Staff Paper

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Abstract:

Investment Analysis of Alternative Fruit Tree Sprayers in Michigan Orchards

Changing orchard sprayer technology and rising pesticide costs to fruit growers raise the need to analyze the profitability of alternative sprayer investments. This study analyzes investments in four orchard sprayers for use in Michigan apple production: an air blast sprayer, a tower boom sprayer, a tower boom sprayer equipped with electronic sensors that activate spray nozzles when foliage is detected, and an air curtain sprayer that targets spray with a layer of forced air. Assuming equal pest control efficacy, the study calculates the annualized net present cost per acre of owning and operating each sprayer for ten years using a baseline discount rate of 10 percent over 200 acres of semi-dwarf apple trees.

The analysis found the annualized net present cost per acre, from least to greatest, to be $287 for the air curtain sprayer, $312 for the tower sprayer with electronic sensors, $345 for the plain tower sprayer, and $391 for the conventional air blast sprayer. Sensitivity analysis revealed that the ranking of these cost results was sensitive to farm size, but not to percentage of funds borrowed, discount rate, loan interest rate, or pesticide costs within the ranges investigated. The air curtain sprayer was lowest cost for orchards of 25 acres or more; the conventional air blast sprayer was lowest cost for 10-acre orchards.

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Introduction

Rapid change in pesticide sprayer technology and attendant costs to fruit growers raises the need to analyze these investments. The new technologies challenging the established air blast sprayers include sprayers with tower booms, sprayers with electronic sensors to detect the presence of foliage, and air curtain sprayers that target their spray with a layer of forced air (Van Ee et al.; Van Ee and Ledebuhr).

The new spray technologies have arisen in response to increasing pesticide costs and public concerns with minimizing spray residues and off-target spray deposition. The direct costs of pesticide use have been rising as certain low-cost pesticides are lost through the reregistration process administered by the U.S. Environmental Protection Agency under the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA), and the Food Quality Protection Act of 1996 (FQPA) (Swinton and Scorsone; 1995 Specialty Crop Pesticide Committee). New pesticides typically have higher prices which reflect rising research and development costs, including the more rigorous toxicology testing procedures required since 1985.

Indirect costs of pesticide spraying include all those factors that raise the cost of doing business with pesticides. At the local level, some producers must contend with neighbors' complaints about pesticide drift. At the national level, falling tolerance thresholds under FQPA for pesticides that share the same mode of action will shortly force farmers to make a choice between lower thresholds for pesticides that pose low human health risks or higher thresholds for pesticides that pose negligible human health risks. Given the very limited number of pest control measures from which fruit growers can typically choose, growers place a premium on retaining the option of using needed compounds. Altogether, both the direct and the indirect cost factors work to raise the cost of pesticide use to the fruit grower.

These cost pressures have induced the development of fruit sprayers that economize on pesticide use. Because the new sprayers do more than the models they replace, they are more costly. This study examines the returns to investments in alternative pesticide sprayers for Michigan apple growers. Apples were selected as the focal crop because a) they are the most widely grown temperate fruit in the United States, b) they face a diverse complex of insect and disease pests, and c) all Michigan growers rely on spraying as a component of their pest management programs in apples (NASS, p. 26).

Air curtain and tower sprayer technology

The conventional rotary air-blast tree sprayers have been available for over 40 years. They use a rotating fan to disperse spray radially outward from the rear of a sprayer pulled behind a tractor. The power required to propel spray into the top of the tree usually results in surplus spray rising into the air beyond. In order to deliver adequate spray to the top of the tree, an air-blast sprayer typically must apply more spray than necessary to the lower half. These facts have meant that a significant amount of spray from an air-blast sprayer misses its target.

