3.63	14.51	187.44	2923.95	310.32	2426.19
1.00	0.91	7.26	29.02	93.72	2923.95	310.32	2519.90
1.50	1.36	10.88	43.54	62.48	2923.95	310.32	2551.14
2.00	1.81	14.51	58.05	46.86	2923.95	310.32	2566.76
2.50	2.27	18.14	72.56	37.49	2923.95	310.32	2576.14
3.00	2.72	21.77	87.07	31.24	2923.95	310.32	2582.38

10 HOURS PER DAY

SPEED	ACRE/HOUR	ACRE/DAY	CAPACITY	COST	INCOME	YLD RED	PROFIT
0.50	0.45	4.53	18.14	172.01	2923.95	310.32	2441.61
1.00	0.91	9.07	36.28	86.01	2923.95	310.32	2527.62
1.50	1.36	13.60	54.42	57.34	2923.95	310.32	2556.29
2.00	1.81	18.14	72.56	43.00	2923.95	310.32	2570.62
2.50	2.27	22.67	90.70	34.40	2923.95	310.32	2579.22
3.00	2.72	27.21	108.84	28.67	2923.95	310.32	2584.95

APPENDIX D (Continued)

PURCHASE PRICE = 9000.00

8 HOURS PER DAY

SPEED	ACRE/HOUR	ACRE/DAY	CAPACITY	COST	INCOME	YLD RED	PROFIT
0.50	0.45	3.63	14.51	217.74	2923.95	310.32	2395.88
1.00	0.91	7.26	29.02	108.87	2923.95	310.32	2504.75
1.50	1.36	10.88	43.54	72.58	2923.95	310.32	2541.04
2.00	1.81	14.51	58.05	54.44	2923.95	310.32	2559.19
2.50	2.27	18.14	72.56	43.55	2923.95	310.32	2570.07
3.00	2.72	21.77	87.07	36.29	2923.95	310.32	2577.33

10 HOURS PER DAY

SPEED	ACRE/HOUR	ACRE/DAY	CAPACITY	COST	INCOME	YLD RED	PROFIT
0.50	0.45	4.53	18.14	197.91	2923.95	310.32	2415.71
1.00	0.91	9.07	36.28	98.96	2923.95	310.32	2514.67
1.50	1.36	13.60	54.42	65.97	2923.95	310.32	2547.65
2.00	1.81	18.14	72.56	49.48	2923.95	310.32	2564.15
2.50	2.27	22.67	90.70	39.58	2923.95	310.32	2574.04
3.00	2.72	27.21	108.84	32.99	2923.95	310.32	2580.64

PURCHASE PRICE = 11000.00

8 HOURS PER DAY

SPEED	ACRE/HOUR	ACRE/DAY	CAPACITY	COST	INCOME	YLD RED	PROFIT
0.50	0.45	3.63	14.51	248.05	2923.95	310.32	2365.57
1.00	0.91	7.26	29.02	124.02	2923.95	310.32	2489.60
1.50	1.36	10.88	43.54	82.68	2923.95	310.32	2530.94
2.00	1.81	14.51	58.05	62.01	2923.95	310.32	2551.61
2.50	2.27	18.14	72.56	49.61	2923.95	310.32	2564.01
3.00	2.72	21.77	87.07	41.34	2923.95	310.32	2572.28

10 HOURS PER DAY

SPEED	ACRE/HOUR	ACRE/DAY	CAPACITY	COST	INCOME	YLD RED	PROFIT
0.50	0.45	4.53	18.14	223.81	2923.95	310.32	2389.81
1.00	0.91	9.07	36.28	111.90	2923.95	310.32	2501.72
1.50	1.36	13.60	54.42	74.60	2923.95	310.32	2539.02
2.00	1.81	18.14	72.56	55.95	2923.95	310.32	2557.67
2.50	2.27	22.67	90.70	44.76	2923.95	310.32	2568.86
3.00	2.72	27.21	108.84	37.30	2923.95	310.32	2576.32

APPENDIX D (Continued)

