Cost Factors To Consider In The Mechanical Harvesting Of Florida Citrus

by

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Over the past decade, citrus picking costs have risen 75% in Florida (2). This has created a genuine interest in the development of mechanical harvesters. Research has been conducted on mechanical harvesting concepts for both fresh and processed fruit. However, since the majority of Florida citrus is destined for processing, and harvest mechanization for processed fruit is much easier to realize, most of the research efforts have been in this direction.

Several harvesting systems have been under development. The main components of these systems have usually been foliage shakers, limb shakers, and air shakers for fruit removal and catch frames or rake-pickup machines for fruit collectors. Abscission chemicals have also been under development as an assist to the fruit removal devices. Many different combinations of these machines and chemicals have been tried in an attempt to develop an acceptable mechanical harvesting system. At present, no mechanical harvesting system has been completely acceptable to the citrus industry. One of the reasons for this is that none of the proposed systems has been developed to the stage where it is economically feasible under a wide range of grove conditions. How can one estimate the economics of a system? This paper discusses some of the cost factors which determine the feasibility of a system.

As long as an adequate supply of handpickers is available, a mechanical harvester must successfully compete with the cost of hand harvesting. What must be the competitive cost of the mechanical harvester itself? This can be estimated by equating the net returns per acre for handpicking and for mechanical harvesting. The net returns in either case would be the gross returns at the processing plant less costs required to produce, harvest, and deliver the fruit to the plant. Formulae for calculating the annual returns and costs are itemized in Table 1 on an acre basis. Item 1 assumes that the "at plant" price of fruit per box is the same for both methods of harvest and that handpickers achieve 100% removal. In Item 2, the pruning costs per acre would be in addition to that required for handpickers. This cost would be for some type of tree shaping service such as removing lower tree limbs (lifting tree skirts) if this is necessary for operating the harvesting machinery. The mechanical harvesting cost in Item 3 refers to the cost of a machine system that will remove the fruit from the tree and deliver it to a hi-lift truck. The hauling cost/hour is the charge for a hi-lift truck with driver.

Item 4 is self-explanatory. The extra cost (Item 5) refers to mechanical harvesting damage, trash removal, etc. Abscission chemicals were included in Item 6 as a cost for mechanical harvesters since they may sometimes be used.

If the net returns (Table 1, gross returns less costs) are equated for handpicking and mechanical harvesting, an equation results which expresses the break-even or allowable cost of the mechanical harvester as follows:

$$C/A = Y \left[(HCRP-PR) \left(\frac{100-\%R}{100}\right) - \frac{\%R}{100} (EC) + PC \right] - PRC/A - HCGR \div A/H - AC/A$$

and

$$C/H = C/A \times A/H$$

where: C/H = Allowable cost of mechanical harvester, dollars/hour

C/A = Allowable cost of mechanical harvester, dollars/acre

A/H = Grove capacity of mechanical harvester hi-lift system, acres/hour

Y = Potential yield of grove without effects of mechanical harvester, boxes/acre

HCRP = Hauling cost from roadside at grove to plant, dollars/box

PR = "At plant" price of fruit, dollars/box

%R = Percentage of fruit in grove which is delivered to roadside

EC = Extra cost (above that of handpicked fruit) at plant due to mechanical harvesting damage, dollars/box delivered

PC = Handpicking ("roadsiding") cost, dollars/box

PRC/A = Pruning cost to accommodate mechanical harvester, dollars/acre

HCGR = Hauling (grove to roadside) cost, dollars/hour

AC/A = Abscission chemical cost (material + application), dollars/acre

Damage to future crops as a result of mechanical harvesting tree damage has not been mentioned. For all practical purposes, it can be accounted for by reducing the %R by an equivalent amount. For example, if a mechanical harvester can deliver 90% of the fruit in a grove to roadside, but in doing so reduces the subsequent yield by 10%, it is only harvesting 90% - 10% = 80% of the potential yield when compared to

handpicking. The HCGR cost is that of a hi-lift truck to haul fruit from the harvester to roadside. The mechanical harvester must be penalized for abandoning fruit which is not delivered to the plant, if it is assumed that this fruit cannot be profitably handpicked. It has been taken into account in the above expression for C/A as follows:

$$\frac{\text{Fruit abandonment penalty}}{\text{acre}} = Y \left[(HCRP - PR) \quad \frac{(100 - \%R)}{(100)} \right]$$

This is a negative quantity since it reduces the allowable cost of a mechanical harvester when %R is less than 100. The fruit abandonment penalty, for all practical purposes, is proportional to fruit yield, "at plant" price of fruit, and per cent of abandoned fruit (100-%R).