The air curtain sprayer uses a tall (15-foot) tower mounted with 3-4 fans to propel a straight-stream of more concentrated, more finely atomized spray directed by a “curtain” of air to focus the spray into the orchard canopy (Ledebuhr and Van Ee 1987). This sprayer uses lower rates of pesticide active ingredient per acre (reduction of 40-50%) and offers greater speed, because fine spray mist rolls through to the next row of trees, allowing growers to skip spraying every other row. As pesticide costs have climbed, the appeal of lower-rate sprayers has grown. The air-curtain design has been developed, beginning in the 1980's, by Michigan State University agricultural engineers Gary van Ee and Richard Ledebuhr.

Another recent development in sprayer technology that reduces pesticide spray quantities has been the tower design with separate spray nozzles. This delivers spray into the upper canopy and also permits alternate-row spraying, reducing pesticide rates up to 20% compared with the conventional air-blast sprayer. Tower sprayers were first sold in Michigan in 1989.[1]

More recently, tower sprayers have been mounted with electric eyes or sonic sensors connected to individual spray nozzles to trigger spraying when tree branches are sensed (Roper 1988), an example being the FMC SmartSpray™ sprayer. This design avoids wasting spray where orchard rows have gaps or trees are too small to spray to have high branches in need of spray. These sensor-based sprayers were introduced in Michigan in 1993.[1]

Objectives

While the forces that have fostered the development of the new sprayer technologies include some environmental policies and regulations, this analysis will examine the appeal of these new sprayers strictly from a long-term profitability perspective. The study works from the assumption that the sprayers being compared are capable of achieving equal pest control, resulting in equal quantity and quality of harvested fruit yield (despite some evidence that greater

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[1]Phillip Brown, Durand Wayland, Inc., personal communication to Gary van Ee, November 20, 1997.

pest control can be achieved with the air curtain sprayer [Jones et al., 1995]). Hence, profit maximization is measured here as cost minimization. This paper applies the tools of investment analysis to estimate the net present value of total cost (NPC or total cost in present dollars) of sprayer investments which will be used over a period of years. Specifically, our objectives are:

Objective 1: To compare annualized ten-year NPC's per acre for investments in four alternative fruit sprayer technologies:

(a) Basic air-blast sprayer,

(b) Air-blast sprayer with tower boom,

(c) Air-blast sprayer with tower boom and Smart Spray™ system,

(d) Air curtain prototype sprayer (costs from Curtec™ commercial sprayer).

Because budgeting analyses are limited by their assumptions, a second objective is:

Objective 2: To analyze the sensitivity of results that occur due to changes in key assumptions regarding:

(a) Farm size

(b) Financial terms (proportion of borrowed funds, interest rate, discount rates)

(c) Pesticide cost

Methods

Among the common measures of investment returns over time, net present value (NPV) offers the clearest measure of investment profitability. It sums up cash flows from benefits and costs (C_t) over each period of the investment's life, using a discount rate (i) to downweight the present value of cash flows in future periods. Put differently, NPV is the present worth of net benefits less the present worth of the cost stream (Gittinger, 1982). Since our focus is on costs alone, net present total cost, NPC, can be stated mathematically as:

$$NPC = \sum_{t=1}^{n} \frac{C_t}{(1 + i)^t} \quad \textbf{(1)}$$

where C_t is cost in each year, n is number of years, and t is the time period (from 1 to *n*).

Ordinary analysis of mutually exclusive investments, such as choice of pesticide sprayer, would choose the one with the highest NPV. Since the focus here is on costs, the preferred investment will be the one with the lowest NPC.

Financial and Technical Assumptions

The NPC analysis is based on various assumptions about the characteristics of the farm operation, the equipment used, financial conditions, and other matters. As indicated above, several key assumptions were varied in the sentivity analyses under Objective 2. The baseline assumptions applied to the present analysis are presented in Appendix Table 1 and outlined below.

(a) *Financial assumptions*

The financial assumptions include the discount rate, loan interest rate, federal income marginal tax rate, single business tax rate, insurance rate, equipment salvage value, and rate of inflation.