PURCHASE PRICE = 13000.00

8 HOURS PER DAY

SPEED	ACRE/HOUR	ACRE/DAY	CAPACITY	COST	INCOME	YLD RED	PROFIT
0.50	0.45	3.63	14.51	278.36	2923.95	310.32	2335.27
1.00	0.91	7.26	29.02	139.18	2923.95	310.32	2474.44
1.50	1.36	10.88	43.54	92.79	2923.95	310.32	2520.84
2.00	1.81	14.51	58.05	69.59	2923.95	310.32	2544.03
2.50	2.27	18.14	72.56	55.67	2923.95	310.32	2557.95
3.00	2.72	21.77	87.07	46.39	2923.95	310.32	2567.23

10 HOURS PER DAY

SPEED	ACRE/HOUR	ACRE/DAY	CAPACITY	COST	INCOME	YLD RED	PROFIT
0.50	0.45	4.53	18.14	249.71	2923.95	310.32	2363.91
1.00	0.91	9.07	36.28	124.85	2923.95	310.32	2488.77
1.50	1.36	13.60	54.42	83.24	2923.95	310.32	2530.39
2.00	1.81	18.14	72.56	62.43	2923.95	310.32	2551.20
2.50	2.27	22.67	90.70	49.94	2923.95	310.32	2563.68
3.00	2.72	27.21	108.84	41.62	2923.95	310.32	2572.01

PURCHASE PRICE = 15000.00

8 HOURS PER DAY

SPEED	ACRE/HOUR	ACRE/DAY	CAPACITY	COST	INCOME	YLD RED	PROFIT
0.50	0.45	3.63	14.51	308.66	2923.95	310.32	2304.96
1.00	0.91	7.26	29.02	154.33	2923.95	310.32	2459.29
1.50	1.36	10.88	43.54	102.89	2923.95	310.32	2510.74
2.00	1.81	14.51	58.05	77.17	2923.95	310.32	2536.46
2.50	2.27	18.14	72.56	61.73	2923.95	310.32	2551.89
3.00	2.72	21.77	87.07	51.44	2923.95	310.32	2562.18

10 HOURS PER DAY

SPEED	ACRE/HOUR	ACRE/DAY	CAPACITY	COST	INCOME	YLD RED	PROFIT
0.50	0.45	4.53	18.14	275.61	2923.95	310.32	2338.02
1.00	0.91	9.07	36.28	137.80	2923.95	310.32	2475.82
1.50	1.36	13.60	54.42	91.87	2923.95	310.32	2521.75
2.00	1.81	18.14	72.56	68.90	2923.95	310.32	2544.72
2.50	2.27	22.67	90.70	55.12	2923.95	310.32	2558.50
3.00	2.72	27.21	108.84	45.93	2923.95	310.32	2567.69

APPENDIX D (Continued)

5 DAY PICKING INTERVAL

PURCHASE PRICE = 1000.00

8 HOURS PER DAY

SPEED	ACRE/HOUR	ACRE/DAY	CAPACITY	COST	INCOME	YLD RED	PROFIT
0.50	0.45	3.63	18.14	77.22	2923.95	509.01	2337.72
1.00	0.91	7.26	36.28	38.61	2923.95	509.01	2376.33
1.50	1.36	10.88	54.42	25.74	2923.95	509.01	2389.20
2.00	1.81	14.51	72.56	19.30	2923.95	509.01	2395.63
2.50	2.27	18.14	90.70	15.44	2923.95	509.01	2399.49
3.00	2.72	21.77	108.84	12.87	2923.95	509.01	2402.07

10 HOURS PER DAY

SPEED	ACRE/HOUR	ACRE/DAY	CAPACITY	COST	INCOME	YLD RED	PROFIT
0.50	0.45	4.53	22.67	75.45	2923.95	509.01	2339.48
1.00	0.91	9.07	45.35	37.73	2923.95	509.01	2377.21
1.50	1.36	13.60	68.02	25.15	2923.95	509.01	2389.79
2.00	1.81	18.14	90.70	18.86	2923.95	509.01	2396.07
2.50	2.27	22.67	113.37	15.09	2923.95	509.01	2399.84
3.00	2.72	27.21	136.05	12.58	2923.95	509.01	2402.36

