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BENEFIT-COST ANALYSIS OF ABSCISSION

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Introduction

An abscission agent enhances the separation of citrus fruit from stems. This enhancement is particularly important for mechanical harvesting of late season Valencia oranges picked after early May and roughly accounting for about 37% of the Valencia crop in recent years. At harvesting, Valencia trees have two crops—the current season's crop and the next season's crop of developing fruit. An Abscission agent makes it easier to remove the current season fruit without harming the developing fruit. Without abscission, mechanical harvesting of these Valencia oranges results in unacceptable losses of developing fruit; if the mechanical harvesting shaker is set low enough to reduce loss of developing fruit, the recovery of the present-season fruit is unacceptable.

The purpose of this paper is to provide estimates of the benefits of using abscission to mechanically harvest late season Valencia oranges, as well as early and midseason oranges. The primary expected benefit is a reduction in harvesting costs. With abscission, mechanical harvesting systems can be run faster and about six weeks longer, spreading out costs and significantly reducing the per-box cost. Abscission may also increase the recovery rate of mechanical harvesting.

Before an abscission agent can be used it must be registered with the Federal government. Registration could take up to six years and cost an estimated $7 to $11 million. There is a risk that the agent might not be approved. Even if the agent is approved, there is an additional risk that it may not work in the field as expected. Management of the agent to avoid fruit drop may prove to be difficult for some grove conditions. Additionally, toxicological-related risks, including (real or perceived) consumer perceptions about the product's safety, should probably not be completely discounted. In this report, such risks are considered by providing expected benefits for alternative risk assumptions.

Use of an abscission agent with mechanical harvesting also involves a number of issues that this reports does not address. These issues include the cost of reconfiguring groves for mechanical harvesting (planting trees with appropriate spacing, pruning and skirting), the impact of mechanical harvesting on tree health, and potential bottleneck problems at processing plants (higher harvesting capacity than processing capacity).

Benefit-Cost Analysis

Mechanical harvesting is presently used to pick about 17,600 acres of oranges or about 2.8% of the 622,821 acres of oranges in Florida. With use of an abscission agent, the mechanically-harvested acreage is expected to increase in the future. To be conservative, in the following analysis

100,000 acres are assumed to be mechanically harvested using an abscission agent—this is a guesstimate of the acreage that could be relatively easily converted for mechanical harvesting.

On-tree value estimates for manual harvesting and mechanical harvesting with-abscission versus without-abscission are presented in Table 1. Four scenarios are presented. The first scenario assumes all harvesting is manual. The second assumes all early and midseason oranges and 75% of the Valencia oranges are mechanically harvested without abscission (before May 7, Valencia oranges are mechanically harvested; after May 7, they are manually harvested). The third scenario is the same as the second except Valencia oranges harvested after May 7 are assumed to be mechanically harvested with abscission. The last scenario assumes all early and midseason and Valencia oranges are mechanically harvested with abscission.

The 100,000 acres are assumed to be split fifty-fifty between early and midseason oranges and Valencia oranges as shown in the first three rows. Average boxes per acre over the five-year period from 1998-99 through 2002-03 are assumed. Based on these assumptions, 20.6 million boxes of early and midseason and 15.4 million boxes of Valencia oranges are considered.

The next eight rows (rows 4-13) show assumptions on how these two crops are allocated between manual and mechanical harvesting, and the percentages and amounts (mechanically) recovered, gleaned and lost. For example, for scenario two, three and four, all 20.6 million boxes of the early and midseason oranges are assumed to be mechanically harvested with or without abscission. Assuming a 90% recovery rate, 18.5 million boxes would be recovered by mechanical harvesting. In addition, 8% or 1.6 million boxes are assumed to be gleaned and 2% or .4 million boxes are assumed to be lost. For Valencia oranges, the same recovery, gleaning and loss rates are assumed, but, without abscission, 25% of the late season Valencia crop is assumed to be manually harvested.

Delivered-in price assumptions are shown in rows 14 through 16. The early and midseason and Valencia delivered-in prices are assumed to be \$.85/PS and \$1.00/PS, or \$4.87/box and \$6.62/box , respectively.