The discount rate for financial analysis represents the marginal cost of money to the farm or firm under investigation. This is often based on the rate at which the farm is able to borrow money, adjusted for risk and inflation expectations (Barry et al.). In this analysis, where inflation is assumed zero, the discount rate is assumed to be 10%. In the baseline scenarios, equipment is assumed to be purchased with a 60-month commercial bank loan to finance 50% of purchase cost. The loan interest rate is set at 6.0%, reflecting current market rates of 9.5% to 10% minus an inflation premium of 3.5% to 4%. The total marginal tax rate was assumed to be 32.6%, composed of a federal income marginal tax rate of 28% and small business tax rate of 4.6%. The insurance rate was estimated at 1% of the cost of the tractor and equipment (Boehlje and Eidman). The salvage value of 30% of the equipment's initial cost at the end of a useful lifetime of nine years. For income tax purposes, depreciation was taken over seven years, following the 150% declining balance method (with conversion to straight line when appropriate) with a half-year convention and no Section 179 "expensing" (Internal Revenue Service, 1995). No cost inflation was assumed.

(b) Representative farm characteristics

Technical assumptions made cover both the nature of the representative farm operation as a whole and characteristics of the spraying equipment and practices reviewed. The farm operation was assumed to manage 200 acres of semi-dwarf apple trees planted at 200 trees per acre in rows 18 feet apart with a spacing of 12 feet between trees. Labor was assumed provided by a single operator working 10 hours per day. Twelve sprays per season were assumed necessary to insure acceptable pest control.

A standard 70Hp tractor was assumed for both the air curtain sprayer and the three modifications of the conventional sprayer. Turn-around time to reload the sprayer tank was assumed to average one half hour per full load of spray. Fuel and lubrication costs were assumed to be $12.96 per hour based on Kelsey and Schwallier (1989). The average annual cost per acre of pesticides for the conventional air blast sprayer was estimated at $532 (Swinton and Scorsone).

Alternative sprayer configurations

The four sprayer configurations vary in a number of technical aspects specified below. Each configuration is described below in addition to comparative specifications in Table 1. All are powered by PTO.

Table 1: Selected technical specifications for four sprayer configurations.

Specification	**Conventional “air blast”**	**Tower Boom**	**Tower Boom w/Smart Spray™**	**Air Curtain (Curtec)**
Spraying speed (mph)	3	3	3	4
Distance covered (ft/acre)[1]	2508	1254	1254	1254
Chemical sprayed (gal/acre)	30	30	30	15
Chemical savings (% over air blast)	0	20	35	40
Sprayer capacity (gals/tank)	500	500	500	325
(acres/tank)	16	16	16	21
Mean daily spray coverage (ac/day)	51	87	87	110

[1]Alternate row middles sprayed for all cases, except conventional “air blast.”

Silhouettes of the air-blast and tower sprayer designs are shown in Figure 1, which also highlights the fact that the tower designs can be used to spray alternate rows.