PURCHASE PRICE = 3000.00

8 HOURS PER DAY

SPEED	ACRE/HOUR	ACRE/DAY	CAPACITY	COST	INCOME	YLD RED	PROFIT
0.50	0.45	3.63	18.14	101.46	2923.95	509.01	2313.47
1.00	0.91	7.26	36.28	50.73	2923.95	509.01	2364.20
1.50	1.36	10.88	54.42	33.82	2923.95	509.01	2381.12
2.00	1.81	14.51	72.56	25.37	2923.95	509.01	2389.57
2.50	2.27	18.14	90.70	20.29	2923.95	509.01	2394.64
3.00	2.72	21.77	108.84	16.91	2923.95	509.01	2398.03

10 HOURS PER DAY

SPEED	ACRE/HOUR	ACRE/DAY	CAPACITY	COST	INCOME	YLD RED	PROFIT
0.50	0.45	4.53	22.67	96.17	2923.95	509.01	2318.76
1.00	0.91	9.07	45.35	48.09	2923.95	509.01	2366.85
1.50	1.36	13.60	68.02	32.06	2923.95	509.01	2382.88
2.00	1.81	18.14	90.70	24.04	2923.95	509.01	2390.89
2.50	2.27	22.67	113.37	19.23	2923.95	509.01	2395.70
3.00	2.72	27.21	136.05	16.03	2923.95	509.01	2398.91

APPENDIX D (Continued)

PURCHASE PRICE = 5000.00

8 HOURS PER DAY

SPEED	ACRE/HOUR	ACRE/DAY	CAPACITY	COST	INCOME	YLD RED	PROFIT
0.50	0.45	3.63	18.14	125.71	2923.95	509.01	2289.23
1.00	0.91	7.26	36.28	62.85	2923.95	509.01	2352.08
1.50	1.36	10.88	54.42	41.90	2923.95	509.01	2373.03
2.00	1.81	14.51	72.56	31.43	2923.95	509.01	2383.51
2.50	2.27	18.14	90.70	25.14	2923.95	509.01	2389.79
3.00	2.72	21.77	108.84	20.95	2923.95	509.01	2393.98

10 HOURS PER DAY

SPEED	ACRE/HOUR	ACRE/DAY	CAPACITY	COST	INCOME	YLD RED	PROFIT
0.50	0.45	4.53	22.67	116.89	2923.95	509.01	2298.04
1.00	0.91	9.07	45.35	58.45	2923.95	509.01	2356.49
1.50	1.36	13.60	68.02	38.96	2923.95	509.01	2375.97
2.00	1.81	18.14	90.70	29.22	2923.95	509.01	2385.71
2.50	2.27	22.67	113.37	23.38	2923.95	509.01	2391.56
3.00	2.72	27.21	136.05	19.48	2923.95	509.01	2395.45

PURCHASE PRICE = 7000.00

8 HOURS PER DAY

SPEED	ACRE/HOUR	ACRE/DAY	CAPACITY	COST	INCOME	YLD RED	PROFIT
0.50	0.45	3.63	18.14	149.95	2923.95	509.01	2264.99
1.00	0.91	7.26	36.28	74.98	2923.95	509.01	2339.96
1.50	1.36	10.88	54.42	49.98	2923.95	509.01	2364.95
2.00	1.81	14.51	72.56	37.49	2923.95	509.01	2377.45
2.50	2.27	18.14	90.70	29.99	2923.95	509.01	2384.95
3.00	2.72	21.77	108.84	24.99	2923.95	509.01	2389.94

10 HOURS PER DAY

SPEED	ACRE/HOUR	ACRE/DAY	CAPACITY	COST	INCOME	YLD RED	PROFIT
0.50	0.45	4.53	22.67	137.61	2923.95	509.01	2277.33
1.00	0.91	9.07	45.35	68.80	2923.95	509.01	2346.13
1.50	1.36	13.60	68.02	45.87	2923.95	509.01	2369.07
2.00	1.81	18.14	90.70	34.40	2923.95	509.01	2380.53
2.50	2.27	22.67	113.37	27.52	2923.95	509.01	2387.41
3.00	2.72	27.21	136.05	22.93	2923.95	509.01	2392.00

APPENDIX D (Continued)