Allowable C/A for machine harvest systems have been plotted in Figs. and 2 for some pricing conditions which should be appropriate in the Florida citrus industry. Costs held constant in the figures were:

1. PRC/A = $20.00 (annual cost)
2. HCGR = $7.00/hour (1 hi-lift)
3. HCRP = $0.15/box
4. EC = 0 (values for this are needed but not known)

All other factors were varied as follows:

1. Y = 200, 400, 600 boxes/acre
2. A/H = .1 to 1.0 acres/hour
3. PR = 1.50 and 3.00 dollars/box
4. %R = 90 and 100
5. PC = 0.65 and 0.95 dollars/box
6. AC/A = $0 and $50/acre

Fig. 3 illustrates the relationship between a machine's cost/hour, grove capacity, and cost/acre. The cost/hour of a mechanical harvesting

system is usually fairly constant. Knowing this hourly cost for a particular system, the cost per acre can be determined at a known grove capacity. This cost per acre can then be used to determine the economic feasibility of the system by comparison with allowable per acre costs as given in Figs. 1 and 2.

Three situations are assumed in the following examples to illustrate the procedure for using the figures. They are:

1. Yield of grove, Y, is 400 boxes/A. Harvesting machine operates at $40/hr and delivers 90% of the yield to the grove roadside at 0.2 A/hr grove capacity. Abscission chemical costs are zero.
2. Yield of grove, Y, is 400 boxes/A. Harvesting machine operates at $40/hr and delivers 90% of the yield to the grove roadside at 0.3 A/hr grove capacity. Abscission chemical costs are $50/A.
3. Yield of grove, Y, is 400 boxes/A. Harvesting machine operates at $40/hr and delivers 100% of the yield to the grove roadside at 0.2 A/hr grove capacity. Abscission chemical costs are $50/A.

GROVE CAPACITY

In this section, situations 1 and 2 will be discussed. They assume an increase in the machine's grove capacity at the expense of an abscission chemical.

From Fig. 3, the operating costs of the machine in situations 1 and 2 are $200/A ($40/hr at 0.2 A/hr) and $133/A ($40/hr at 0.3 A/hr), respectively. Apply these costs to the pricing structure in Figs. 1A and 1B. The allowable cost/A for situation 1 in Fig. 1A is $151/A. The harvester cost of $200/A exceeds that of hand harvesting by $49/A ($200 less $151).

For situation 2 in Fig. 1B, the allowable cost/A is $113 or $20 less ($133 less $113) than that cost at which the harvester will operate.

How do the 2 situations compare at higher fruit prices (Figs. 1C & 1D, PR = $3.00/box)? The allowable costs/A for situations 1 and 2 are $91 and $53, respectively. The per acre mechanical harvesting costs exceed those of hand harvesting by $109 ($200 less $91) and $80 ($133 less $53).

Compare situations 1 and 2 at higher hand harvesting costs (PC = $0.95, Fig. 2). For PR = $1.50/box,Figs. 2A & 2B, the allowable costs/A are $271 and $233. Mechanical harvester costs are $71 ($271 less $200) and $100 ($233 less $133) less than the allowable or break even costs. At PR = $3.00/box,Figs. 2C and 2D, the allowable costs are only $11 ($211 less $200) and $40 ($173 less $133) greater than those for mechanical harvesting.

All of the above illustrations dealt with increasing the mechanical harvesters grove capacity when changing from situation 1 to situation 2. Even though the economic feasibility of the harvesters varied considerably with each illustration, one factor remained constant--the economics of situation 2 was always $29 better than that of situation 1. Specifically, the economic gain or loss associated with a grove capacity change is dependent on the mechanical harvester's hourly costs and is <u>independent</u> of hand harvesting costs and "at plant" fruit prices. It can be shown in a similar manner that these economic gains or losses are also independent of yield.

PERCENT REMOVAL

Situations 1 and 3 are discussed in this section. The assumption here is that the percent removal (%R) of the mechanical harvester is increased at the expense of an abscission chemical.