Manual pick and haul costs are shown in rows 17 through 19. Without-abscission mechanical harvesting pick and haul costs are shown in rows 20 through 22, while with-abscission mechanical harvesting pick and haul costs are shown in rows 23 through 26. Based on estimates made by Ron Muraro (University of Florida, IFAS), the pick and roadside costs for manual harvesting are set at \$1.59/box[1]; based on estimates made by Fritz Roka (University of Florida, IFAS), the without-abscission pick and roadside costs for mechanical harvesting are set at \$1.10/box (no gleaning); the with-abscission-after-May-7 pick and roadside costs for mechanical harvesting are set at \$.95/box (no gleaning); and the with-abscission-from-December-through-mid-June pick

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[1] Late season manual pick and roadside costs may be higher with tightness in the labor supply that may occur during the latter part of the season. To the extent these costs are higher, the subsequently discussed benefits of using abscission to mechanically harvest late-season Valencia oranges would be greater, compared to manual harvesting them.

and roadside costs for mechanical harvesting are set at $.75/box (no gleaning). As alluded to earlier, the reduction in the pick and roadside costs resulting from the use of abscission is related to extending the mechanical harvesting season and running the harvesters at higher speeds, spreading out the mechanical harvesting costs over more boxes. The $.95/box pick and roadside cost of scenario three is based on extending the mechanically harvesting and spreading out costs across more boxes. The $.75/box pick and roadside cost of scenario four is based on both extending the season and running the harvesters at higher speeds with abscission applied to all early and midseason and Valencia oranges. The cost advantage of mechanically harvesting with abscission is partially offset by the cost of the abscission agent and its application (row 25). Assuming a quantity discount, this cost is guesstimated at $100 per acre when abscission is just used after May 7, and $70 per acre when abscission is used for the entire season from December through mid-June.[2] Glean pick and haul costs are shown in rows 27 through 29. The glean pick and roadside cost was set so the weighted average pick and roadside costs for mechanically harvesting and gleaning was $1.30/box, consistent with industry prices charged.

Given these various assumptions, on-tree prices for manual harvesting, mechanical harvesting without-abscission, mechanical harvesting with-abscission, and gleaning are calculated in rows 30 through 33. Applying these prices to the assumed volumes, estimated on-tree revenues are obtained as shown in rows 34 through 38.

Comparing scenario one to the other scenarios shows the benefits of mechanically harvesting. The on-tree revenue for manual harvesting is $125.8 million or $7.1 million, $11.4 million and $12.2 million less than the on-tree revenue estimates for mechanical harvesting without abscission, mechanical harvesting with abscission after May 7, and mechanical harvesting with abscission used from December through mid-June, respectively.

Focusing on just the benefits of abscission (without-abscission scenario two versus with-abscission scenarios three and four), rows 39 through 41 show that using abscission after May 1 and from December through mid-June results in estimated annual benefits of $4.4 million and $5.1 million, respectively. The lower pick and roadside costs of using abscission for the longer period of scenario four are offset to a relatively large degree by higher abscission costs (scenario three: $100/acre times 25% of the 50,000 acres of Valencia oranges harvested with abscission or $1.25 million; versus scenario four: $70/acre times 100% of the 100,000 acres of early and mid season oranges and Valencia oranges harvested with abscission or $7.0 million).

Estimates for alternative abscission assumptions are provided in Table 2. The first scenario summarizes the baseline estimates and key assumptions in Table 1. The next four scenarios show estimates for a 95% recovery rate with abscission, a $.05/box increase and decrease in the with- and with-out-abscission mechanical harvesting costs, and a 50% reduction in the abscission cost. Based on these assumptions, the annual benefits of abscission range from $4.2 million to $4.9 million for

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[2] The cost of the abscission chemical is not known. The costs assumed here are based on industry guesstimates.

use of abscission after May7, and \$4.9 million to \$10.0 million for use of abscission from December through mid-June.

