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CAVEAT

It should be noted strongly at the outset that the NIMCO harvester used in the field experiments was the prototype machine. Many improvements have been made in this machine since this experiment was conducted, which will likely improve the profitability of the NIMCO relative to the other technologies. The results presented herein for the NIMCO may not be representative of the current capabilities of that machine.

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I. INTRODUCTION

The Problem of Harvesting Lowbush Blueberries

Lowbush, or wild, blueberries grow very close to the ground and because they are a relatively fragile fruit, care must be taken in harvesting them to avoid having crushed or damaged berries and too much foreign material mixed in with the harvested fruit. Until recently, almost all lowbush blueberries were raked by hand using a wooden or metal scoop (or rake) with teeth on the outside edge, requiring a lot of backbreaking labor. During the blueberry harvest all able-bodied people available were recruited to help with the raking. This scenario is still true for most of the blueberries harvested in Maine, although recent years have seen an increase in the use of several kinds of mechanical harvesters.

There are several reasons for the appearance of mechanical harvesting technologies. First, the technologies have been improved to the point that they are usable on lowbush blueberries. Second, as with many agricultural production activities that are labor-intensive, it has become increasingly difficult to recruit or hire enough rakers to complete the harvest in a timely manner. Third, the demand for lowbush blueberries is increasing, causing existing acreage to be managed more intensively for higher productivity and new acreage to come into production, making a larger total crop to be harvested at a time when the pool of harvest labor is shrinking.

The appearance of mechanical harvesters on the blueberry barrens and elsewhere in Maine has caused some concern for the workers who still gain all or part of their livelihood from blueberry raking. They see the harvesters as a potential threat to that livelihood, while the growers see the harvesters as a possible substitute for the harvest labor that is becoming more difficult to obtain.

The purpose of this research is to evaluate the new mechanical harvesting technologies and to compare them to the traditional technology of hand raking under different assumptions about prices, costs, farm size, and yield. It will provide information to growers about the circumstances where mechanical harvesting will be most useful and where the hand rakers can be used to the best advantage. The results reported here indicate that certain mechanical harvesting technologies will be more profitable under certain circumstances, but, by and large, hand raking will be the optimal technology to use on much of the blueberry land under most current and short-run future market and production conditions.

The report is divided into three main sections. First is the introduction and description of the harvesting technologies tested and the experiment conducted. Second is a section on the experiment results. For the reader disinterested in the statistical analysis of the experiment, the second section can be skipped without loss of continuity. The final section contains the economic results and the conclusions drawn from the study.

Description of the Harvesting Technologies

Four harvesting technologies were evaluated in the experiment. The three mechanical harvesters evaluated were the Bragg, the Darlington, and the NIMCO. These three were tested along with crews of hand rakers chosen randomly from the pool of rakers hired by the growers for the 1988 harvest season.

The Bragg Harvester

The Bragg Harvester

The Bragg harvester is manufactured by Bragg Lumber Company in Collingwood, Nova Scotia and is the principal mechanical harvester used by some of the largest blueberry growers in Maine and Canada. The harvester is mounted on two- or four-wheel-drive tractors. It is normally operated with one tractor operator and one other worker who rides on the back of the tractor, inspecting berries and providing fresh boxes for the berries dropping from the conveyor belt. The tractors range in size from 60 to 100 horsepower (hp) and provide more than ample power for the harvesting operation. Power is delivered to the harvester from the tractor, which drives the motor of a self-contained hydraulic system.

Blueberries are stripped from the bushes with a pick-up (harvesting) head which is 30 inches wide in the multiple-head units and 36 inches wide in the single-head units. The head design is essentially the same as that developed by Chisom Ryder in cooperation with the University of Maine Agricultural Engineering Department in 1970. Because the heads are narrower than the tractor and offset, it is necessary that all harvesting take place in the same direction. This requires the tractor to circle back after each pass to begin the next harvesting strip or to harvest the field in a circular fashion.

All harvesters perform best on level ground. The Bragg harvester adjusts to uneven terrain by way of two sensing wheels located ahead of the pick-up head. Because the harvester is hydraulic, the tractor tends to supply as much power as required. Consequently, plants, bushes, or other foreign material will yield to the force of the pick-up head. In blueberry fields that are being harvested for the second consecutive year, the bush is occasionally pulled from the field along with the blueberries—often necessitating downtime for head cleaning and possibly reducing future field productivity. The loss of bushes may be associated with stem height, which would be higher the second year after pruning. This problem is more prevalent at the borders of fields, and operators are advised to lift the head as the border of a field is reached. This research did not consider the effects of bushes pulled from the field. Casual observation during the trials suggests that it might be a factor important enough to warrant some future research. The effect of stem height was considered, but was found to be an insignificant factor in this test.

The Darlington Harvester

The Darlington harvester essentially is a cranberry harvester that has been modified for use with blueberries. It is a walk-behind, single-head unit, which is normally powered by a 5 hp stationary engine and requires a single operator with some box handling help. The harvesting head is 24 inches wide. It adjusts to uneven terrain with a roller that is as wide as the harvesting head. The roller, however, causes the harvester to tilt as it rises over moguls, digging into the soil on one side of the mogul and lifting above the berries on the other side. Due to the complicated nature and number of sprockets and pulleys on the Darlington, downtime may be a problem in some harvesting situations. Chains slip off and the raking teeth or pins in the head shear off frequently. If the teeth are not replaced immediately, the head will leave berries in the field. The head tends to pick up foreign material, and since the harvester has no cleaning blower, the

The Darlington Harvester

berries and foreign material are not separated. Thus, the Darlington harvester generally requires the use of a winnower.

The NIMCO Harvester

The NIMCO harvester is similar to the Darlington in many respects, except that it is a completely original design. The harvester is manufactured by Nashua Industrial Machine Co. in Nashua, New Hampshire. It is a walk-behind, single-head unit, which is normally powered by a 5 hp stationary engine and requires a single operator with some box handling help. The harvesting head is 24 inches wide and operates within 3/4 inch of ground level. It uses skid shoes to accommodate uneven terrain and rides up and over obstructions and foreign material. Any undesired material that enters the pick-up reel subsequently is removed

The NIMCO Harvester Prototype

from the berries with a built-in blower (winnower). The NIMCO has hardened teeth that resist breakage and are more easily replaced when necessary than are the Darlington's. In addition, the reel features a comb that removes debris from the teeth on each revolution. The NIMCO has a much less complicated design than the Darlington and uses a readily adjustable belt tightener to optimize the timing of conveyors from the reel to the collection box.

The Hand Rakers

The hand rakers chosen to participate in the project were typical of the mix of people commonly found working the blueberry harvest. Many were Washington County natives, but some came from as far away as Arkansas. Some were faster rakers than others and some were more careful than others to rake as many berries as possible from their assigned plots. They all supplied their own rakes and buckets.

The Experiment

The field tests were conducted over a four-day period during the 1988 blueberry harvest in Washington County, Maine. The tests were set up at four different locations, each designed to be typical of a combination of low- and high-yielding land and low- and high-stemmed plants. The experimental design was set up as a split-split plot design with five replications of each technology on 1/4 acre plots at each location.

One hypothesis was that some technologies would drop more berries than others, thus reducing the harvested yield relative to the potential yield in the field (as measured by the yield recoverable by the hand rakers). To test this, dropped berries were counted in four, randomly selected, 1/4 square foot sections of each plot after it was harvested.

Another hypothesis was that some technologies might be rougher on the berries than others, resulting in poorer quality berries delivered to the processing plant. To test this hypothesis, the number of split berries was counted in four, randomly chosen 1/2 pint samples from the harvested boxes from each plot before they were delivered to the plant.

To compare the total harvest acreage potential per season for each technology, the total time (in minutes) to harvest each plot was recorded. All blueberries were harvested into standard, plastic stacking boxes and loaded into trucks at the field every day for delivery to the processing plant. The berries from each plot were weighed separately at the plant, and box counts from each plot also were recorded as a check on the plot weights. All berries were left at the processing plant at the end of each day. Because of unexpected downtime and other events, not all of the technologies were able to be tested five times at each location. The NIMCO harvester was tested at only the first two locations; one high yield and one low yield, but both with low-stemmed plants. Consequently, the effect of stem height could not be evaluated for all four of the technologies. Standard, paired, statistical tests of the mean difference in harvest time and yield showed no difference between high- and low-stem locations for the other three technologies. We concluded that stem height was not an important factor and left it out of further experimental analysis. The statistical analysis presented in the next section is based, therefore, on the more consistent assumption of a two-way, unbalanced factorial design using analysis of variance (ANOVA) statistical techniques and linear regression techniques (Neter and Wasserman 1974).

The two factors analyzed are: potential yield of the field (high and low) and harvest technology (Bragg, Darlington, NIMCO, and hand rakers). The effect of these factors on harvest time, harvested yield, dropped berries, and split berries is presented in the next section.

II. THE EXPERIMENTAL RESULTS

Descriptive Summary of the Data

Overall mean values of the measured variables for the 1/4 acre plots harvested by each technology are presented in Tables 1 and 2. Since the mean values for some of the measured variables seemed to be quite different in the high- and low-yielding plots, the means are presented separately by potential yield. Statistical tests confirming this separation are presented below.

Table 1 contains the mean values for the plots with high potential yield (approximately 6,000 lbs per acre). The yields recovered in these plots by the Bragg, Darlington, and NIMCO were 60%, 67%, and 50%, respectively, of that recovered by the hand rakers. The average times to harvest a 1/4 acre plot for the Bragg, Darlington, and NIMCO were 6%, 36%, and 15%, respectively, of the hand rakers' time. Average split berries per 1/4 square foot ranged from 13.8 for the hand rakers to 19.15 for the Bragg. Average dropped berries per 1/2 pint sample ranged from 15.5 for the hand rakers to over 41 for the NIMCO.