From Fig. 3, the cost per acre for the harvester remains constant at $200. Entering Figs. 1A & 1B, the allowable costs/A are $151 and $155 for situations 1 and 3, respectively. Thus, the mechanical harvester cost/A exceeds the allowable by $49 and $45. When the price of fruit is increased (PR = $3.00/box, Figs. 1C & 1D), the allowable costs/A are $91 and $155 or the mechanical harvester cost/A exceeds the allowable by $109 ($200 less $91) and $45 ($200 less $155).

Make the situation comparisons at higher hand harvesting costs in Fig. 2 (PC = $0.95/box). When PR = $1.50/box, Figs. 2A and 2B, the allowable costs of situations 1 and 3 are $271 and $275. The savings with the mechanical harvester would be $71 ($271 less $200) and $75 ($275 less $200), respectively. For PR = $3.00/box, Figs. 2C and 2D, the savings would be $11 ($211 less $200) and $75 ($275 less $200) per acre.

The illustrations in this section point out that economic gains or losses associated with changes in percent removal are independent of hand harvesting costs, but are dependent on "at plant" fruit prices. Similarly, it can be shown that these economic gains or losses are dependent on yield.

GENERAL DISCUSSION

The two previous sections discussed the economic effects of changing a machine's grove capacity and percent removal. The conclusions reached were:

1. The economic gains or losses of a mechanical harvester which are associated with a change in its grove capacity are independent of hand harvesting costs, fruit prices, and yield and are dependent on the mechanical harvester's hourly cost.
2. The economic gains or losses of a mechanical harvester which are associated with a change in its percent removal are independent of hand harvesting costs and mechanical harvesting hourly costs and dependent on fruit prices and yield.

These conclusions do not state that the economic feasibility of a mechanical harvester is independent of hand harvesting costs, mechanical harvester, hourly costs, fruit prices, and yield. Quite the contrary is true. Enter Figs. 1 & 2 at a given grove capacity and a percent removal (less than 100%). The allowable mechanical harvester cost per acre increases with increasing yield and hand harvesting costs and with decreasing "at plant" fruit prices. In Fig. 3 at a given grove capacity, the per acre cost of the mechanical harvester decreases with decreasing hourly costs of the harvester. Conclusions 1 and 2 as stated above are meant to be applied to changes in a machine's performance after a characteristic operating point (namely, a percent removal corresponding to a grove capacity) has been established.

Another way of describing the effects of grove capacity and percent removal is as follows. Grove capacity generally establishes the per acre cost of the mechanical harvester, whereas percent removal defines the per acre fruit abandonment penalty at a given fruit price and yield. An economically feasible mechanical harvester must show a plus when per acre machine, fruit abandonment penalty, and abscission chemical costs are subtracted from the per acre hand harvesting costs.

The above discussion has centered around the difference in net returns between mechanical harvesting and hand harvesting and has been presented strictly from an economic basis. What other considerations are of practical importance when the acceptability of mechanical harvesting is being analyzed? The management of hand harvesting crews has become more difficult with time and maintaining harvesting crews that will deliver predictable quantities of quality fruit has not been easy in recent years. Bargaining power which determines the harvesting cost has shifted from the grower and toward the picker. The use of mechanical harvesters will create new machinery management problems. Therefore, what can a grower afford to sacrifice in making the change from hand harvesting to mechanical harvesting?

Again, consider Fig. 1A. Assume that the production costs including interest on the investment are $300/A (1). The gross returns from hand harvested fruit would be 400 boxes/A x $1.50/box = $600/A. The net returns per acre after production, hand harvesting, and hauling would be $600 less $300 less (400 x $0.65) less (400 x $0.15) = -$20. If situation 1 was applied, the mechanical harvester would yield a net return of $49 less or -$69/A.

Make the same comparisons in Fig. 1C. The gross returns from hand harvesting would be 400 boxes/A x $3.00/box = $1200/A. Net returns per acre would be $1200 less $300 less $320 = $580. Situation 1 with the mechanical harvester would net a per acre return of $109 less or $471.

If the same comparisons were made in Figs. 2A and 2C, greater net returns would be realized with the mechanical harvester than with hand

harvesting. In Fig. 2A, hand harvesting would net -$140/A while mechanical harvesting would net -$69/A. The corresponding returns in Fig. 2C would be $460/A and $471/A.

Where do mechanical harvesting concepts presently under development fit into the economic picture? In early and mid-season oranges without abscission chemicals, the author estimates that 90% of the fruit could be removed at a minimum machine cost of $185/A. This figure includes a pruning cost of $20/A and a hi-lift cost of $15/A. In 'Valencias', the economic picture is not that good. With abscission chemicals, results are not consistently predictable.