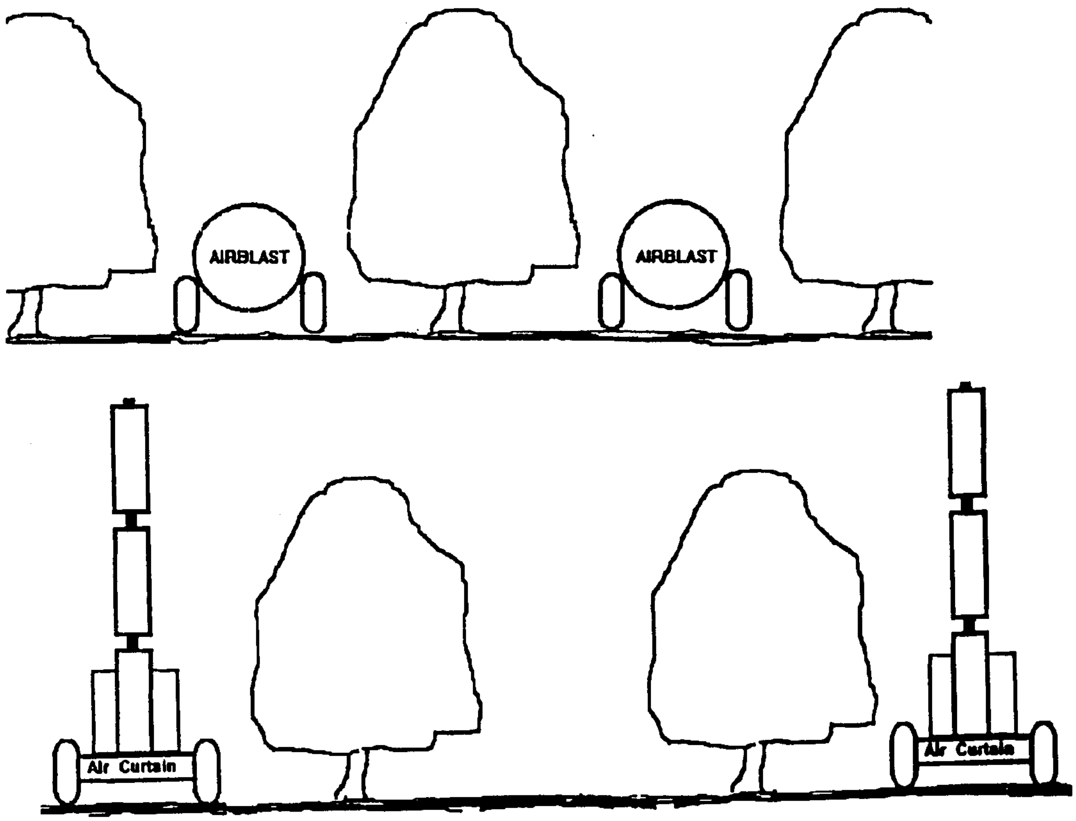

Figure 3: Schematic comparison of conventional "air blast" sprayer (top) and air curtain or "Curtec" sprayer (bottom), a type of tower sprayer.

1. Conventional "air blast" sprayer

As the most common sprayer in use today, this configuration provides the benchmark against which the other, more expensive configurations were judged. It assumed to sell for an initial cost of $56,000, which includes $35,000 for a standard 70Hp tractor plus $21,000 for the sprayer unit. It includes a 500-gallon spray tank, sprays 30 gal/ac (conservative estimate), and operates at 3 miles per hour (mph), covering 16 acres per 500-gallon tank. Cleaning and maintenance are assumed to required one half hour per spraying. Annual maintenance cost is assumed to be $500. The conventional air blast sprayer is assumed to use 100% of the annual average pesticide cost of $532.

2. "Air blast" sprayer with tower boom

The tower boom sprayer sprays pesticide from nozzles arranged on a tower boom 11 feet high, allowing better penetration of the upper orchard canopy. This configuration's initial investment cost is $61,000, including the conventional air blast sprayer components plus a $5,000 tower boom. Other characteristics are the same as for the conventional air blast sprayer except for pesticide use, which is assumed to be 20% less (Table 1).

3. "Air blast" sprayer with tower boom and SmartSpray™ system

The third sprayer configuration adds the FMC SmartSpray™ system to the tower boom. The SmartSpray™ system uses sonar technology to sense the presence of foliage and turn the sprayer nozzles on only where tree foliage is sensed, saving spray material. The initial investment cost of this system is $82,000, including the components of the previous configuration, plus a $21,000 SmartSpray™ system. A 35% reduction in pesticide use is assumed, compared to the benchmark air blast sprayer configuration. Other characteristics are assumed to be similar (Table 1).