Table 1. Mean Values of Measured Variables for Quarter-Acre Plots by Technology; High Potential Yield

Measured Variable	Technology: Bragg	Darlington	NIMCO	Hand Rakers
	Mean (Standard Deviation)			
Yield in Pounds	919.30	1022.00	715.40	1533.80
	(183.73)	(247.01)	(106.02)	(268.08)
Harvest Time in Minutes	27.57	193.78	79.80	535.60
	(3.05)	(43.66)	(4.60)	(232.77)
Box Count	41.30	41.00	31.00	67.00
	(7.79)	(8.40)	(4.64)	(11.35)
Average Split Berries	19.15	14.94	19.00	13.80
per 1/2 Pint	(10.64)	(2.11)	(3.97)	(6.35)
Average Dropped Berries	18.40	30.19	41.15	15.50
per 1/4 Square Foot	(4.66)	(11.80)	(14.67)	(9.04)
Number of Observations	10	4	5	10

For the plots with low potential yield (approximately 3,000 lbs per acre), recovered yields, relative to the potential yield recoverable by hand raking, were 62%, 68%, and 64% for the Bragg, Darlington and NIMCO harvesters (Table 2). The mean harvest times for the Bragg, Darlington, and NIMCO were 8%, 41%, and 23% of the hand rakers' time. Average split berries in the low yielding plots ranged from 13.4 for the Darlington to 20.06 for the Bragg. Average dropped berries ranged from a low of 7.3 for the hand rakers to a high of 27.8 for the NIMCO.

Table 2. Mean Values of Measured Variables for Quarter Acre Plots by Technology; Low Potential Yield

Measured Variable	Technology			
	Bragg	Darlington	NIMCO	Hand Rakers
	Mean (Standard Deviation)			
Yield in Pounds	471.44 (150.50)	533.80 (143.14)	495.20 (112.89)	781.13 (163.06)
Harvest Time in Minutes	24.12 (2.91)	125.06 (14.19)	69.20 (10.85)	302.13 (74.23)
Box Count	20.44 (5.63)	22.20 (3.56)	22.60 (5.47)	32.62 (5.43)
Average Split Berries per 1/2 Pint	20.06 (5.63)	13.35 (3.56)	15.90 (5.47)	16.34 (5.43)
Average Dropped Berries per 1/4 Square Foot	18.14 (8.99)	12.60 (6.20)	27.80 (10.04)	7.34 (3.19)
Number of Observations	9	5	5	8

ANOVA Results

The first set of hypotheses to be tested with the experimental information is whether there are statistically significant effects of technology choice, potential yield, and the interaction between these two factors on any of the measured variables (yield, harvest time, split or dropped berries) in the analysis. The appropriate statistical test for these hypotheses is the standard F test for the Type I sums of squares for each factor from an analysis of variance (ANOVA) model (Neter and Wasserman 1974). Tables 3-6 present ANOVA results for harvest time, yield, split berries, and dropped berries, respectively.

It is clear from Table 3 that both potential yield (F=10.77) and technology choice (F=47.83) have a statistically significant effect on the yield recovered from the plots. Since the interaction effect (yield x technology) also is statistically significant (F=4.07), the quantitative effect of technology choice on recovered yield is different, depending on whether the potential yield is high or low. Further analysis of recovered yield must, therefore, be performed separately for the high- and low-yielding plots.

The same qualitative results are true for the effect of potential yield (F=112.74) and technology choice (F=28.16) on harvest time (Table 4). The interaction effect is statistically significant (F=4.68) as well, so further analysis of harvest time is performed as with that of recovered yield.

Table 3. ANOVA Results for Recovered Yield

Source	DF	Type I Sum of Squares	F Value
Potential Yield	1	124857.05	10.77***[a]
Technology	3	1663227.78	47.83***
Yield x Technology	3	141437.55	4.07**

Model R^2 = .78; Model F = 23.78***; MSE = 11591.95; ERROR DF = 46.
[a]***(**) = Significant at the 99% (95%) level of confidence.

Table 4. ANOVA Results for Harvest Time

Source	DF	Type I Sum of Squares	F Value
Potential Yield	1	3943291.39	112.74***[a]
Technology	3	2954487.64	28.16***
Yield x Technology	3	491038.93	4.68***

Model R^2 = .81; Model F = 30.18***; MSE = 34977.66; ERROR DF = 48.
[a]*** = Significant at the 99% level of confidence.

The overall model for split berries is not statistically significant (F=1.70) (Table 5). The fact that the technology choice factor is statistically significant, is a necessary, but not sufficient, condition for the factor to influence the measured variable. The insignificance of the overall model takes precedence. We conclude, therefore, that the number of split berries in the harvested plots is not affected by potential yield or technology choice.

Table 5. ANOVA Results for Split Berries

Source	DF	Type I Sum of Squares	F Value
Potential Yield	1	4.45	0.171
Technology	3	242.16	3.06**[a]
Yield x Technology	3	66.91	0.85

Model R^2 = .20; Model F = 1.70; MSE = 26.38; ERROR DF = 48.
[a]** = Significant at the 95% level of confidence.

The number of dropped berries differs by both potential yield (F=10.32) and technology choice (F=12.29), but the quantitative effect of technology choice does not depend on the potential yield of the plots (F=1.88) (Table 6). Therefore, the information on dropped berries can be further analyzed by combining data from plots with high- and low-potential yield.

The ANOVA results provide information on which overall factors have a significant effect on the measured variables, but they do not indicate which factor

Table 6. ANOVA Results for Dropped Berries

Source	DF	Type I Sum of Squares	F Value
Potential Yield	1	926.51	10.32***[a]
Technology	3	3309.21	12.29***
Yield x Technology	3	506.93	1.88

Model R^2 = .52; Model F = 7.55***; MSE = 89.75; ERROR DF = 48.
[a]*** = Significant at the 99% level of confidence.

levels (or values in the case of a qualitative factor, such as technology choice) are responsible for the significance of the overall factor. For example, the information in Table 3 indicates that the yield recovered from the same field will be different for *at least one* technology, but it does not provide information on *which* technology (or technologies) are responsible for the statistical difference. It also does not give any information about the differences *between* technologies. To answer these questions, multiple comparisons of technology means are performed. Because the experimental design is unbalanced, the Tukey Studentized Range test is the most appropriate way to compare the differences in the means between the technology choices (SAS). This test will control the minimum experiment error rate and is a more powerful test than the other available means comparison tests when the sample sizes are unequal (Dunnett 1980).

The Tukey tests were performed to compare the four technology means for all four measured variables, separating the high- and low-yielding plots in the cases of recovered yield and harvest time. Information for split and dropped berries by potential yield was combined by considering all plots together in these two cases. The results of these comparisons appear in Tables 7-9.

Table 7. Tukey Studentized Tests for Means Comparison of Recovered Yield—High vs. Low Potential Yield

	Potential Yield	
Means Comparison	High	Low
	-difference between means- (lbs/quarter acre)	
Hand - Darlington	511.80**[a]	247.33**
Hand - Bragg	614.50**	285.93**
Hand - NIMCO	818.40**	309.68**
Darlington - Bragg	102.70	38.60
Darlington - NIMCO	306.60	62.36
Bragg - NIMCO	203.90	-23.76

[a]**Significant at the 95% level of confidence.

The test results for recovered yield are similar in the high- and low- yielding plots. All machine harvested plots recovered significantly less yield than the hand rakers, but no significant differences were found between pairs of machine harvesters (Table 7). For the measured harvesting time, all machine harvesters used significantly less time than the hand rakers in both high- and low-yield plots. In addition, the Bragg harvester took significantly less time than the Darlington in the low-yield plots (Table 8).

No significant differences could be found in paired comparisons of average split berries by technology choice (Table 9). This is consistent with the ANOVA results in Table 5. The NIMCO harvester averaged significantly more dropped berries than each of the other technology choices (Table 9). No significant differences could be found in the average number of dropped berries between any other pair of technologies, including the hand rakers vs. the Bragg or the hand rakers vs. the Darlington.

Table 8. Tukey Studentized Tests for Means Comparison of Harvest Time—High vs. Low Potential Yield

Means Comparison	Potential Yield	
	High	Low
	-difference between means- (minutes per 1/4 acre)	
Hand—Darlington	341.82**[a]	177.06**
Hand—Bragg	455.80**	232.93**
Hand—NIMCO	508.03**	278.00**
Darlington—Bragg	166.20	100.94**
Darlington—NIMCO	113.97	55.86
Bragg—NIMCO	-52.23	-45.08

[a]**Significant at the 95% level of confidence.

Table 9. Tukey Studentized Range Tests for Means Comparison for Split and Dropped Berries

Means Comparison	Split Berries per 1/2 pint	Dropped Berries per 1/4 sq. ft.
	-difference between means-	
Hand—Darlington	0.88	-8.54
Hand—NIMCO	-2.52	22.60**[a]
Hand—Bragg	-4.25	-6.80
Darlington—Bragg	-5.13	1.75
Darlington—NIMCO	-3.39	14.06**
Bragg—NIMCO	1.73	15.80**

[a]**Significant at the 95% level of confidence.

Conclusions from the Experimental Data

When compared to the traditional technology of hand raking blueberries, the machine harvesters do appear to save a significant amount of time. The trade-off is that less yield can be recovered from a field using any of the machine harvesters relative to the yield recovered by the hand rakers. The quality of the harvested berries, as measured crudely by the average number of split berries, does not appear to be significantly different between technologies. Although the NIMCO tended to leave more berries on the ground than the other technologies, its overall recovered yield did not differ from either of the other two machine harvesters.

III. THE ECONOMIC RESULTS

Introduction

The experiment results, while essential for determining the relative profitability of the technologies tested, cannot be interpreted directly to yield conclusions as to which technology is economically superior. This is because all of the variables measured (yield, time, split berries, and dropped berries) contribute to the total cost or total revenue of each technology. For example, knowing how much yield can be recovered by a technology is meaningless in an economic sense unless the time required to recover it, and possibly, some notion of the quality of the recovered yield is considered also. The economic analysis, therefore, draws from the experiment results and from information on current prices and practices in the industry to produce information in the form from which choices can be made.

Certain underlying assumptions must be made when conducting the economic analysis, determining, to some degree, the end results. These assumptions are listed below so the reader can judge fairly the results that follow.

Assumptions Maintained Throughout the Economic Analysis

General

1. The fields to be harvested are flat, smooth, and relatively free of rocks or other obstructions. This is an important underlying assumption when interpreting the economic results presented below. Much of the blueberry land is rough and rocky and not well-suited to the use of any of the machines tested.
2. The length of the harvest season is five weeks, with a six-day work week and one-half day lost per week due to inclement weather. This results in a 27.5 day harvest season for all technologies.
3. Total acreage is allocated evenly among the machines used in those cases where the acreage to be harvested requires multiple harvesters. The resulting excess seasonal capacity of each harvester used is ignored—i.e., we ignore any opportunity for custom harvesting with the unused portion of the machines' maximum, seasonal harvesting capacity. Annual machinery costs presented here would be lower by the amount of *net* revenue from the custom work in cases where opportunity for custom harvesting exists.
4. We assume that potential yield has little impact on the time required to harvest by machine. There is some evidence that difference in machine harvesting time between extreme yield levels is statistically significant, but either the difference is very small, as in the case of the Bragg and NIMCO, or variation in harvest time in the experimental data is too large to discern any reli-

able functional relationship between time and yield density, as in the case of the Darlington.