The total picture is very difficult to assess for the following reasons. First of all, without information on the long term operation of a harvest system, its hourly cost, grove capacity, and % removal are not easy to estimate. Secondly, little is known about the costs which will have to be charged against the harvester because of additional problems at the processing plant. Finally, the development of a harvest machine and/or an abscission chemical for 'Valencia' oranges is still in its early stages, when compared to developments for early and mid-season oranges. Information on all of these factors must be more fully developed in order to make an accurate assessment.

Literature Cited

1. Brooke, D. L. 1970. Citrus production costs and returns in Florida season 1968-1969 with comparisons. Coop. Ext. Serv. Econ. Ser. 70-2: 8.

2. Spurlock, A. H. 1971. Costs of picking and hauling Florida citrus fruits 1969-1970 season. Univ. of Fla. Agr. Econ. Rept. 16: 10.

Table 1.--Annual citrus returns and costs per acre related to harvesting.

Item No.	Handpicking	Mechanical harvesting
	Gross returns	
1	$\frac{\text{'At plant' price}}{\text{box}} \times \frac{\text{boxes}}{\text{acre}}$	$\frac{\text{'At plant' price}}{\text{box}} \times \frac{\text{boxes}}{\text{acre}} \times \frac{\%R}{100}$
	Costs	
2	Production costs/acre	Production costs/acre + pruning costs/acre
3	$\frac{\text{Picking ("roadsiding") cost}}{\text{box}} \times \frac{\text{boxes}}{\text{acre}}$	$\left[\frac{\text{Mech. harv. cost}}{\text{hour}} + \frac{\text{Hauling (grove to roadside) cost}}{\text{hour}}\right] \div \frac{\text{acres}}{\text{hour}}$
4	$\frac{\text{Hauling (roadside to plant) cost}}{\text{box}} \times \frac{\text{boxes}}{\text{acre}}$	$\frac{\text{Hauling (roadside to plant) cost}}{\text{box}} \times \frac{\text{boxes}}{\text{acre}} \times \frac{\%R}{100}$
5	None	Extra cost (above that of hand-picked fruit) at plant per box delivered x boxes per acre x $\frac{\%R}{100}$
6	None	Abscission chemical cost (material + application) per acre