PURCHASE PRICE = 9000.00

8 HOURS PER DAY

SPEED	ACRE/HOUR	ACRE/DAY	CAPACITY	COST	INCOME	YLD RED	PROFIT
0.50	0.45	3.63	18.14	174.19	2923.95	509.01	2240.74
1.00	0.91	7.26	36.28	87.10	2923.95	509.01	2327.84
1.50	1.36	10.88	54.42	58.07	2923.95	509.01	2356.87
2.00	1.81	14.51	72.56	43.55	2923.95	509.01	2371.39
2.50	2.27	18.14	90.70	34.84	2923.95	509.01	2380.10
3.00	2.72	21.77	108.84	29.03	2923.95	509.01	2385.90

10 HOURS PER DAY

SPEED	ACRE/HOUR	ACRE/DAY	CAPACITY	COST	INCOME	YLD RED	PROFIT
0.50	0.45	4.53	22.67	158.33	2923.95	509.01	2256.61
1.00	0.91	9.07	45.35	79.16	2923.95	509.01	2335.77
1.50	1.36	13.60	68.02	52.78	2923.95	509.01	2362.16
2.00	1.81	18.14	90.70	39.58	2923.95	509.01	2375.35
2.50	2.27	22.67	113.37	31.67	2923.95	509.01	2383.27
3.00	2.72	27.21	136.05	26.39	2923.95	509.01	2388.55

PURCHASE PRICE = 11000.00

8 HOURS PER DAY

SPEED	ACRE/HOUR	ACRE/DAY	CAPACITY	COST	INCOME	YLD RED	PROFIT
0.50	0.45	3.63	18.14	198.44	2923.95	509.01	2216.50
1.00	0.91	7.26	36.28	99.22	2923.95	509.01	2315.72
1.50	1.36	10.88	54.42	66.15	2923.95	509.01	2348.79
2.00	1.81	14.51	72.56	49.61	2923.95	509.01	2365.32
2.50	2.27	18.14	90.70	39.69	2923.95	509.01	2375.25
3.00	2.72	21.77	108.84	33.07	2923.95	509.01	2381.86

10 HOURS PER DAY

SPEED	ACRE/HOUR	ACRE/DAY	CAPACITY	COST	INCOME	YLD RED	PROFIT
0.50	0.45	4.53	22.67	179.05	2923.95	509.01	2235.89
1.00	0.91	9.07	45.35	89.52	2923.95	509.01	2325.41
1.50	1.36	13.60	68.02	59.68	2923.95	509.01	2355.25
2.00	1.81	18.14	90.70	44.76	2923.95	509.01	2370.17
2.50	2.27	22.67	113.37	35.81	2923.95	509.01	2379.13
3.00	2.72	27.21	136.05	29.84	2923.95	509.01	2385.09

APPENDIX D (Continued)

PURCHASE PRICE = 13000.00

8 HOURS PER DAY

SPEED	ACRE/HOUR	ACRE/DAY	CAPACITY	COST	INCOME	YLD RED	PROFIT
0.50	0.45	3.63	18.14	222.68	2923.95	509.01	2192.25
1.00	0.91	7.26	36.28	111.34	2923.95	509.01	2303.59
1.50	1.36	10.88	54.42	74.23	2923.95	509.01	2340.71
2.00	1.81	14.51	72.56	55.67	2923.95	509.01	2359.27
2.50	2.27	18.14	90.70	44.54	2923.95	509.01	2370.40
3.00	2.72	21.77	108.84	37.11	2923.95	509.01	2377.82

10 HOURS PER DAY

SPEED	ACRE/HOUR	ACRE/DAY	CAPACITY	COST	INCOME	YLD RED	PROFIT
0.50	0.45	4.53	22.67	199.77	2923.95	509.01	2215.17
1.00	0.91	9.07	45.35	99.88	2923.95	509.01	2315.05
1.50	1.36	13.60	68.02	66.59	2923.95	509.01	2348.35
2.00	1.81	18.14	90.70	49.94	2923.95	509.01	2364.99
2.50	2.27	22.67	113.37	39.95	2923.95	509.01	2374.98
3.00	2.72	27.21	136.05	33.29	2923.95	509.01	2381.64