5. Yield recovery rates for each machine harvesting technology are estimated as a percentage of yield recovery potential by hand harvesting. A mean percentage yield recoverable was estimated for each technology over all yield levels. The Bragg was estimated to recover 59.0% of the hand-raked harvest, the Darlington, 62.6%, and the NIMCO, 50.5%. These rates are assumed to be constant over all potential yield levels throughout the economic analysis. The reader is referred to the section on the experiment results for an elaboration of these assumptions.
6. The annual interest rate on operating capital is 9%, and the operating capital required is for 60 days around harvest. All machinery is amortized using the capital recovery method and an inflation adjusted, real interest rate of 4% per year over the useful life of the machine (Boehlje and Eidman 1984). The use of an inflation adjusted interest rate assures that the opportunity cost of payments in later years are accounted for in dollars with purchasing power equal to the purchasing power of a dollar today and that the annual costs are not distorted by the effects of inflation. This is a necessary assumption when all other prices and costs are denominated in current dollars.
7. When winnowing is required, we assume that two rakers or machines share one winnowing machine.
8. All property taxes and insurance charges are based on those presently prevailing in Washington County, Maine. The analyses are performed ignoring the income tax effects of any of the technologies.
9. Fuel cost is assumed to be $0.95 per gallon for applicable technologies.

The Bragg Harvester

1. We assume a two-headed harvester is employed with a purchase list price of $31,000, a 20 year useful life, and a $0 salvage value at the end of 20 years. One-and three-headed Bragg Harvesters are available and are used by some growers. We used the most common configuration for this analysis.
2. We assume a 70 hp, 4-wheel-drive tractor is operated jointly with the harvester with a purchase price of $31,000, a 20 year useful life, and a $0 salvage value at the end of 20 years. One fourth of the tractor ownership costs are attributed to the harvesting operation. Average fuel use is 1.5 gallons per hour. It is possible to use a 2-wheel-drive tractor for many field operations in blueberry production. Assuming the use of a 70 hp, 2-wheel drive tractor would lower the purchase price by approximately $6,000. The alternative assumption, however, makes very little difference in the per acre harvesting costs presented below, since the purchase price is amortized over 20 years, and only one fourth of its use is attributed to the harvesting operation.

3. The Bragg harvester is used an average of 10 hours per day and can harvest 5.76 acres per day.
4. Lubrication costs are estimated to be 15% of fuel costs.
5. Wages are paid hourly, benefits accrue at the rate of 10% of wages, and a bonus is paid based on the number of boxes harvested per hour. We assume a harvest rate of 65 boxes per hour.
6. Repair costs for the 4-wheel-drive tractor are estimated using the appropriate repair category and estimated hours of use (Boehlje and Eidman 1984). Repair costs for the harvester are estimated, based on industry sources, at $4.09 per hour of use.

The Darlington Harvester

1. Purchase list price is $3,320, useful life is 20 years, and salvage value after 20 years is $0.
2. Fuel consumption is .75 gallons per hour.
3. The Darlington is used 8 hours per day and can harvest approximately 1/2 acre per day.
4. Users and vendors of the Darlington recommend that planned use per harvester be no more than 12–14 days per season due to repair and maintenance downtime. We maintain this assumption throughout the analysis.
5. Approximately one winnowing machine is required for every two harvesters. One winnowing machine is shared by three harvesters in cases when an odd number of harvesters are employed.
6. One box attendant is required for approximately every two harvesters. It is assumed, therefore, that the box attendants' total hours are one-half the total harvester operators' hours.
7. Benefits are paid to workers at the rate of 10% of wages.
8. Repair costs for the harvester are estimated, based on industry sources, at $1.12 per hour of use. A lump sum of $32.50 seasonal repair cost is estimated for each winnowing unit based on its 20-year useful life, $650 list price, and a linear annual repair cost function, assuming a total accumulated repair cost equal to 100% of list.

The NIMCO Harvester

1. Purchase list price is $8,000, useful life is 20 years, salvage value after 20 years is $0.
2. Fuel consumption is .75 gallons per hour.
3. The NIMCO is used 8 hours per day and can harvest 1.6 acres per day.
4. We assume one additional worker per two machines for box handling.
5. A mechanic is employed at a wage independent of the harvesting crew to conduct daily maintenance equivalent to 15 minutes per harvester employed. The harvesting crew and mechanic receive benefits at 10% of wages.

6. Per unit harvester repair costs can only be roughly approximated from industry sources at $0.34 per hour of use.

Hand Raking Crews

1. The number of rakers required to harvest acreage increases linearly with yield density per acre. The following relationship (Model F=23.23, significant at the 99% confidence level) was estimated from the experimental data using linear regression techniques:

$$T = -10.14 + 0.3685\,Y$$
$$(97.44)\quad(0.0765)$$

where:

T = Time in minutes to harvest a 1/4 acre plot.

Y = Potential yield of the plot.

The numbers in parentheses are the standard errors of the estimates.

From this regression, assuming the hand rakers work 6 hours per day, the relationship between acres harvested per day by the hand rakers and the potential yield of the field is:

ACRES HARVESTED
PER RAKER PER DAY = 0.51 - (0.0000573 x POTENTIAL YIELD).

This indicates that at a potential yield of 3,000 lbs per acre the average harvest rate per raker per day is 0.338 acres and at 6,000 lbs, 0.166 acres. The number of rakers required to harvest the acreage increases proportionately, as acres harvested per day decreases with increasing yield levels.

2. Housing and supervisory costs are approximately $1.15 per box.
3. Stringing and removal costs are $13.20 per acre.
4. Winnowing and miscellaneous costs are charged on a per worker basis at $16.00.
5. The current box rate paid to rakers averages $2.75 per box.

Relative Profitability Using Current Prices and Wages

Since both revenue and harvest costs are affected by technology choice, the relative profitabilities can be assessed by comparing the return over harvesting costs for each technology under different circumstances. Tables 10-17 present the baseline budgets for each technology and potential yield assumption for a representative, 100-acre farm under the price and wage conditions existing in 1988 in Washington County, Maine. These budgets are presented to acquaint the reader with the method of calculation of the return over harvesting cost for each technology. The calculations underlying the sensitivity analysis presented later are omitted, but all per acre returns over harvesting costs that follow are calculated by the same methods as presented in Tables 10-17.

In 1988, the average field price for blueberries ($.52/pound) was higher than it had been since 1982 (Hoelper et al. 1988). With this field price, the hand rakers appear to be the most profitable way to harvest blueberries on a 100-acre farm at current wage and box rates, regardless of the average potential yield of the farm. The Bragg harvester is the next most profitable technology under these conditions.

Table 10. Baseline Budget for the Bragg Harvester at Current Wages and Field Price for 100 Acres; Low Yield

PRODUCTION ASSUMPTIONS		
Maximum Yield Potential (Lbs/Acre):	3000	
Recovery Rate for Harvester (%):	59	
Recoverable Yield (Lbs/Acre):	1770.0	
Average Field Price ($/Lb):	$0.52	
TOTAL REVENUE		$92,040.00
OPERATING COSTS		
Fuel	$247.40	
Lube	$37.11	
TOTAL FUEL AND LUBE COSTS		$284.51
Repairs		
Tractor	$53.95	
Harvester	$709.80	
TOTAL REPAIR COSTS		$763.75
Labor		
Wages	$1,909.72	
Benefits	$190.97	
Bonuses	$2,256.94	
TOTAL LABOR COSTS		$4,357.63
TOTAL NON-INTEREST OPERATING COSTS		$5,405.89
INTEREST ON OPERATING CAPITAL		80.56
TOTAL OPERATING COSTS		$5,486.45
OWNERSHIP COSTS		
Tractors		
Depreciation and Interest	$2,281.03	
Insurance	$248.00	
Housing	$193.75	
Taxes	$77.50	
TOTAL TRACTOR COSTS		$2,800.28
Tractor utilized at 25% for harvesting purposes:		$700.07
Harvesters		
Depreciation and Interest	$2,281.03	
Insurance	$248.00	
Housing	$193.75	
Taxes	$77.50	
TOTAL HARVESTER COSTS		$2,800.28
TOTAL OWNERSHIP COSTS		$3,500.35
TOTAL ANNUAL HARVESTING COST FOR SPECIFIED ACREAGE		$8,986.80
TOTAL ANNUAL HARVESTING COST PER ACRE		$89.87
RETURN OVER HARVESTING COST		
TOTAL	$83,053.00	
PER ACRE	$830.53	

Table 11. Baseline Budget for the Bragg Harvester at Current Wages and Field Price for 100 Acres; High Yield

PRODUCTION ASSUMPTIONS		
Maximum Yield Potential (Lbs/Acre):	6000	
Recovery Rate for Harvester (%):	59	
Recoverable Yield (Lbs/Acre):	3540.0	
Average Field Price ($/Lb):	$0.52	
TOTAL REVENUE		$184,080.00
OPERATING COSTS		
Fuel	$247.40	
Lube	$37.11	
TOTAL FUEL AND LUBE COSTS		$284.51
Repairs		
Tractor	$53.95	
Harvester	$709.80	
TOTAL REPAIR COSTS		$763.75
Labor		
Wages	$1,909.72	
Benefits	$190.97	
Bonuses	$2,256.94	
TOTAL LABOR COSTS'		$4,357.63
TOTAL NON-INTEREST OPERATING COSTS		$5,405.89
INTEREST ON OPERATING CAPITAL		$80.56
TOTAL OPERATING COSTS		$5,486.45
OWNERSHIP COSTS		
Tractors		
Depreciation and Interest	$2,281.03	
Insurance	$248.00	
Housing	$193.75	
Taxes	$77.50	
TOTAL TRACTOR COSTS		$2,800.28
Tractor utilized at 25% for harvesting purposes:		$700.07
Harvesters		
Depreciation and Interest	$2,281.03	
Insurance	$248.00	
Housing	$193.75	
Taxes	$77.50	
TOTAL HARVESTER COSTS		$2,800.28
TOTAL OWNERSHIP COSTS		$3,500.35
TOTAL ANNUAL HARVESTING COST FOR SPECIFIED ACREAGE		$8,986.80
TOTAL ANNUAL HARVESTING COST PER ACRE		$89.87
RETURN OVER HARVESTING COST		
TOTAL	$175,093.00	
PER ACRE	$1,750.93	