4. Air curtain sprayer

The Curtec™ C2000 air curtain sprayer is commercialized by BEI, Inc., of South Haven, Michigan, under license from Michigan State University. It includes a 15½-foot tall tower mounted with six adjustable crossflow fans with twin rotary atomizers which diffuse the spray into a fine mist. Air blowers create a "curtain" of air to focus the spray into the orchard canopy. The initial investment cost is assumed to be $75,000, including $40,000 for the sprayer unit and $35,000 for a 70Hp tractor. Although the model described here is not commercialized at present, prices and maintenance information are adapted from those of the Curtec™ C2000 commercial sprayer, with performance specifications based on field tests at the Michigan Agricultural Experiment Station. The sprayer tank is assumed to carry 325 gallons, dispense 15 gal/ac of pesticide spray (i.e., half the rate of the air-blast sprayer), and operate at 4 mph. This results in orchard coverage of 21 acres per 325-gallon tank. Pesticide use is assumed to be 40% less than for the benchmark air blast sprayer. Because it has more moving parts, the air curtain sprayer requires more care for cleaning and maintenance, one hour per spray operation. Annual maintenance cost is assumed to be $1000.

Net Present Cost Analysis and Results

The NPC analysis paired the air curtain sprayer with each of the other three configurations in order to assess comparative long-term costs. Because the systems were paired and returns were assumed equal, only costs that vary across systems were evaluated.

The results of the baseline NPC analysis (Table 2 below) ranked the sprayers from least to most expensive as the air curtain sprayer, the SmartSpray™ system, the tower boom system, and the conventional air blast sprayer. Results were strongly driven by the long-term costs of pesticide spray and labor for spray tank refills; the cost rankings were exactly the inverse rankings of pesticide spray rates.

Table 2: Baseline NPC results for four apple sprayer configurations.

Sprayer configuration	Net Present Cost	Annualized NPC per acre
Conventional “air blast”	$480,171	$391
Tower boom	$424,566	$345
Tower boom w/SmartSpray™	$383,861	$312
Air curtain	$352,190	$287

Sensitivity Analysis

Because this kind of capital budgeting exercise can be very sensitive to the assumptions made, the analyses were repeated, varying key cost parameters. These sensitivity analyses covered 1) percent of funds borrowed, 2) discount rates, 3) loan interest rates, 4) farm size, and 5) pesticide costs (Appendix tables A1-A4). The sensitivity analyses were done by changing specific variables believed to play an influential role in determining total cost, while holding constant all other parameters.

Three financial assumptions were examined: percent of funds borrowed, loan interest rate, and discount rate. Percent of funds borrowed indicates what percentage of the total cost came as a loan from sources other than the farmer’s own equity. Appendix table A1 indicates that annualized per-acre cost increases only marginally as the share of borrowed funds increases. Similarly, when the real loan interest rate was varied between 6 and 20 percent, the change in per-acre annualized cost was slight among the four sprayer configurations. Discount rate, however, has a bigger impact. Over the range of 5 to 20 percent, the relative ranking of annualized NPC per acre remained stable. However, at a discount rate of 25 percent, the tower boom with Smart Spray™ system achieved a lower annualized NPC per acre than the air curtain sprayer (Table A1).

Varying farm size revealed that while the air curtain sprayer is most economical for orchards of 25 acres and larger, the air blast sprayer is lowest cost for 10-acre orchards (Table A2). This results from the difficulty in amortizing the high fixed cost of the more expensive sprayers over a smaller acreage. For small orchards, the lower investment cost of the air blast sprayer outweighs the higher spray consumption and operating cost.

Given the likelihood that pesticide spray compounds will increase with increasing regulatory restraints, one scenario examined the sensitivity of annualized NPC per acre to pesticide cost rises up to 50 percent over the base case (Table A3). The results show no change in ranking of annualized NPC's. However, as pesticide costs rise, the cost advantages rise proportionately for the three new sprayers that economize on pesticide. The advantage of the air curtain sprayer over the air blast one rises from $101 per acre at present pesticide costs to $171 per acre with a 50% pesticide cost increase (Table A3). By contrast, modifying apple tree density appears to cause no significant differences in annualized NPC's per acre (Table A4).

Summing up the sensitivity analyses, the air curtain sprayer had the lowest NPC across all scenarios considered, except for small farm sizes. The air curtain sprayer appears to dominate due to economizing on spray usage and labor costs. The labor cost saving arises from the faster operating speed (4 mph versus 3 mph for the other models) and more concentrated spray (allowing it to cover 21 acres per tank), since the air curtain sprayer actually required more labor time for maintenance and spray filling.