For Situation 1
Abscission Chemical Cost=$0/Ac

For Situations 2 & 3
Abscission Chemical Cost=$50/Ac

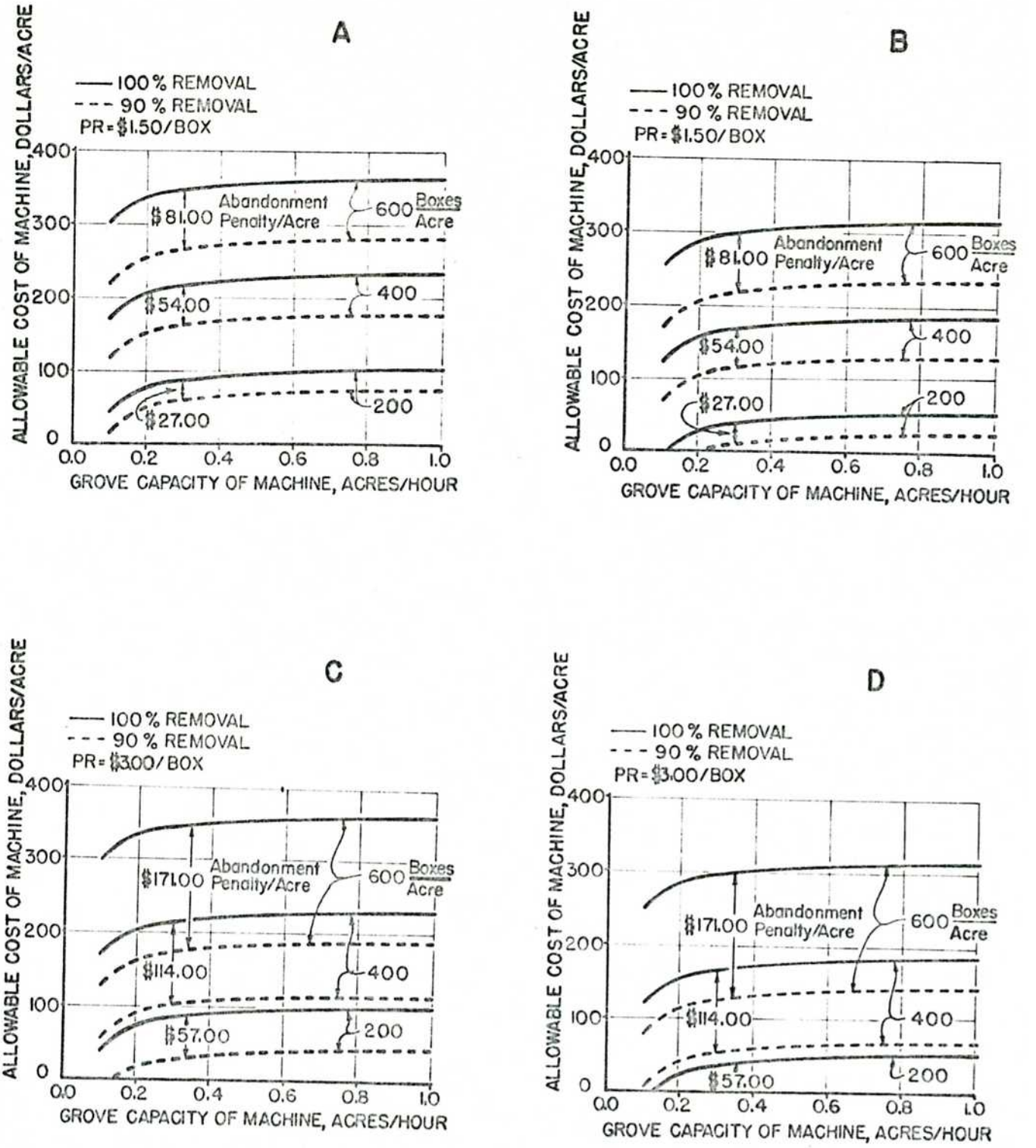

Fig. 1. Allowable cost per acre for mechanical harvester to break even with hand harvesting. These cost factors were held constant: PC=$0.65/box; EC=0; PRC/A=$20/Ac; HCGR=$7.00/hr; HCRP=$0.15/box.