Table 12. Baseline Budget for the Darlington Harvester at Current Wages and Field Price for 100 Acres; Low Yield

PRODUCTION ASSUMPTIONS		
Maximum Yield Potential (Lbs/Acre):	3000	
Recovery Rate for Harvester (%):	62.6	
Recoverable Yield (Lbs/Acre):	1878.0	
Average Field Price ($/Lb):	$0.52	
TOTAL REVENUE		$97,656.00
OPERATING COSTS		
Fuel	$1,140.00	
TOTAL FUEL AND LUBE COSTS		$1,140.00
Repairs		
Harvester	$1,792.00	
Winnower	$227.50	
TOTAL REPAIR COSTS		$2,019.50
Labor		
Wages	$13,200.00	
Benefits	$1,320.00	
TOTAL LABOR COSTS		$14,520.00
TOTAL NON-INTEREST OPERATING COSTS		$17,679.50
INTEREST ON OPERATING CAPITAL		$263.47
TOTAL OPERATING COSTS		$17,942.97
OWNERSHIP COSTS		
Harvesters		
Depreciation and Interest	$3,664.37	
Insurance	$398.40	
Housing	$311.25	
Taxes	$124.50	
TOTAL HARVESTER COSTS		$4,498.52
Winnowers		
Depreciation and Interest	$334.80	
Insurance	$36.40	
Housing	$28.44	
Taxes	$11.38	
TOTAL WINNOWER COSTS		$411.02
TOTAL OWNERSHIP COSTS		$4,909.54
TOTAL ANNUAL HARVESTING COST FOR SPECIFIED ACREAGE		$22,852.51
TOTAL ANNUAL HARVESTING COST PER ACRE		$228.53
RETURN OVER HARVESTING COST		
TOTAL	$74,803.00	
PER ACRE	$748.03	

Table 13. Baseline Budget for the Darlington Harvester at Current Wages and Field Price for 100 Acres; High Yield

PRODUCTION ASSUMPTIONS		
Maximum Yield Potential (Lbs/Acre):	6000	
Recovery Rate for Harvester (%):	62.6	
Recoverable Yield (Lbs/Acre):	3756.0	
Average Field Price ($/Lb):	$0.52	
TOTAL REVENUE		$195,312.00
OPERATING COSTS		
Fuel	$1,140.00	
TOTAL FUEL AND LUBE COSTS		$1,140.00
Repairs		
Harvester	$1,792.00	
Winnower	$227.50	
TOTAL REPAIR COSTS		$2,019.50
Labor		
Wages	$13,200.00	
Benefits	$1,320.00	
TOTAL LABOR COSTS		$14,520.00
TOTAL NON-INTEREST OPERATING COSTS		$17,679.50
INTEREST ON OPERATING CAPITAL		$263.47
TOTAL OPERATING COSTS		$17,942.97
OWNERSHIP COSTS		
Harvesters		
Depreciation and Interest	$3,664.37	
Insurance	$398.40	
Housing	$311.25	
Taxes	$124.50	
TOTAL HARVESTER COSTS		$4,498.52
Winnowers		
Depreciation and Interest	$334.80	
Insurance	$36.40	
Housing	$28.44	
Taxes	$11.38	
TOTAL WINNOWER COSTS		$411.02
TOTAL OWNERSHIP COSTS		$4,909.54
TOTAL ANNUAL HARVESTING COST FOR SPECIFIED ACREAGE		$22,852.50
TOTAL ANNUAL HARVESTING COST PER ACRE		$228.53
RETURN OVER HARVESTING COST		
TOTAL	$172,459.00	
PER ACRE	$1,724.59	

Table 14. Baseline Budget for the NIMCO Harvester at Current Wages and Field Price for 100 Acres; Low Yield

PRODUCTION ASSUMPTIONS		
Maximum Yield Potential (Lbs/Acre):	3000	
Recovery Rate for Harvester (%):	50.5	
Recoverable Yield (Lbs/Acre):	1515.0	
Average Field Price ($/Lb):	$0.52	
TOTAL REVENUE		$78,780.00
OPERATING COSTS		
Fuel	$356.25	
TOTAL FUEL AND LUBE COSTS		$356.25
Repairs		
Harvester	$170.00	
Maintenance	$93.75	
TOTAL REPAIR COSTS		$263.75
Labor		
Wages	$4,125.00	
Benefits		
Workers	$412.50	
Mechanic	$9.38	
Total Benefits	$421.88	
TOTAL LABOR COSTS		$4,546.88
TOTAL NON-INTEREST OPERATING COSTS		$5,166.88
INTEREST ON OPERATING CAPITAL		$77.00
TOTAL OPERATING COSTS		$5,243.88
OWNERSHIP COSTS		
Harvesters		
Depreciation and Interest	$1,765.96	
Insurance	$192.00	
Housing	$150.00	
Taxes	$60.00	
TOTAL HARVESTER COSTS		$2,167.96
TOTAL OWNERSHIP COSTS		$2,167.96
TOTAL ANNUAL HARVESTING COST FOR SPECIFIED ACREAGE		$7,411.84
TOTAL ANNUAL HARVESTING COST PER ACRE		$74.12
RETURN OVER HARVESTING COST		
TOTAL	$71,368.00	
PER ACRE	$713.68	

Table 15. Baseline Budget for the NIMCO Harvester at Current Wages and Field Price for 100 Acres; High Yield

PRODUCTION ASSUMPTIONS		
Maximum Yield Potential (Lbs/Acre):	6000	
Recovery Rate for Harvester (%):	50.5	
Recoverable Yield (Lbs/Acre):	3030.0	
Average Field Price ($/Lb):	$0.52	
TOTAL REVENUE		$157,560.00
OPERATING COSTS		
Fuel	$356.25	
TOTAL FUEL AND LUBE COSTS		$356.25
Repairs		
Harvester	$170.00	
Maintenance	$93.75	
TOTAL REPAIR COSTS		$263.75
Labor		
Wages	$4,125.00	
Benefits		
Workers	$412.50	
Mechanic	$9.38	
Total Benefits	$421.88	
TOTAL LABOR COSTS		$4,546.88
TOTAL NON-INTEREST OPERATING COSTS		$5,166.88
INTEREST ON OPERATING CAPITAL		$77.00
TOTAL OPERATING COSTS		$5,243.88
OWNERSHIP COSTS		
Harvesters		
Depreciation and Interest	$1,765.96	
Insurance	$192.00	
Housing	$150.00	
Taxes	$60.00	
TOTAL HARVESTER COSTS		$2,167.96
TOTAL OWNERSHIP COSTS		$2,167.96
TOTAL ANNUAL HARVESTING COST FOR SPECIFIED ACREAGE		$7,411.84
TOTAL ANNUAL HARVESTING COST PER ACRE		$74.12
RETURN OVER HARVESTING COST		
TOTAL	$150,148.00	
PER ACRE	$1501.48	

Table 16. Baseline Budget for Hand Harvesting at Current Wages and Field Price for 100 Acres; Low Yield

PRODUCTION ASSUMPTIONS		
Maximum Yield Potential (Lbs/Acre):	3000	
Recoverable Yield (Lbs/Acre):	3000	
Average Field Price ($/Lb):	$0.52	
TOTAL REVENUE		$156,000.00
OPERATING COSTS		
Wages		
Rakers	$35,106.38	
Supervisors	$12,765.96	
TOTAL WAGES		$47,872.34
Field Costs		
Stringing and Removal	$1,320.00	
Worker Housing	$1,914.89	
Winnowing and Miscellaneous	$172.11	
TOTAL FIELD COSTS		$3,407.00
TOTAL NON-INTEREST OPERATING COSTS		$51,279.34
INTEREST ON OPERATING CAPITAL		$764.20
TOTAL OPERATING COSTS		$52,043.54
TOTAL ANNUAL HARVESTING COST FOR SPECIFIED ACREAGE		$52,043.54
TOTAL ANNUAL HARVESTING COST PER ACRE		$520.44
RETURN OVER HARVESTING COST		
TOTAL	$103,956.00	
PER ACRE	$1,039.56	

Table 17. Baseline Budget for Hand Harvesting at Current Wages and Field Price for 100 Acres; High Yield

PRODUCTION ASSUMPTIONS		
Maximum Yield Potential (Lbs/Acre):	6000	
Recoverable Yield (Lbs/Acre):	6000	
Average Field Price ($/lb):	$0.52	
TOTAL REVENUE		$312,000.00
OPERATING COSTS		
Wages		
Rakers	$70,212.77	
Supervisors	$25,531.91	
TOTAL WAGES		$95,744.68
Field Costs		
Stringing and Removal	$1,320.00	
Worker Housing	$3,829.79	
Winnowing and Miscellaneous	$350.78	
TOTAL FIELD COSTS		$5,500.57
TOTAL NON-INTEREST OPERATING COSTS		$101,245.25
INTEREST ON OPERATING CAPITAL		$1,508.82
TOTAL OPERATING COSTS		$102,754.07
TOTAL ANNUAL HARVESTING COST FOR SPECIFIED ACREAGE		$102,754.07
TOTAL ANNUAL HARVESTING COST PER ACRE		$1,027.54
RETURN OVER HARVESTING COST		
TOTAL	$209,246.00	
PER ACRE	$2,092.46	

Relative Profitability with Different Farm Sizes and Economic Conditions

The results presented above are based on the assumption of a 100-acre farm and the economic conditions as they existed during the 1988 season. In particular, they are dependent upon the 1988 field price and wages paid for rakers and other required labor, as well as upon farm size. All of these factors influence the return over harvesting costs for each technology, and the relative profitability of the technologies could change with changing values of these factors. The results of sensitivity analysis on the return over harvesting costs are presented in this section.