The sensitivity analysis indicates that for farms with 10 to 25 acres of apple orchards, the tower boom sprayer had the lowest annualized NPC per acre, followed by the air blast sprayer, the air curtain sprayer, and the SmartSpray™ system (Figure 2). However, for farms with 50 acres or more of apple orchards, the air curtain sprayer was lowest cost. On farms with 50 acres of apple orchards, it was followed by the tower boom sprayer; on farms with 100 acres or more of apples, it was followed by the SmartSpray™ sprayer.

The sensitivity of results to size of farm appears linked to the savings in pesticide sprayed and the associated labor costs, which tend to increase with size of farm. This implies that whereas the air blast and tower boom sprayers are less expensive to operate than the air curtain and SmartSpray™ sprayer on small farms, their per-acre operating costs become more expensive as farm size increases. Figure 2 illustrates the long-run cost curves for the different sprayers over different farm sizes.

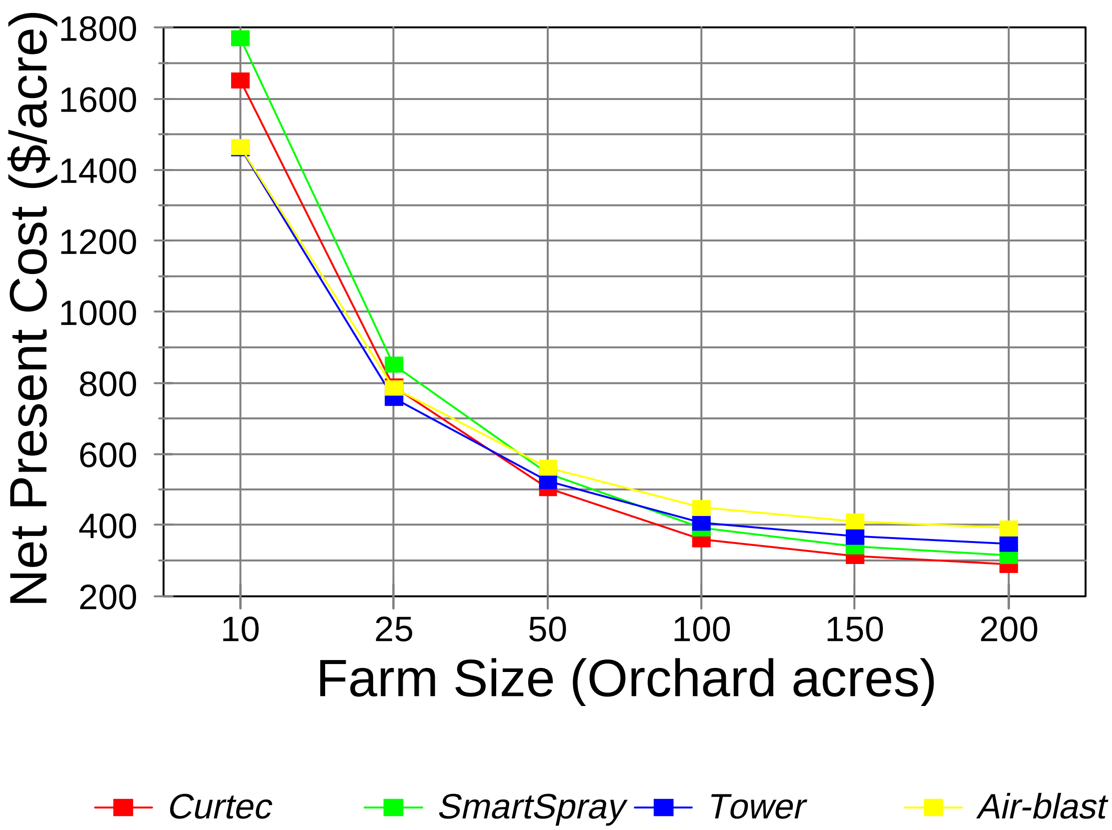

Figure 2: Long-run net present cost per acre of four apple orchard sprayers as farm size increases (assumes ten-year useful sprayer lifetime at 10% discount rate).