As shown in Appendix A, the net benefits of changing from a mixed harvesting system with manual harvesting and without-abscission mechanical harvesting components to an all mechanical harvesting system with abscission are due to:

1) the abscission-induced reduction in the mechanical harvesting pick and haul costs, net of the cost of the abscission agent, for all boxes recovered;
2) the mechanical-harvesting-induced reduction in pick and haul costs, for those boxes previously manually harvested and now recovered by mechanical harvesting;
3) minus the on-tree value of boxes previously manually picked but now lost with mechanical harvesting;
4) minus the additional gleaning cost for boxes previously manually picked and now gleaned with mechanical harvesting.

Stream of Benefits Over Time and Discounting

Over time the abscission agent is expected to generate a stream of benefits. Let B_n be the benefit in period n.

Assume the abscission agent will be available k_1 years in the future and can be used for the next k_2 years. Then, the present discounted value (PDV) of the benefits is

(1) $$PDV = \sum_{n=k1 \text{ to } (k1+k2)} B_n/(1+i)^n ,$$

where i is the discount rate.

Assuming $B_n = B$; i.e., the same benefit in each year, the PDV can be written as

(2) $$\begin{aligned} PDV &= B \sum_{n=k1 \text{ to } (k1+k2)} 1/(1+i)^n , \\ &= B\,[1/(1+i)^{k1}] \sum_{n=0 \text{ to } k2} 1/(1+i)^n . \end{aligned}$$

If the abscission agent provides benefits forever; i.e., $k_2 = \infty$, the PDV is

(3) $$\begin{aligned} PDV &= B\,[1/(1+i)^{k1}] \sum_{n=0 \text{ to } \infty} 1/(1+i)^n \\ &= B\,[1/(1+i)^{k1}]\,(1+i)/i. \\ &= B^*D, \end{aligned}$$

where we define the discount factor $D = [1/(1+i)^{k1}]\,(1+i)/i$. For example, if $k_1 = 6$ and i=5%, then D = 15.7. Note that i and D are inversely related. Also note that when k_2 is less than infinity but large, the error in using $D = [1/(1+i)^{k1}]\,(1+i)/i$, as opposed to $\sum_{n=k1 \text{ to } k2} 1/(1+i)^n$, is small. Hence, for our initial analysis, we use D for discounting.

If the annual on-tree benefits are $5.1 million (Table 1), the discount rate is 5%, and stream of benefits begin in six years, then the PDV is $79.7 million (Table 3).

Benefits Versus Costs

We need to compare the stream of benefits of abscission to its registration cost (more generally, abscission research costs and the costs of configuring acreage for mechanical harvesting should also be included with registration costs). Let C be the registration costs appropriately discounted. For the investment in abscission agents to be cost effective, at a minimum (since research and grove configuring costs are excluded) we need the discounted benefits to exceed the registration costs, i.e.,

(4) $PDV > C$,

or, dividing both sides of equation (4) by C,

(5) $PDV/C > 1$.

The term PDV/C is known as the benefit-cost ratio and it should exceed unity to proceed with the registration or, in general, some investment.

About $7 to $11 million dollars may be spent on registration over the next six years. Assuming $9.0 million are spent and distributed over these years as shown in Table 3, footnote b, and a discount rate of 5%, the discounted costs over this six-year period would be $7.8 million.

The Gamble

Efforts to register the abscission agent may fail or the agent may not work as expected in the field. These possibilities should be factored into the decision process. Let w be the probability of success and 1-w the probability of failure. The benefits are PDV for abscission being registered and working in the field as planned versus zero otherwise. Hence, the expected benefits are $w*PDV+(1-w)*0$ or $w*PDV$. For the project to be funded we need

(6) $w*PDV > C$,

or

(7) $w*PDV/C > 1$.

The term w*PDV/C can be viewed as the expected cost benefit ratio—the cost-benefit ratio equals zero for failure (regardless of the cost of failure) and PDV/C for success; hence the expected cost -benefit ratio is 0*(1-w) + w*PDV/C or the left-hand-side of result (7), given the probabilities of failure and success are (1-w) and w, respectively.