The Effect of Farm Size

Figure 1 shows how the relative profitability of the harvesting technologies changes as farm size increases, given an average potential yield of 4,500 lbs per acre, 1988 wage rates, and a field price of $0.41 per lb. The $0.41 field price represents the average field price reported from 1985-1987 (DeGomez, pers. comm. 1989). The ratcheting effect observed in Figure 1 for the machines occurs where acreage increases beyond the seasonal capability of the existing number of machines, and an additional machine is added. At $.41 per lb for blueberries and current wage and box rates, the effect of farm size is small. The only change in relative profitability occurs at about 50 acres, where the Bragg becomes more profitable than the Darlington. Hand raking yields the greatest return over harvesting costs under these conditions, regardless of farm size.

The Effect of Potential Yield

Figures 2 and 3 show how the return over harvesting costs changes for each technology as the potential yield increases. Hand raking is the most profitable technology for the small farm (20 acres), as well as for the larger farm (200 acres), at every level of potential yield between 3,000 and 6,000 lbs per acre. This conclusion was reached assuming a field price of $0.41 per lb and 1988 wage rates. The Darlington was the most profitable machine harvester on the small farm, and the Bragg the most profitable on the larger farm.

The Effect of Labor Costs

The effect of changes in labor cost was estimated for each technology given a constant field price of $0.41 per lb and an average potential yield of 4,500 lbs per acre. Changes in wage rates were based on a percentage of 1988 wages in consideration of the various wage structures associated with the different technologies.

Figures 4 and 5 depict the changes in the relative profitability of the technologies on a small and large farm, respectively. Wage and box rates must increase by almost 40% over 1988 levels on the small farm before any mechanical

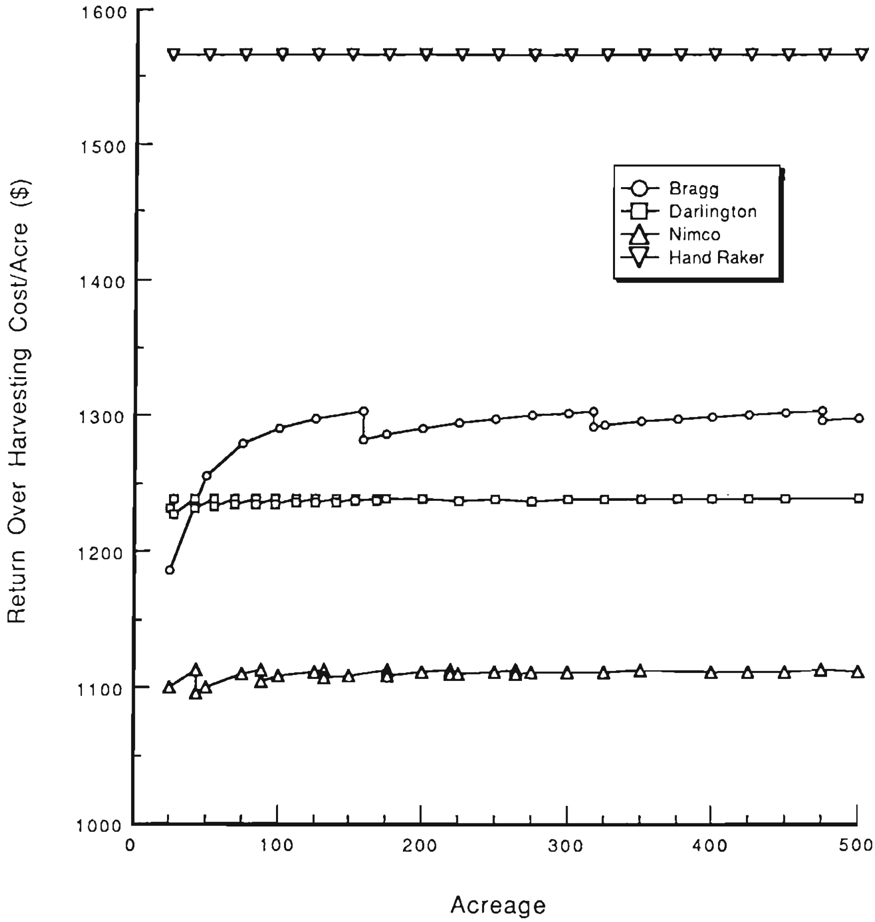

Figure 1. The Effect of Farm Size On the Relative Returns Over Harvesting Costs for the Four Harvesting Technologies.

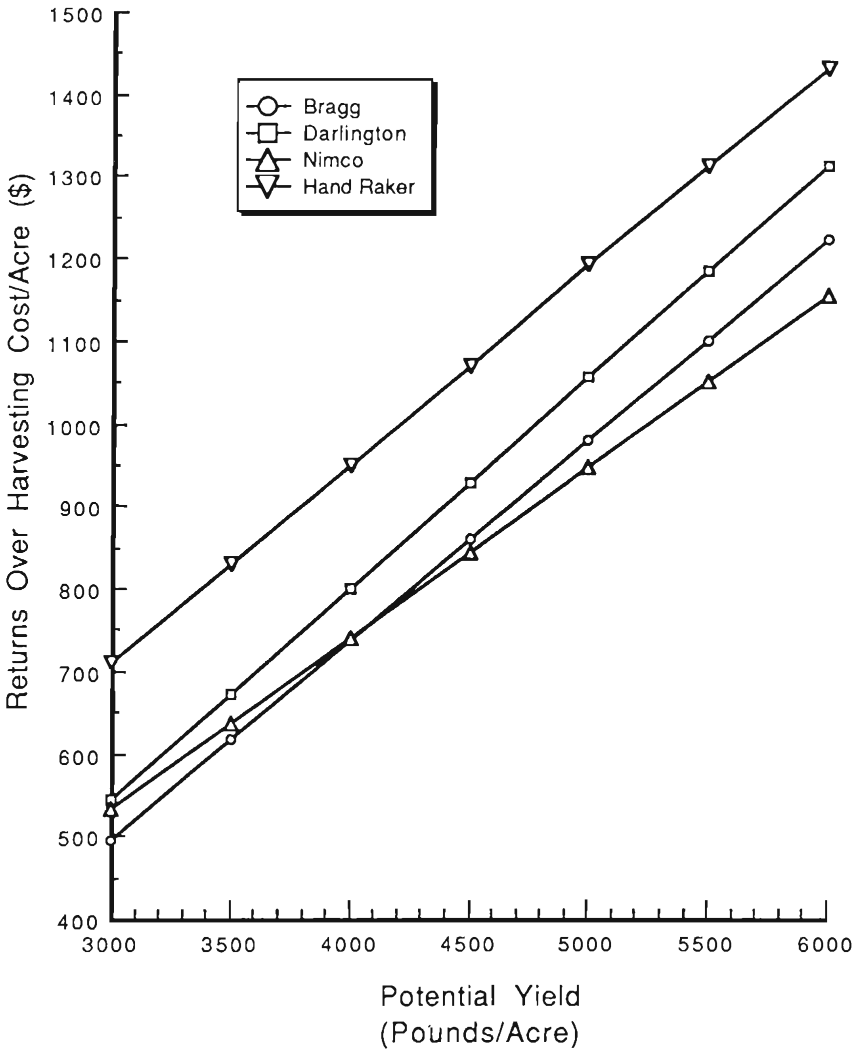

Figure 2. The Effect of Potential Yield On the Relative Returns Over Harvesting Costs for the Four Harvesting Technologies; Given a Field Price of $0.41/lb, 1988 Wages Rates, and a 20-Acre Farm.

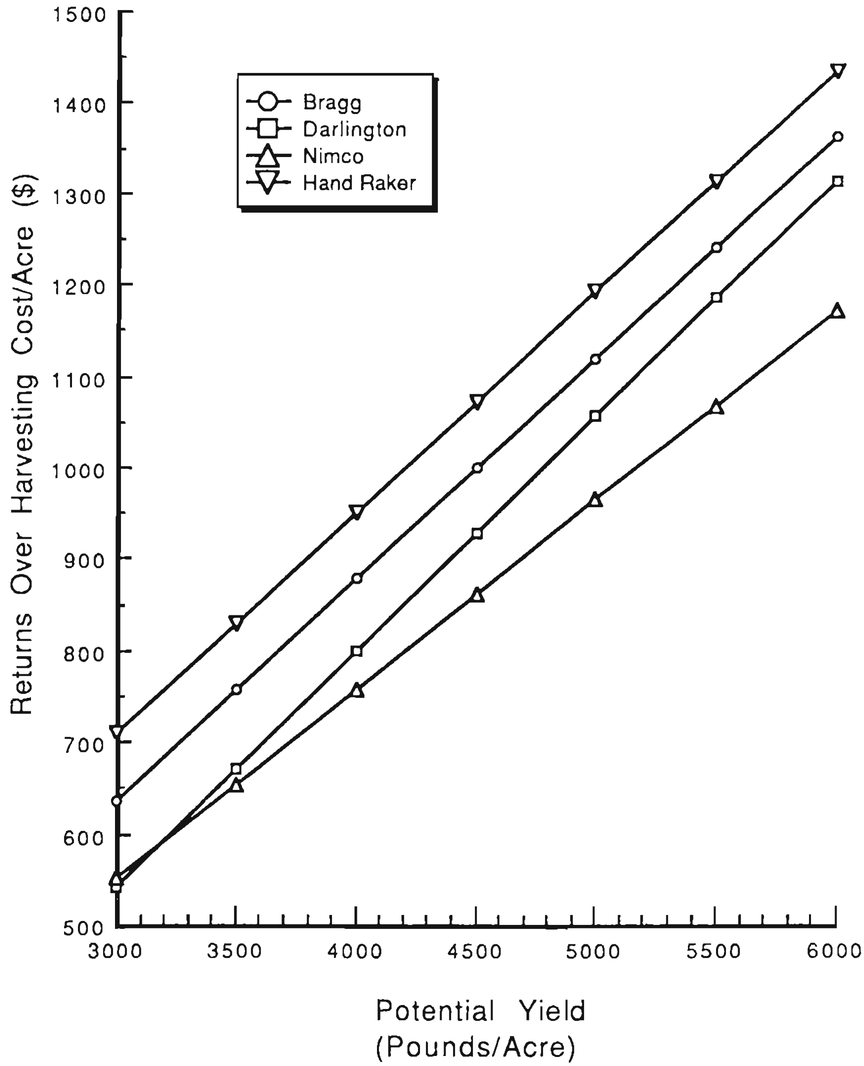

Figure 3. The Effect of Potential Yield On the Relative Returns Over Harvesting Costs for the Four Harvesting Technologies; Given a Field Price of $0.41/lb, 1988 Wages Rates, and a 200-Acre Farm.