PURCHASE PRICE = 15000.00

8 HOURS PER DAY

SPEED	ACRE/HOUR	ACRE/DAY	CAPACITY	COST	INCOME	YLD RED	PROFIT
0.50	0.45	3.63	18.14	246.93	2923.95	509.01	2168.01
1.00	0.91	7.26	36.28	123.46	2923.95	509.01	2291.47
1.50	1.36	10.88	54.42	82.31	2923.95	509.01	2332.62
2.00	1.81	14.51	72.56	61.73	2923.95	509.01	2353.20
2.50	2.27	18.14	90.70	49.39	2923.95	509.01	2365.55
3.00	2.72	21.77	108.84	41.15	2923.95	509.01	2373.78

10 HOURS PER DAY

SPEED	ACRE/HOUR	ACRE/DAY	CAPACITY	COST	INCOME	YLD RED	PROFIT
0.50	0.45	4.53	22.67	220.48	2923.95	509.01	2194.45
1.00	0.91	9.07	45.35	110.24	2923.95	509.01	2304.69
1.50	1.36	13.60	68.02	73.49	2923.95	509.01	2341.44
2.00	1.81	18.14	90.70	55.12	2923.95	509.01	2359.81
2.50	2.27	22.67	113.37	44.10	2923.95	509.01	2370.84
3.00	2.72	27.21	136.05	36.75	2923.95	509.01	2378.19

APPENDIX D (Continued)

6 DAY PICKING INTERVAL

PURCHASE PRICE = 1000.00

8 HOURS PER DAY

SPEED	ACRE/HOUR	ACRE/DAY	CAPACITY	COST	INCOME	YLD RED	PROFIT
0.50	0.45	3.63	21.77	64.35	2923.95	648.33	2211.27
1.00	0.91	7.26	43.54	32.17	2923.95	648.33	2243.44
1.50	1.36	10.88	65.30	21.45	2923.95	648.33	2254.17
2.00	1.81	14.51	87.07	16.09	2923.95	648.33	2259.53
2.50	2.27	18.14	108.84	12.87	2923.95	648.33	2262.74
3.00	2.72	21.77	130.61	10.72	2923.95	648.33	2264.89

10 HOURS PER DAY

SPEED	ACRE/HOUR	ACRE/DAY	CAPACITY	COST	INCOME	YLD RED	PROFIT
0.50	0.45	4.53	27.21	62.88	2923.95	648.33	2212.74
1.00	0.91	9.07	54.42	31.44	2923.95	648.33	2244.18
1.50	1.36	13.60	81.63	20.96	2923.95	648.33	2254.66
2.00	1.81	18.14	108.84	15.72	2923.95	648.33	2259.90
2.50	2.27	22.67	136.05	12.58	2923.95	648.33	2263.04
3.00	2.72	27.21	163.26	10.48	2923.95	648.33	2265.14

PURCHASE PRICE = 3000.00

8 HOURS PER DAY

SPEED	ACRE/HOUR	ACRE/DAY	CAPACITY	COST	INCOME	YLD RED	PROFIT
0.50	0.45	3.63	21.77	84.55	2923.95	648.33	2191.06
1.00	0.91	7.26	43.54	42.28	2923.95	648.33	2233.34
1.50	1.36	10.88	65.30	28.18	2923.95	648.33	2247.43
2.00	1.81	14.51	87.07	21.14	2923.95	648.33	2254.48
2.50	2.27	18.14	108.84	16.91	2923.95	648.33	2258.70
3.00	2.72	21.77	130.61	14.09	2923.95	648.33	2261.52

10 HOURS PER DAY

SPEED	ACRE/HOUR	ACRE/DAY	CAPACITY	COST	INCOME	YLD RED	PROFIT
0.50	0.45	4.53	27.21	80.14	2923.95	648.33	2195.47
1.00	0.91	9.07	54.42	40.07	2923.95	648.33	2235.54
1.50	1.36	13.60	81.63	26.71	2923.95	648.33	2248.90
2.00	1.81	18.14	108.84	20.04	2923.95	648.33	2255.58
2.50	2.27	22.67	136.05	16.03	2923.95	648.33	2259.59
3.00	2.72	27.21	163.26	13.36	2923.95	648.33	2262.26

APPENDIX D (Continued)