Application

The probability of failure can occur at several different points. Consider a 50% chance of success in the registration process, and a 50% success rate with respect to the agent working in the field. If these two events are independent, the overall probability of success is 25% (50% times 50% or like obtaining two heads in a row in flipping a coin). That is, with the possibility of failure at several points, the probability of overall success could be somewhat low.

Table 3 shows expected benefits for alternative assumptions on the probability of success and discount rates. For example, if the discount rate is 5% and the probability of success is 10% then the expected on-tree benefits are $8.0 million. In this case, the benefit-(registration)cost ratio is slightly greater than 1.0, assuming the discounted costs of registration are $7.8 million. Hence, in this example, more than a 10% probability of success would be needed for expected benefits to exceed expected costs by a more comfortable margin. For instance, a 30% probability of success results in a 3.1 benefit-cost ratio as shown in the Table 3.

Summary

The results of this study show various benefits of using abscission, depending on the assumptions made. The benefits are due to the economies of scale that can be obtained by using mechanical harvesting. With abscission, mechanical harvesters can be run about six weeks longer and at higher speeds, spreading out costs across the harvested boxes. Thus investment in abscission may make it possible to fully realize the benefits of mechanical harvesting. Our example (Table 1) shows an estimated advantage of mechanical harvesting without-abscission over manual harvesting at $7.1 million per year. With abscission used over most of the season, this advantage is $12.2 million or 71.8% higher than the $7.1 million advantage.

The expected benefits of abscission, however, could be lower as the abscission chemical may fail to be registered or may fail in the field. The expected benefit-cost framework in Table 3 provides an approach to consider the failure probabilities. Ultimately judgments on these probabilities need to be made.

Appendix A

To formally specify the benefits of abscission, the following terms are first defined.

(A1) q = crop (million boxes)
(A2) r_A = % of the crop hand picked
(A3) $1 - r_A$ = % of the crop desired to be mechanically harvested—recovered by mechanical harvesting, gleaned and lost
(A4) r_1 = % of the crop desired to be mechanically harvested that is recovered
(A5) r_2 = % of the crop desired to be mechanically harvested that is gleaned
(A6) $1 - r_1 - r_2$ = % of the crop desired to be mechanically harvested that is lost
(A7) p = the delivered-in price, \$/box
(A8) c_A = the manual pick and haul costs, \$/box
(A9) d_m = the difference between the manual pick and haul costs and the without-abscission mechanical harvesting pick and haul costs, \$/box
(A10) d_a = the difference between the without-abscission mechanical harvesting pick and haul costs and the with-abscission mechanical harvesting pick and haul costs, \$/box
(A11) d_g = the difference between the manual pick and haul costs and the glean pick and haul costs, \$/box
(A12) $P_A = p - c_A$ = the manual on-tree price, \$/box
(A13) $p - (c_A - d_m) = P_A + d_m$ = the without-abscission mechanical harvesting on-tree price, \$/box
(A14) $p - (c_A - d_m - d_a) = P_A + d_m + d_a$ = the with-abscission mechanical harvesting on-tree price, \$/box
(A15) $p - (c_A + d_g) = P_A - d_g$ = the glean on-tree price, \$/box

Thus, the on-tree revenue for without-abscission mechanical harvesting, with a manual harvesting component, can be written as

(A16) $R_{wo} = q*r_A*P_A + q*(1-r_A)*r_1*(P_A+d_m) + q*(1-r_A)*r_2*(P_A-d_g)$.

The with abscission mechanical harvesting on-tree revenue can be written as

(A17) $R_w = q*r_1*(P_A+d_m+d_a) + q*r_2*(P_A-d_g)$.

Hence, subtracting result (A16) from result (A17), the benefits of abscission can be written as

(A18) $R_w - R_{wo} = q*r_1*(r_A*d_m+d_a) - q*r_A*(P_A*(1-r_1-r_2)+r_2*d_g)$.

Table 1. Estimated On-Tree Benefits of Abscission.