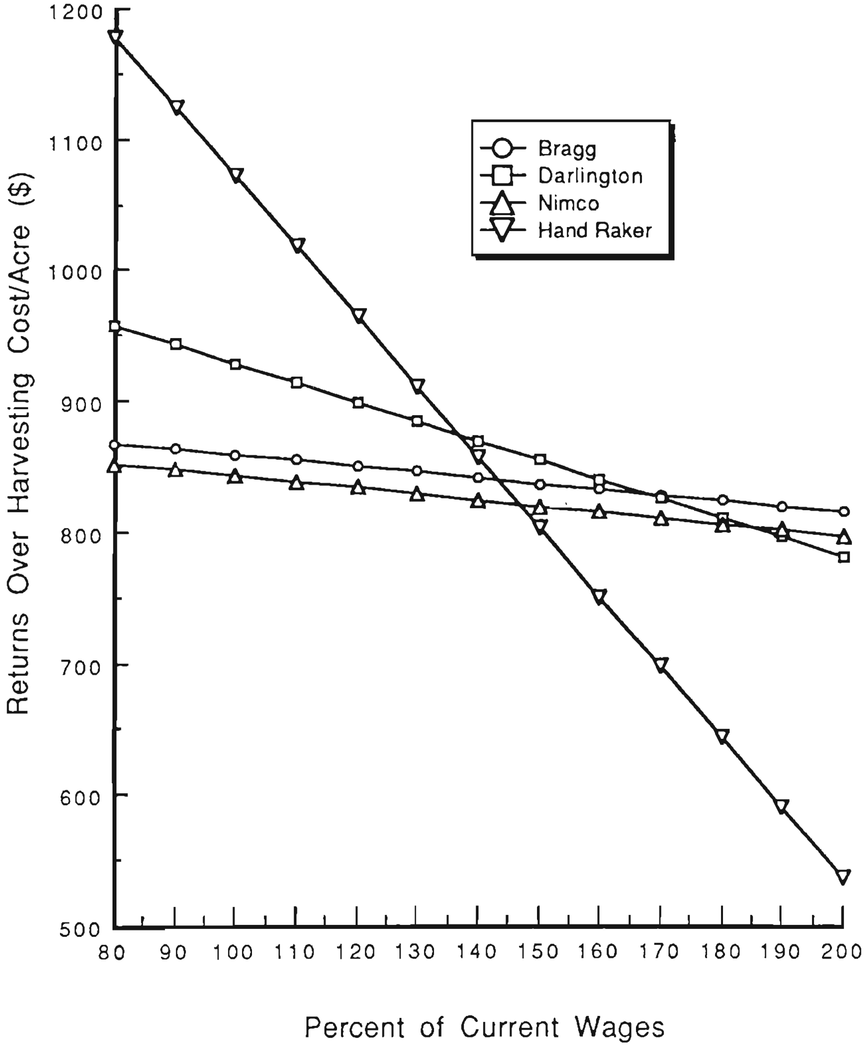

Figure 4. The Effect of Wage Rates On the Relative Returns Over Harvesting Costs for the Four Harvesting Technologies; Given a Field Price of $0.41/lb, 1988 Wage Rates, and a 20-Acre Farm.

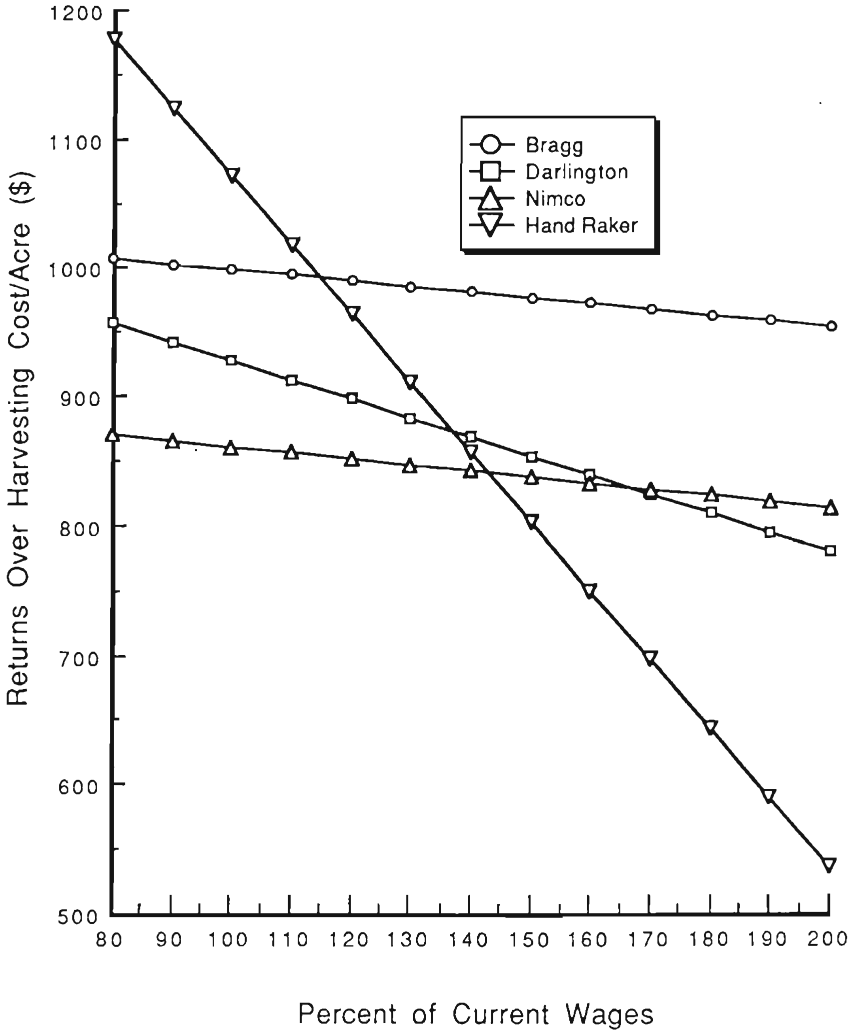

Figure 5. The Effect of Wage Rates On the Relative Returns Over Harvesting Costs for the Four Harvesting Technologies; Given a Field Price of $0.41/lb, 1988 Wage Rates, and a 200-Acre Farm.

harvesting becomes more profitable than hand raking (Figure 4). At that point, the Darlington yields the largest return over harvesting costs. Wages and box rates must increase by 70% before the Bragg harvester becomes the most profitable alternative for the small farm.

The most profitable technology for a 200-acre farm, however, changes with a relatively small increase in wage and box rates, about 15% above 1988 levels (Figure 5). At that point, the Bragg yields the largest return over harvesting costs. The hand rakers are still more profitable than the machines on the larger farms at lower wage and box rates. The less labor intensive technologies become more profitable relative to hand raking as labor costs increase.

The Effect of Blueberry Field Price

Figures 6-9 show how changes in field price affect the relative profitability of the various technologies under several sets of assumptions. Figure 6 depicts the situation of a small farm with low potential yield. In this case hand raking is the preferred technology across all reasonable short-run expectations of field price.

For the larger farm with low potential yield, the Bragg harvester is preferred at low field prices, but if the field price is expected to average above $.36 per lb over the life of the machine (in real terms), then hand raking is the preferred technology (Figure 7).

Figure 8 shows that a small farm, with high potential yield and 1988 wage levels, would prefer to use hand rakers at expected field prices above $.36 per lb. The Darlington would be the preferred technology for the small farm at lower field prices. The break-even field price for the larger farm between hand rakers and machine harvesting is $.38 per lb (Figure 9). In this case the Bragg would be preferred at field prices lower than $.38 per lb, and hand rakers preferred if field prices are higher than this break-even price, given the assumptions of 1988 wages and high yield levels.

The additional recoverable yield from hand raking becomes more valuable, as the blueberry price increases relative to other costs, which explains the above results. Of course, there is a field price above which it would even pay to idle machines already owned and harvest the berries by hand. This scenario becomes less likely, however, as the machine harvesters are improved and/or as labor costs increase.

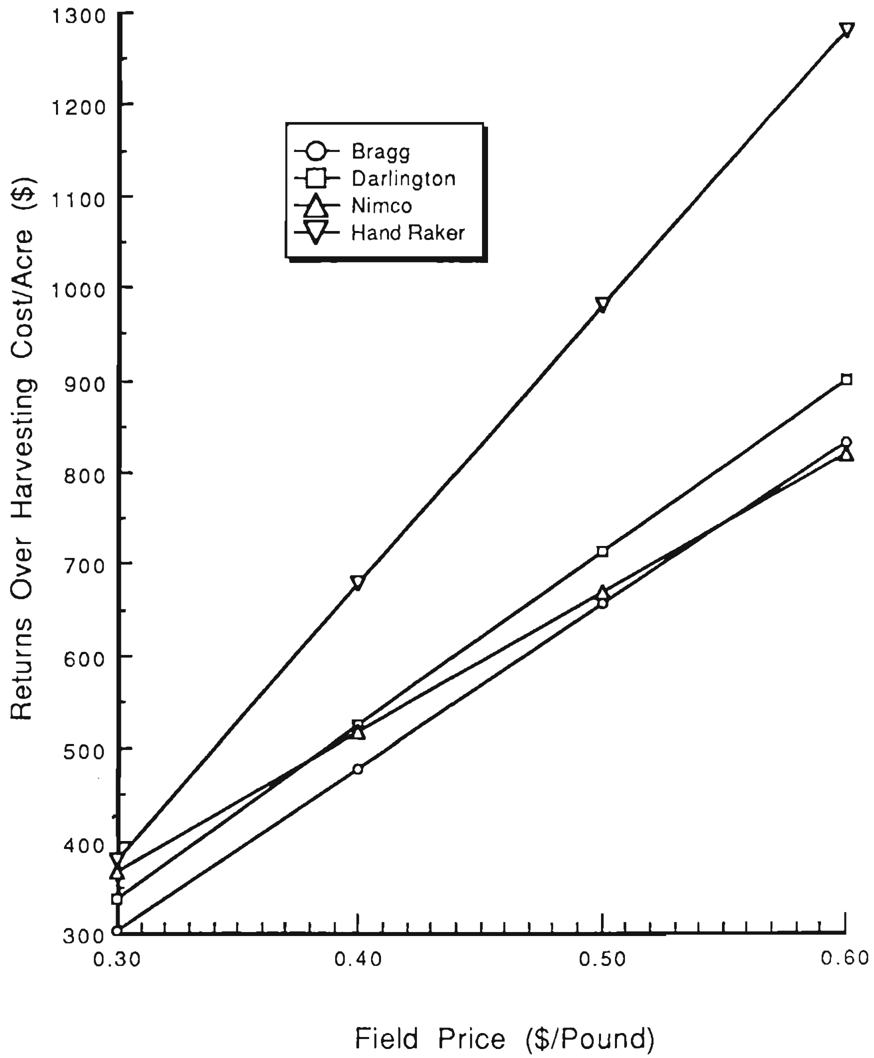

Figure 6. The Effect of Field Price On the Relative Returns Over Harvesting Costs for the Four Harvesting Technologies; Given 1988 Wage Rates, Low Yield, and a 20-Acre Farm.