Conclusion

Prior research on predicting agricultural technology adoption has shown that many kinds of factors play a role: characteristics of the technology, the farm physical environment, the institutional setting, and farmer background (Feder and Umali). As a group, improved fruit orchard sprayers represent a technology that differs little from the air blast sprayers that they could replace: the farm environment, institutional setting, and farmer backgrounds are all unchanged. What matters in the present case is the technology: its impact on farm income, income risk, convenience, and safety. It has been assumed here that the three newer sprayer models all offer equal pest protection, so neither will they affect orchard yields, fruit quality, and prices, nor will they affect yield and price variability or worker safety. Where these sprayer technologies differ from the conventional air blast sprayer is in their cost of operation and the indirect safety effects of reduced pesticide use.

Of the four orchard sprayers reviewed here, this study has found that ten-year investments in the air curtain sprayer generate the lowest estimated long run costs for pest control in Michigan apple orchards of 50 acres and larger. Sensitivity analysis revealed that this result holds under a wide range of farm and investment financing conditions. However, results are sensitive to farm size. The tower boom sprayer, which has a lower purchase cost, was less costly to run for apple orchards of 25 acres and less.

These results suggest that the air curtain sprayer may offer an attractive alternative to tree fruit growers considering the purchase of a new sprayer. Because the new technology is embodied in a costly equipment, growers will naturally weigh the decision on adopting the air curtain sprayer technology against the repair costs and performance of their old sprayer, waiting until the point where pest management costs can better be contained by replacing the old sprayer with a new one (Krause and Black). When that time arrives, the air curtain sprayer technology should be an attractive alternative for medium- to large-scale growers in that it appears to reduce both long run pest control costs and pesticide use.

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Table A1: Sensitivity of annualized net present cost to financial terms.

	Annualized net present cost ($/acre)			
Financial terms	**Air blast**	**Tower boom**	**Smart Spray**	**Air curtain**
Proportion of funds borrowed				
0%	388	343	308	283
10%	389	344	310	284
25%	390	345	312	286
50% (base)	392	347	315	289
75%	395	350	318	292
100%	397	352	321	295
Discount Rate				
5%	375	330	295	270
10% (base)	392	347	315	289
15%	409	364	335	308
20%	425	381	356	326
25%	441	397	337	345
Loan Interest Rate				
6% (base)	391	345	312	287
9.75%	392	347	315	289
12%	394	349	317	290
15%	395	350	319	292
20%	398	353	322	296

Table A2: Sensitivity of annualized net present cost to orchard acreage.

Orchard acreage	Annualized net present cost ($/acre)			
	Air blast	Tower boom	Smart Spray	Air curtain
10	1464	1461	1770	1652
25	787	758	851	751
50	562	523	545	504
100	449	406	391	361
150	411	367	340	313
200 (base)	392	347	315	289

Table A3: Sensitivity of annualized net present cost to pesticide cost

Cost increase (change over base)	Annualized net present cost ($/acre)			
	Air blast	Tower boom	Smart Spray	Air curtain
0%	392	347	315	289
3%	401	354	320	294
5%	409	361	326	299
10%	426	374	337	309
20%	460	401	359	329
50%	561	482	424	390

Table A4: Sensitivity of annualized net present cost to orchard density and tree spacing.

Orchard density (trees/acre) and spacing	**Annualized net present cost ($/acre)**			
	Air blast	**Tower boom**	**Smart Spray**	**Air curtain**
200 (12ft x 18ft)	392	347	315	289
300 (10ft x 14ft)	393	351	319	292
378 (10ft x 12ft)	393	355	322	295
441 (10ft x 10ft)	394	358	326	297
598 (8ft x 9ft)	394	361	328	299
676 (8ft x 8ft)	395	364	332	302