PURCHASE PRICE = 5000.00

8 HOURS PER DAY

SPEED	ACRE/HOUR	ACRE/DAY	CAPACITY	COST	INCOME	YLD RED	PROFIT
0.50	0.45	3.63	21.77	104.75	2923.95	648.33	2170.86
1.00	0.91	7.26	43.54	52.38	2923.95	648.33	2223.24
1.50	1.36	10.88	65.30	34.92	2923.95	648.33	2240.70
2.00	1.81	14.51	87.07	26.19	2923.95	648.33	2249.43
2.50	2.27	18.14	108.84	20.95	2923.95	648.33	2254.66
3.00	2.72	21.77	130.61	17.46	2923.95	648.33	2258.16

10 HOURS PER DAY

SPEED	ACRE/HOUR	ACRE/DAY	CAPACITY	COST	INCOME	YLD RED	PROFIT
0.50	0.45	4.53	27.21	97.41	2923.95	648.33	2178.21
1.00	0.91	9.07	54.42	48.70	2923.95	648.33	2226.91
1.50	1.36	13.60	81.63	32.47	2923.95	648.33	2243.15
2.00	1.81	18.14	108.84	24.35	2923.95	648.33	2251.26
2.50	2.27	22.67	136.05	19.48	2923.95	648.33	2256.13
3.00	2.72	27.21	163.26	16.23	2923.95	648.33	2259.38

PURCHASE PRICE = 7000.00

8 HOURS PER DAY

SPEED	ACRE/HOUR	ACRE/DAY	CAPACITY	COST	INCOME	YLD RED	PROFIT
0.50	0.45	3.63	21.77	124.96	2923.95	648.33	2150.66
1.00	0.91	7.26	43.54	62.48	2923.95	648.33	2213.14
1.50	1.36	10.88	65.30	41.65	2923.95	648.33	2233.96
2.00	1.81	14.51	87.07	31.24	2923.95	648.33	2244.38
2.50	2.27	18.14	108.84	24.99	2923.95	648.33	2250.62
3.00	2.72	21.77	130.61	20.83	2923.95	648.33	2254.79

10 HOURS PER DAY

SPEED	ACRE/HOUR	ACRE/DAY	CAPACITY	COST	INCOME	YLD RED	PROFIT
0.50	0.45	4.53	27.21	114.67	2923.95	648.33	2160.94
1.00	0.91	9.07	54.42	57.34	2923.95	648.33	2218.28
1.50	1.36	13.60	81.63	38.22	2923.95	648.33	2237.39
2.00	1.81	18.14	108.84	28.67	2923.95	648.33	2246.95
2.50	2.27	22.67	136.05	22.93	2923.95	648.33	2252.68
3.00	2.72	27.21	163.26	19.11	2923.95	648.33	2256.50

APPENDIX D (Continued)

PURCHASE PRICE = 9000.00

8 HOURS PER DAY

SPEED	ACRE/HOUR	ACRE/DAY	CAPACITY	COST	INCOME	YLD RED	PROFIT
0.50	0.45	3.63	21.77	145.16	2923.95	648.33	2130.45
1.00	0.91	7.26	43.54	72.58	2922.95	648.33	2203.03
1.50	1.36	10.88	65.30	48.39	2923.95	648.33	2227.23
2.00	1.81	14.51	87.07	36.29	2923.95	648.33	2239.32
2.50	2.27	18.14	108.84	29.03	2923.95	648.33	2246.58
3.00	2.72	21.77	130.61	24.19	2923.95	648.33	2251.42

10 HOURS PER DAY

SPEED	ACRE/HOUR	ACRE/DAY	CAPACITY	COST	INCOME	YLD RED	PROFIT
0.50	0.45	4.53	27.21	131.94	2923.95	648.33	2143.67
1.00	0.91	9.07	54.42	65.97	2923.95	648.33	2209.64
1.50	1.36	13.60	81.63	43.98	2923.95	648.33	2231.63
2.00	1.81	18.14	108.84	32.99	2923.95	648.33	2242.63
2.50	2.27	22.67	136.05	26.39	2923.95	648.33	2249.23
3.00	2.72	27.21	163.26	21.99	2923.95	648.33	2253.62