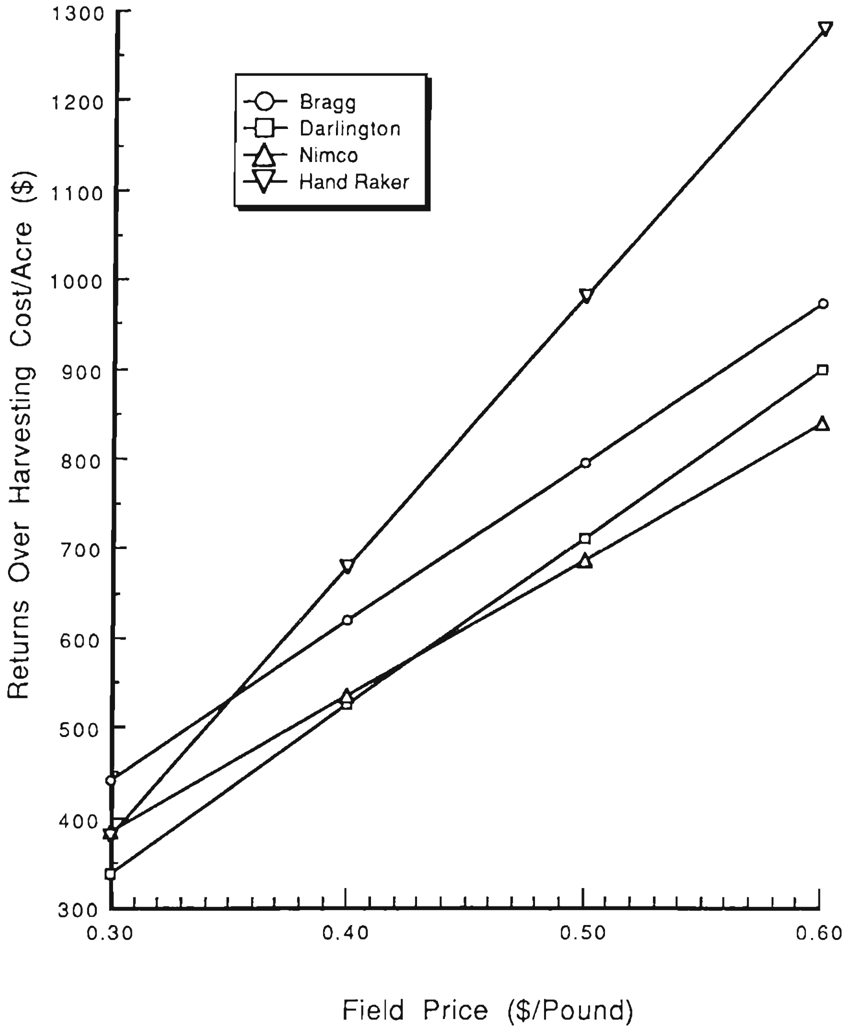

Figure 7. The Effect of Field Price On the Relative Returns Over Harvesting Costs for the Four Harvesting Technologies; Given 1988 Wage Rates, Low Yield, and a 200-Acre Farm.

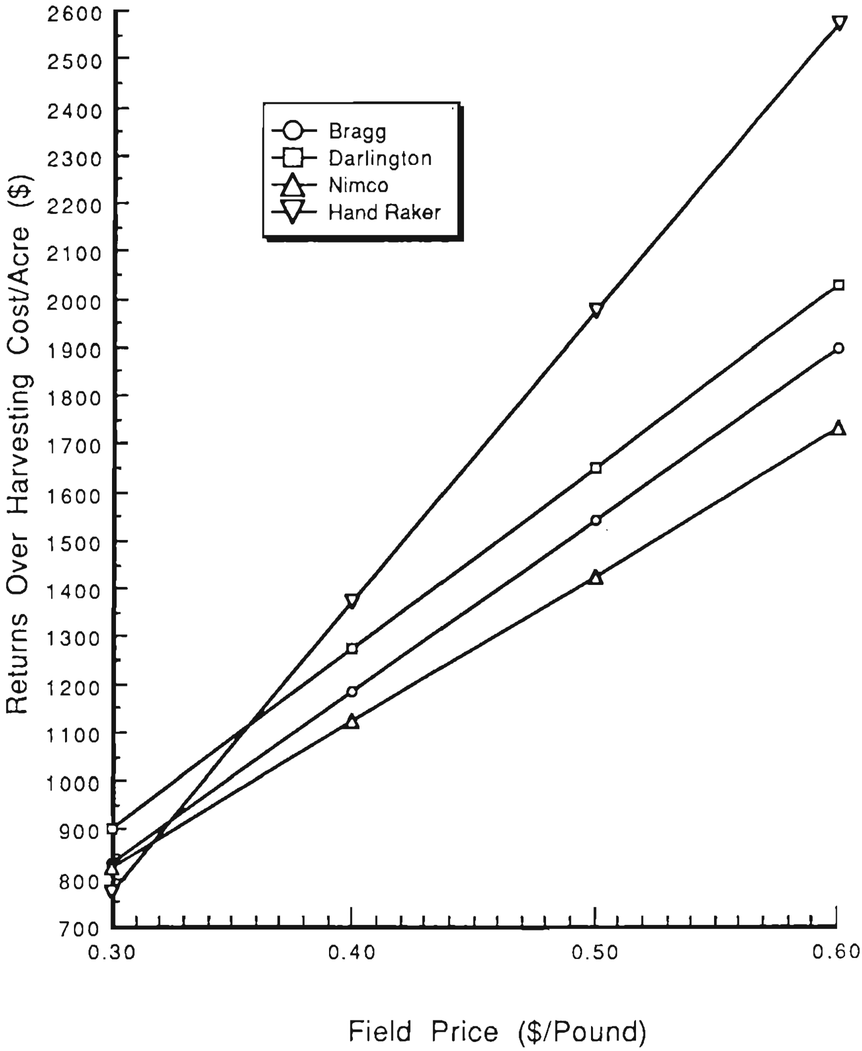

Figure 8. The Effect of Field Price On the Relative Returns Over Harvesting Costs for the Four Harvesting Technologies; Given 1988 Wage Rates, High Yield, and a 20-Acre Farm.

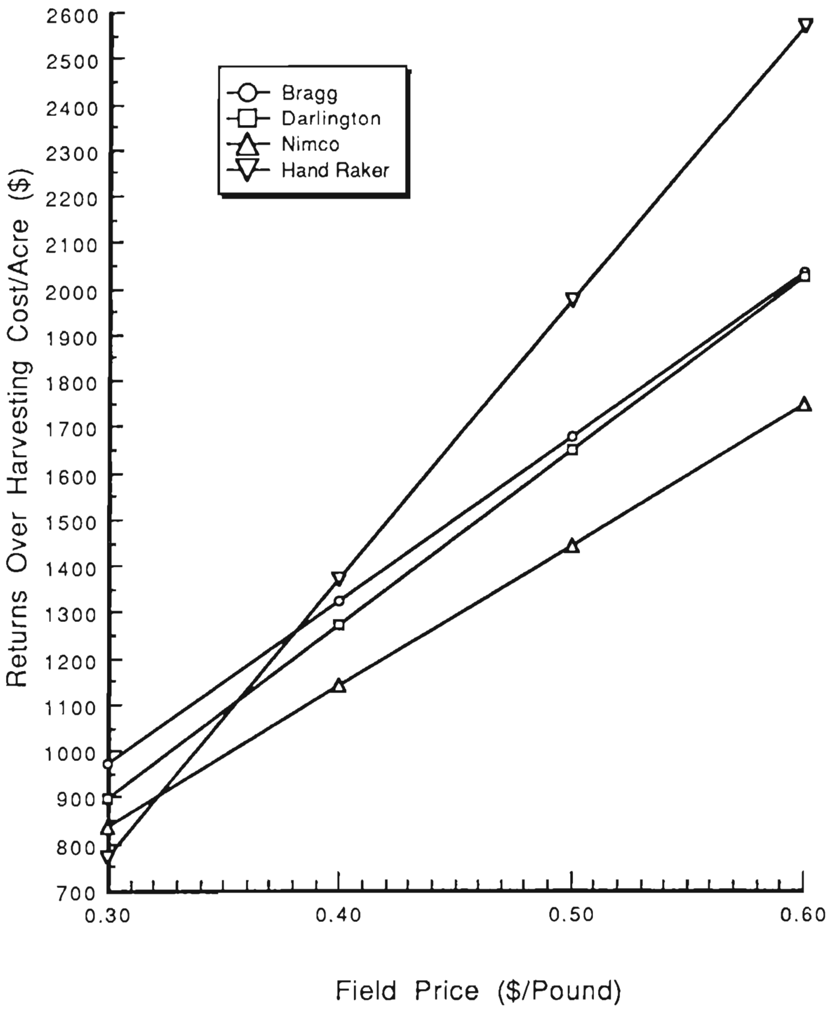

Figure 9. The Effect of Field Price On the Relative Returns Over Harvesting Costs for the Four Harvesting Technologies; Given 1988 Wage Rates, High Yield, and a 200-Acre Farm.

Summary of the Sensitivity Analysis

It is obvious that the above factors probably will not change one at a time. Tables 18-20 summarize the effects of changes in all of the factors on the preferred technology choices. The Appendix contains tables of the returns over harvesting costs that are the basis for Tables 18-20.