		Unit	1: Manual Harvesting EM	1: Val	1: Total	2: Mech. Harv. W/O Abs.[1] EM	2: Val	2: Total	3: Mech. Harv. W. Abs. After May 7[2] EM	3: Val	3: Total	4: Mech. Harv. W. Abs. Dec.-June[3] EM	4: Val	4: Total
1	Acreage	Acres	50,000	50,000	100,000	50,000	50,000	100,000	50,000	50,000	100,000	50,000	50,000	100,000
2	Yield	Boxes/ Acre	411	308	360	411	308	360	411	308	360	411	308	360
3	Total Production	Mil. Boxes	20.6	15.4	36.0	20.6	15.4	36.0	20.6	15.4	36.0	20.6	15.4	36.0
4	Manual Harv.	% Tot. Prod.	100%	100%	100%	0%	25%	11%	0%	0%	0%	0%	0%	0%
5	Mech. Harv	% Tot. Prod.	0%	0%	0%	100%	75%	89%	100%	100%	100%	100%	100%	100%
6	Recovered (90% of Mech Har)	% Tot. Prod.	0%	0%	0%	90%	68%	80%	90%	90%	90%	90%	90%	90%
7	Gleaned (8% of Mech Har)	% Tot. Prod.	0%	0%	0%	8%	6%	7%	8%	8%	8%	8%	8%	8%
8	Lost (2% of Mech Har)	% Tot. Prod.	0%	0%	0%	2%	2%	2%	2%	2%	2%	2%	2%	2%
9	Manual Harv.	Mil. Boxes	20.6	15.4	36.0	0.0	3.9	3.9	0.0	0.0	0.0	0.0	0.0	0.0
10	Mech. Harv	Mil. Boxes	0.0	0.0	0.0	20.6	11.6	32.1	20.6	15.4	36.0	20.6	15.4	36.0
11	Recovered (90% of Mech Har)	Mil. Boxes	0.0	0.0	0.0	18.5	10.4	28.9	18.5	13.9	32.4	18.5	13.9	32.4
12	Gleaned (8% of Mech Har)	Mil. Boxes	0.0	0.0	0.0	1.6	0.9	2.6	1.6	1.2	2.9	1.6	1.2	2.9
13	Lost (2% of Mech Har)	Mil. Boxes	0.0	0.0	0.0	0.4	0.2	0.6	0.4	0.3	0.7	0.4	0.3	0.7
14	Delivered-In Price	$/PS	0.85	1.00	.91	0.85	1.00	0.91	0.85	1.00	0.91	0.85	1.00	0.91
15		PS/Box	5.73	6.62	6.11	5.73	6.62	6.11	5.73	6.62	6.11	5.73	6.62	6.11
16		$/Box	4.87	6.62	5.59	4.87	6.62	5.59	4.87	6.62	5.59	4.87	6.62	5.59
	Manual Pick & Haul Costs													
17	Pick & Roadside Cost	$/Box	1.59	1.59	1.59	na	1.59	1.59	na	na	na	na	na	na
18	Haul Cost	$/Box	0.53	0.53	0.53	na	0.53	0.53	na	na	na	na	na	na
19	Total	$/Box	2.12	2.12	2.12	na	2.12	2.12	na	na	na	na	na	na
	W/O Abs. Mech. Pick & Haul Costs													
20	Pick & Roadside Cost[4]	$/Box	na	na	na	1.10	1.10	1.10	na	na	na	na	na	na
21	Haul Cost	$/Box	na	na	na	0.53	0.53	0.53	na	na	na	na	na	na
22	Total	$/Box	na	na	na	1.63	1.63	1.63	na	na	na	na	na	na