PURCHASE PRICE = 11000.00

8 HOURS PER DAY

SPEED	ACRE/HOUR	ACRE/DAY	CAPACITY	COST	INCOME	YLD RED	PROFIT
0.50	0.45	3.63	21.77	165.37	2923.95	648.33	2110.25
1.00	0.91	7.26	43.54	82.68	2923.95	648.33	2192.93
1.50	1.36	10.88	65.30	55.12	2923.95	648.33	2220.49
2.00	1.81	14.51	87.07	41.34	2923.95	648.33	2234.27
2.50	2.27	18.14	108.84	33.07	2923.95	648.33	2242.54
3.00	2.72	21.77	130.61	27.56	2923.95	648.33	2248.05

10 HOURS PER DAY

SPEED	ACRE/HOUR	ACRE/DAY	CAPACITY	COST	INCOME	YLD RED	PROFIT
0.50	0.45	4.53	27.21	149.21	2923.95	648.33	2126.41
1.00	0.91	9.07	54.42	74.60	2923.95	648.33	2201.01
1.50	1.36	13.60	81.63	49.74	2923.95	648.33	2225.88
2.00	1.81	18.14	108.84	37.30	2923.95	648.33	2238.31
2.50	2.27	22.67	136.05	29.84	2923.95	648.33	2245.77
3.00	2.72	27.21	163.26	24.87	2923.95	648.33	2250.75

APPENDIX D (Continued)

PURCHASE PRICE = 13000.00

8 HOURS PER DAY

SPEED	ACRE/HOUR	ACRE/DAY	CAPACITY	COST	INCOME	YLD RED	PROFIT
0.50	0.45	3.63	21.77	185.57	2923.95	648.33	2090.04
1.00	0.91	7.26	43.54	92.79	2923.95	648.33	2182.83
1.50	1.36	10.88	65.30	61.86	2923.95	648.33	2213.76
2.00	1.81	14.51	87.07	46.39	2923.95	648.33	2229.22
2.50	2.27	18.14	108.84	37.11	2923.95	648.33	2238.50
3.00	2.72	21.77	130.61	30.93	2923.95	648.33	2244.69

10 HOURS PER DAY

SPEED	ACRE/HOUR	ACRE/DAY	CAPACITY	COST	INCOME	YLD RED	PROFIT
0.50	0.45	4.53	27.21	166.47	2923.95	648.33	2109.14
1.00	0.91	9.07	54.42	83.24	2923.95	648.33	2192.38
1.50	1.36	13.60	81.63	55.49	2923.95	648.33	2220.12
2.00	1.81	18.14	108.84	41.62	2923.95	648.33	2234.00
2.50	2.27	22.67	136.05	33.29	2923.95	648.33	2242.32
3.00	2.72	27.21	163.26	27.75	2923.95	648.33	2247.87

PURCHASE PRICE = 15000.00

8 HOURS PER DAY

SPEED	ACRE/HOUR	ACRE/DAY	CAPACITY	COST	INCOME	YLD RED	PROFIT
0.50	0.45	3.63	21.77	205.77	2923.95	648.33	2069.84
1.00	0.91	7.26	43.54	102.89	2923.95	648.33	2172.73
1.50	1.36	10.88	65.30	68.59	2923.95	648.33	2207.02
2.00	1.81	14.51	87.07	51.44	2923.95	648.33	2224.17
2.50	2.27	18.14	108.84	41.15	2923.95	648.33	2234.46
3.00	2.72	21.77	130.61	34.30	2923.95	648.33	2241.32

10 HOURS PER DAY

SPEED	ACRE/HOUR	ACRE/DAY	CAPACITY	COST	INCOME	YLD RED	PROFIT
0.50	0.45	4.53	27.21	183.74	2923.95	648.33	2091.88
1.00	0.91	9.07	54.42	91.87	2923.95	648.33	2183.75
1.50	1.36	13.60	81.63	61.25	2923.95	648.33	2214.37
2.00	1.81	18.14	108.84	45.93	2923.95	648.33	2229.68
2.50	2.27	22.67	136.05	36.75	2923.95	648.33	2238.87
3.00	2.72	27.21	163.26	30.62	2923.95	648.33	2244.99