As can be seen from the tables, hand raking is the dominant technology under most circumstances considered in this analysis, as measured by return over harvesting costs. As expected, if the crop value is relatively low and/or labor costs begin to increase, the machine harvesting technologies are preferred. The effect on the turnover harvesting costs of wage rate increases of 10% and 20% are presented in Tables 19 and 20, respectively. Otherwise, at the current stage of mechanical harvesting technology, hand raking blueberries is still the more profitable way to harvest lowbush blueberries.

Table 18. Harvesting Technologies with the Greatest ROHC/A at Various Field Price Levels, Yields and Acreages; Current Wages[a]

	Blueberry Field Price ($/Lb)								
	0.30			0.41			0.52		
	Yield Level[b]								
Acres	*Low*	*Medium*	*High*	*Low*	*Medium*	*High*	*Low*	*Medium*	*High*
20	Hand NIMCO	Drlngtn NIMCO	Drlngtn Bragg	Hand Drlngtn	Hand Drlngtn	Hand Drlngtn	Hand Drlngtn	Hand Drlngtn	Hand Drlngtn
50	Bragg Hand	Bragg Drlngtn	Bragg Drlngtn	Hand Bragg	Hand Bragg	Hand Bragg	Hand Bragg	Hand Bragg	Hand Drlngtn
200	Bragg NIMCO	Bragg Drlngtn	Bragg Drlngtn	Hand Bragg	Hand Bragg	Hand Bragg	Hand Bragg	Hand Bragg	Hand Bragg

[a]Top entry is the most profitable technology; second entry is the second most profitable technology.
[b]Low yield level is 3000 lbs/acre, medium yield, 4500 lbs/acre, and high yield, 6000 lbs/acre.

Table 19. Harvesting Technologies with the Greatest ROHC/A at Various Field Price Levels, Yields and Acreages; Current Wages Increased by 10%[a]

	Blueberry Field Price ($/Lb)								
	0.30			0.41			0.52		
	Yield Level[b]								
Acres	*Low*	*Medium*	*High*	*Low*	*Medium*	*High*	*Low*	*Medium*	*High*
20	NIMCO Hand	Drlngtn NIMCO	Drlngtn Bragg	Hand Drlngtn	Hand Drlngtn	Hand Drlngtn	Hand Drlngtn	Hand Drlngtn	Hand Drlngtn
50	Bragg NIMCO	Bragg Drlngtn	Bragg Drlngtn	Hand Bragg	Hand Bragg	Hand Bragg	Hand Bragg	Hand Bragg	Hand Bragg
200	Bragg NIMCO	Bragg NIMCO	Bragg Drlngtn	Hand Bragg	Hand Bragg	Hand Bragg	Hand Bragg	Hand Bragg	Hand Bragg

[a]Top entry is the most profitable technology; second entry is the second most profitable technology.
[b]Low yield level is 3000 lbs/acre, medium yield, 4500 lbs/acre, and high yield, 6000 lbs/acre.

Table 20. Harvesting Technologies with the Greatest ROHC/A at Various Field Price Levels, Yields and Acreages; Current Wages Increased by 20%[a]

	Blueberry Field Price ($/Lb)								
	0.30			0.41			0.52		
	Yield Level[b]								
Acres	*Low*	*Medium*	*High*	*Low*	*Medium*	*High*	*Low*	*Medium*	*High*
20	NIMCO	Drlngton	Drlngtn	Hand	Hand	Hand	Hand	Hand	Hand
	Hand	NIMCO	Bragg	NIMCO	Drlngtn	Drlngtn	Drlngtn	Drlngtn	Drlngtn
50	Bragg	Bragg	Bragg	Hand	Hand	Bragg	Hand	Hand	Hand
	NIMCO	NIMCO	Drlngtn	Bragg	Bragg	Hand	Bragg	Bragg	Bragg
200	Bragg	Bragg	Bragg	Hand	Bragg	Bragg	Hand	Hand	Hand
	NIMCO	NIMCO	Drlngtn	Bragg	Hand	Hand	Bragg	Bragg	Bragg

[a]Top entry is the most profitable technology; second entry is the second most profitable technology.
[b]Low yield level is 3000 lbs/acre, medium yield, 4500 lbs/acre, and high yield, 6000 lbs/acre.

IV. SUMMARY AND CONCLUSIONS

Summary

A field experiment was conducted in the summer of 1988 to evaluate the relative performance of four lowbush blueberry harvest technologies. These four technologies are the Bragg Harvester, the Darlington Harvester, the NIMCO Harvester, and hand raking crews. The performance measures evaluated include the recovered yield, the harvesting time, the number of split berries, and the number of berries left on the ground by each harvest technology.

The experimental data suggest that there are differences in the performance measures both among the mechanical harvesters and between the mechanical harvest technologies and hand raking crews. The experimental data were then used as a basis for economic evaluation of the harvest technologies.

The economic performance of the four technologies was evaluated by comparing the relative returns over harvesting costs (ROHC). First, each technology was evaluated under the assumption of 1988 economic conditions. Then, sensitivity analysis was performed to evaluate under what conditions the most profitable technology would change.

The sensitivity analysis included the evaluation of the four technologies with changes in: farm size, potential yield, labor costs, and blueberry field prices.

Conclusions

The traditional harvest technology of hand raking crews provides the greatest return over harvesting costs under 1988 economic conditions over a broad range of farm sizes and potential yields. The mechanical harvesting technologies are favored when the crop value is expected to be low, farm size is quite large, and/or if labor costs are relatively high. The Bragg Harvester becomes the most profitable technology for large farms (greater than 200 acres) if labor costs increase more than 15% above 1988 levels. The small mechanical harvesting technologies tend to become profitable on smaller farms if the crop value is expected to be low.

The conclusions drawn from this study are based upon the 1988 experimental results. If actual field conditions were not represented in the experiment, then the economic results may be different. For example, it is possible that the hand raking crews chosen for the study were, on average, faster or slower than the crews available to an individual grower. This difference would have a profound effect on the economic choice made by a grower. It could be also that the potential yield levels experienced in the test plots are well without the range experienced on an individual farm. This difference also could change the relative performance of the technologies.

It is clear from this study that a multitude of factors, both technical and economic can effect the relative performance of the technologies. It would be impossible to present the results considering all combinations of factors in a report of this nature. Therefore, the two senior authors have written a companion piece to this report in the form of a Lotus-based spreadsheet software program and user's manual so that individual growers can assess their economic choices using information tailored to their farm.

If the reader is interested in this companion piece (Woods et al. 1989), it is available from Thomas E. DeGomez, Blueberry Specialist, Maine Cooperative Extension, Deering Hall, University of Maine, Orono, Maine 04469.

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APPENDIX

Appendix Table 1. Comparisons of Return Over Harvesting Cost Per Acre at Various Field Price Levels, Yield Levels, and Acreages; Current (1988) Wages

		Blueberry Price ($/Lb)								
		0.30			0.41			0.52		
		Yield Level								
Average	*Harvester*	*Low*	*Medium*	*High*	*Low*	*Medium*	*High*	*Low*	*Medium*	*High*
		ROHC/A($)			ROHC/A($)			ROHC/A($)		
20	Bragg	301	567	832	496	859	1222	691	1151	1611
	Darlington	337	618	900	543	928	1313	750	1238	1726
	NIMCO	366	593	820	533	843	1154	699	1093	1487
	HandRaker	380	576	722	710	1071	1432	1040	1566	2092
50	Bragg	406	672	937	601	964	1327	796	1256	1716
	Darlington	331	613	894	538	923	1308	744	1232	1721
	NIMCO	373	600	828	540	850	1161	706	1100	1494
	HandRaker	380	576	772	710	1071	1432	1040	1566	2092
200	Bragg	441	707	972	636	999	1362	831	1291	1751
	Darlington	336	618	900	543	928	1313	750	1238	1726
	NIMCO	394	611	839	551	861	1172	717	1111	1505
	HandRaker	380	576	772	710	1071	1432	1040	1566	2092

Appendix Table 2. Comparisons of Return Over Harvesting Cost Per Acre at Various Field Price Levels, Yield Levels, and Acreages; Current (1988) Wages Increased by 10%

		Blueberry Price ($/Lb)								
		0.30			0.41			0.52		
		Yield Level								
Average	*Harvester*	*Low*	*Medium*	*High*	*Low*	*Medium*	*High*	*Low*	*Medium*	*High*
		ROHC/A($)			ROHC/A($)			ROHC/A($)		
20	Bragg	297	563	828	492	855	1217	686	1147	1607
	Darlington	322	604	885	529	914	1299	753	1223	1712
	NIMCO	361	588	816	528	838	1149	695	1088	1482
	Hand Raker	344	523	701	674	1018	1361	1044	1513	2021
50	Bragg	402	667	933	597	959	1322	791	1251	1712
	Darlington	316	598	880	523	908	1293	729	1218	1706
	NIMCO	368	596	823	535	846	1156	702	1096	1490
	Hand Raker	344	523	701	674	1018	1361	1004	1513	2021
200	Bragg	437	702	968	631	994	1357	826	1286	1747
	Darlington	322	603	885	520	913	1298	735	1224	1711
	NIMCO	379	607	834	546	857	1167	713	1106	1500
	Hand Raker	344	523	701	674	1018	1361	1004	1513	2021

Appendix Table 3. Comparisons of Returns Over Harvesting Cost Per Acre at Various Field Price Levels, Field Levels, and Acreages; Current (1988) Wages Increased by 20%

		Blueberry Price ($/Lb)								
		0.30			0.41			0.52		
		Yield Level								
Average	*Harvester*	*Low*	*Medium*	*High*	*Low*	*Medium*	*High*	*Low*	*Medium*	*High*
		ROHC/A($)			ROHC/A($)			ROHC/A($)		
20	Bragg	293	558	824	487	850	1213	682	1142	1602
	Darlington	307	589	871	514	899	1284	720	1209	1697
	NIMCO	357	584	811	523	834	1144	690	1084	1478
	Hand Raker	308	469	630	638	964	1290	968	1459	1950
50	Bragg	397	663	928	592	955	1318	787	1247	1707
	Darlington	301	583	865	508	893	1278	715	1203	1691
	NIMCO	364	591	818	530	841	1152	697	1091	1485
	Hand Raker	308	469	630	638	964	1290	968	1459	1950
200	Bragg	432	698	963	627	990	1353	821	1282	1742
	Darlington	307	589	870	513	898	1283	720	1208	1697
	NIMCO	375	602	829	541	852	1162	708	1102	1496
	Hand Raker	308	469	630	638	964	1290	968	1459	1950

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