Table 1 continued

	With Abs. Mech. Pick & Haul Costs													
23	Pick & Roadside Cost[4]	$/Box	na	na	na	na	na	na	0.95	0.95	0.95	0.75	0.75	0.75
24	Haul Cost	$/Box	na	na	na	na	na	na	0.53	0.53	0.53	0.53	0.53	0.53
25	Abscission Cost[5]	$/Box	na	na	na	na	na	na	0	0.09	0.04	0.19	0.25	0.22
26	Total	$/Box	na	na	na	na	na	na	1.48	1.57	1.52	1.47	1.53	1.50
	Glean Pick & Haul Costs													
27	Pick & Roadside Cost	$/Box	na	na	na	3.50	3.50	3.50	3.50	3.50	3.50	3.50	3.50	3.50
28	Haul Cost	$/Box	na	na	na	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53
29	Total	$/Box	na	na	na	4.03	4.03	4.03	4.03	4.03	4.03	4.03	4.03	4.03
30	Manual On-Tree Price	$/Box	2.75	4.50	4.50	na	4.50	4.50	na	na	na	na	na	na
31	W/O Abs. Mech. On-Tree P.	$/Box	na	na	na	3.24	4.99	3.87	na	na	na	na	na	na
32	With Abs. Mech. On-Tree P.	$/Box	na	na	na	na	na	na	3.39	5.05	4.10	3.40	5.09	4.12
33	Glean On-Tree Price	$/Box	na	na	na	0.84	2.59	1.47	0.84	2.59	1.59	0.84	2.59	1.59
34	Manual On-Tree Revenue	Mil. $	56.5	69.3	125.8	na	17.3	17.3	na	na	na	na	na	na
35	W/O Abs. Mech. On-Tree Rev.	Mil. $	na	na	na	59.9	51.9	111.8	na	na	na	na	na	na
36	With Abs. Mech. On-Tree Rev.	Mil. $	na	na	na	na	na	na	62.7	70.0	132.7	62.9	70.5	133.4
37	Glean On-Tree Revenue	Mil. $	na	na	na	1.4	2.4	3.8	1.4	3.2	4.6	1.4	3.2	4.6
38	Total	Mil. $	56.5	69.3	125.8	61.3	71.6	132.9	64.1	73.2	137.3	64.3	73.7	138.0
	Time Period Abscission Used		After May 7	Dec-Mid June										
39	Total On-Tree Rev With Abs.	Mil. $	137.3	138.0										
40	Total On-Tree Rev W/O Abs.	Mil. $	132.9	132.9										
41	Abscission Benefit	Mil. $	4.4	5.1										

[1] Assumes 800 hours of mechanical harvesting from December through May 7.

[2] Assumes 1000 hours of mechanical harvesting from December through Mid June.

[3] Assumes 1000 hours of mechanical harvesting from December through Mid June, and harvest speeds increase by 25%.

[4] Without gleaning.

[5] For Scenario 3, assumes cost for abscission chemical and application is $100/acre; all costs allocated to boxes recovered---
for Valencias: 12,500 acres * $100/acre / 13,900,000 million boxes.
for Scenario 4, assumes cost for abscission chemical and application is $70/acre; all costs allocated to boxes recovered—
50,000 acres * $70/acre / 13,900,000 million boxes; for early & mids: 50,000 acres * $70/acre / 18,500,000 million boxes.

Table 2. Alternative Scenarios of Estimated On-Tree Benefits of Abscission.