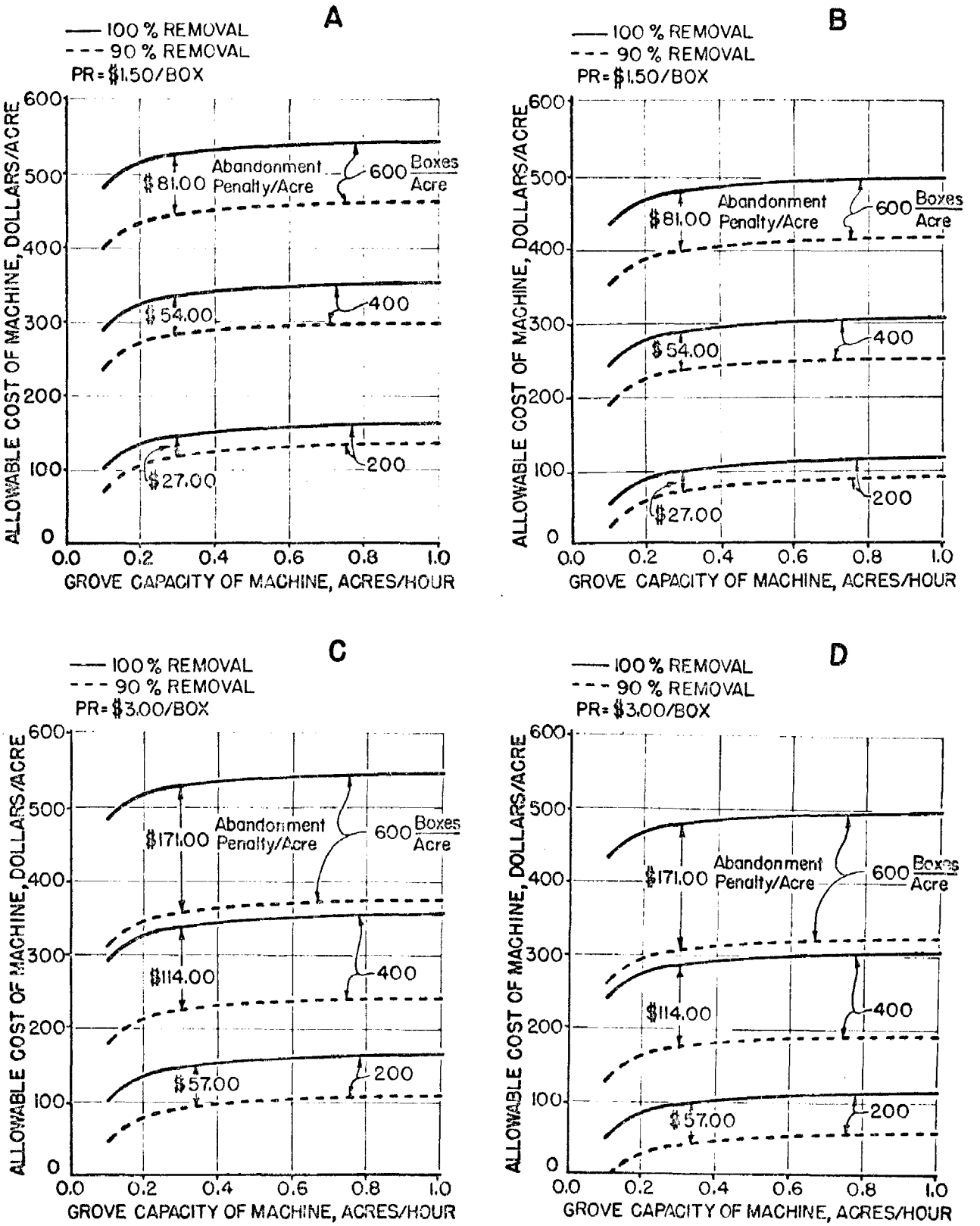

Fig. 2. Allowable cost per acre for mechanical harvester to break even with hand harvesting. These cost factors were held constant: PC=$0.95/box; EC=0; PRC/A=$20/ac; HCGR=$7.00/hr; HCRP=$0.15/box.

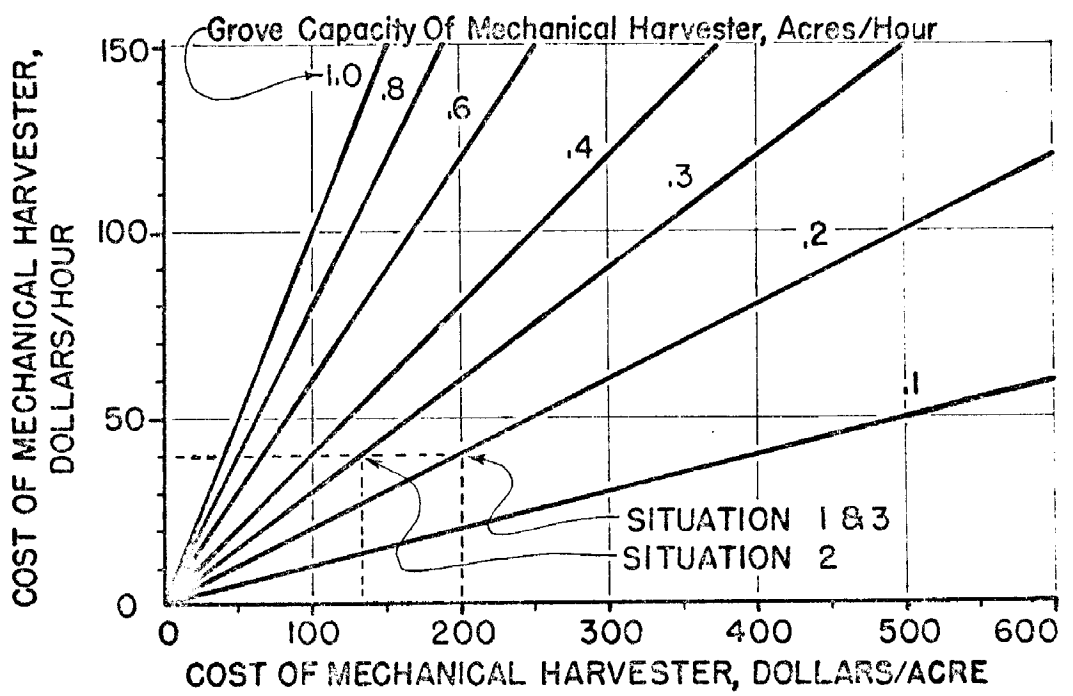

Fig. 3. Relationship between a mechanical harvester's cost/hour, grove capacity, and cost per acre.