		Mechanical Harvesting No Abscission		With	Mechanical Harvesting With Absc., After May 7			Mechanical Harvesting With Absc., Dec-Mid June		
Scenario 1:Base		EM	Val	Total	EM	Val	Total	EM	Val	Total
Recovery	%	90%	68%	80%	90%	90%	90%	90%	90%	90%
W/O Absc. Mech. Pick & Roadsiding Cost	$/Box	1.10	1.10	1.10	na	na	na	na	na	na
With Absc. Mech. Pick & Roadsiding Cost	$/Box	na	na	na	0.95	0.95	0.95	0.75	0.75	0.75
Abscission Cost5	$/Box	na	na	na	0.00	0.09	0.04	0.19	0.25	0.22
On-Tree Revenue	Mil. $			132.9			137.3			138.0
Abscission Benefit	Mil. $						**4.4**			**5.1**
Scenario 2: 5% Recovery Increase		EM	Val	Total				EM	Val	Total
Recovery	%	90%	68%	80%	90%	91%	91%	95%	95%	95%
On-Tree Revenue	Mil. $			132.9			137.8			142.9
Abscission Benefit	Mil. $						**4.9**			**10.0**
Scenario 3: $.05/Box Pick Cost Increase		EM	Val	Total				EM	Val	Total
W/O Absc. Mech. Pick & Roadsiding Cost	$/Box	1.15	1.15	1.15	na	na	na	na	na	na
With Absc. Mech. Pick & Roadsiding Cost	$/Box	na	na	na	1.00	1.00	1.00	0.80	0.80	0.80
On-Tree Revenue	Mil. $			131.5			135.7			136.4
Abscission Benefit	Mil. $						**4.2**			**4.9**
Scenario 4: $.05/Box Pick Cost Decrease		EM	Val	Total				EM	Val	Total
W/O Absc. Mech. Pick & Roadsiding Cost	$/Box	1.05	1.05	1.05	na	na	na	na	na	na
With Absc. Mech. Pick & Roadsiding Cost	$/Box	na	na	na	0.90	0.90	0.90	0.70	0.70	0.70
On-Tree Revenue	Mil. $			134.3			138.9			139.6
Abscission Benefit	Mil. $						**4.5**			**5.3**
Scenario 5: 50% Abscission Cost Decrease		EM	Val	Total				EM	Val	Total
Abscission Cost	$/Box	na	na	na	0.00	0.07	0.03	0.14	0.19	0.16
On-Tree Revenue	Mil. $			132.9			137.6			139.7
Abscission Benefit	Mil. $						**4.7**			**6.8**

Table 3. Expected Beneffits Versus Registration Costs.

Discount Rate		r	%	2%	3%	4%	5%	6%	7%	8%
Discount Factor[a]		D		45.3	28.8	20.5	15.7	12.5	10.2	8.5
Annual Benefits		B	Mil. $	5.1	5.1	5.1	5.1	5.1	5.1	5.1
Expected Discounted Benefits: w*PDF	Prob. of Success	100%	Mil. $	230.4	146.3	104.5	79.7	63.4	51.8	43.3
		70%		161.3	102.4	73.2	55.8	44.4	36.3	30.3
		50%		115.2	73.1	52.3	39.9	31.7	25.9	21.6
		30%		69.1	43.9	31.4	23.9	19.0	15.5	13.0
		10%		23.0	14.6	10.5	8.0	6.3	5.2	4.3
		5%		11.5	7.3	5.2	4.0	3.2	2.6	2.2
Discounted Cost[b]		C	Mil. $	8.5	8.2	8.0	7.8	7.5	7.3	7.1
Expected Benefit-Cost Ratio	Prob. of Success	100%	B/C	27.2	17.8	13.1	10.3	8.4	7.1	6.1
		70%		19.0	12.5	9.2	7.2	5.9	4.9	4.2
		50%		13.6	8.9	6.5	5.1	4.2	3.5	3.0
		30%		8.2	5.3	3.9	3.1	2.5	2.1	1.8
		10%		2.7	1.8	1.3	1.0	0.8	0.7	0.6
		5%		1.4	0.9	0.7	0.5	0.4	0.4	0.3

[a] $D = [1/(1+i)^{k1}]\,(1+i)/i$, where i is the discount rate and k1 (6) is the number of years in the future when abscission is first used.

[b] Discounted regristration cost assuming $1.5 million spent per year over the next 7 years:

Disc. Rate	Year in Future 1	2	3	4	5	6	Disc. Cost Sum
				Discounted Mil. $ Spent			
0%	1.00	2.50	2.50	1.50	.75	.75	9.00
2%	.98	2.40	2.36	1.39	.68	.67	8.47
3%	.97	2.36	2.29	1.33	.65	.63	8.22
4%	.96	2.31	2.22	1.28	.62	.59	7.99
5%	.95	2.27	2.16	1.23	.59	.56	7.76
6%	.94	2.22	2.10	1.19	.56	.53	7.54
7%	.93	2.18	2.04	1.14	.53	.50	7.34
8%	.93	2.14	1.98	1.10	.51	.47	7.14