Cost/Benefit Analysis of Abscission Registration for Citrus Mechanical Harvesting

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Selected Paper prepared for presentation at the Southern Agricultural Economics Association Annual Meeting, Atlanta, Georgia, January 31-February 3, 2009

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Abstract

The Florida Department of Citrus (DOC) is spending public funds to register an abscission agent compound (CMNP) with the U.S. EPA as part of its effort to enhance the private benefits associated with citrus mechanical harvesting. An abscission agent application should allow existing harvesting equipment to operate through the entire late season orange harvesting period. When estimating costs and benefits through 2018, the net present value of mechanically harvesting 25,000 acres is between $60.8 and $79.9 million, depending on price, production, and fruit loss scenarios. For any of the scenarios considered, the discounted value of abscission benefits with mechanical harvesting fully pays for the costs of registration and development within four years.

Current Situation

Research and development (R&D) expenditures are investments into new products and technologies. If a private company possesses the financial capital, expects a sufficient financial return, and can maintain control over the intellectual property rights of R&D outputs, then R&D will be funded as a private investment. In many cases, however, the economic benefits of a new technology are widely recognized, but the cost of new product development is beyond the scope of a single firm. In this situation, the benefits of a new technology can be realized only with investment of public funds. Public funds can be secured from either government appropriations or through business associations where member contribute funds into a common investment pool. This paper describes the case of CMNP and the efforts of the Florida Department of Citrus (DOC) to develop and register CMNP as an abscission chemical to facilitate citrus mechanical harvesting.

CMNP (5-chloro-3-methyl-4-nitro-1H-pyrazole) has long been regarded as an effective abscission compound that can circumvent the biological constraints that currently block existing harvesting equipment from achieving their full economic advantage. Before CMNP can be commercially manufactured, the chemical must be tested and registered through the USEPA, a process that has been estimated to cost between $7 and $11 million. Cost-benefit analyses by agro-chemical companies have concluded that the high registration costs and the product's limited use to just citrus acreage for juice processing prevents CMNP from being a profitable privately funded venture.

Since 1995, the DOC has spent public funds from grower mandated taxes and grants from state and federal agencies to develop CMNP and to register it as an abscission agent compound to make citrus mechanical harvesting more cost effective. The most important benefit of an abscission compound will be to allow mechanical harvesting equipment to operate during the late season (May-June) 'Valencia' orange harvest period without imposing a yield loss on next season's crop. Specially, the objectives of this paper are to 1) estimate the annual value from extending the use of mechanical harvesting equipment into the late season 'Valencia' period, and 2) compare a discounted stream of private benefits from mechanical harvesting with CMNP against the public costs of the chemical's development and registration.

Background

Maintaining global competitiveness and offsetting increased production costs from combating serious citrus diseases (greening and canker) are two reasons why the Florida citrus industry needs to find ways to reduce harvest costs. Nearly all of Florida's 621,373 commercial citrus acreage is hand harvested (FASS, 2008). Costs to hand harvest exceed production costs under typical cultural programs, and represent more than 70% when compared to the production costs of programs that include canker and greening management costs (Muraro, 2007).

Mechanical harvesting increases harvest labor productivity, and when combined with economies of scale, the unit cost of harvesting could be reduced by as much as 50% (Roka, 2007). Another important benefit of increasing labor productivity with mechanical harvesting systems is diminishing citrus industry's dependence on a sizable number of seasonal and migrant farm workers, many of whom are in the United States without legal documentation.

Citrus mechanically harvested acreage has been increasing since 1999. The 31,500 acres mechanically harvested in 2007-08 season, however, represented less than 7% of the total sweet orange acreage (UF/IFAS, 2008). Roka (2007) lists several significant impediments to the widespread adoption of mechanical harvesting systems, of which the most significant obstacle is harvesting late-season 'Valencia' oranges.

'Valencia' is an orange variety highly valued for juice processing because of its high solid (sugar) content and rich color score. Typically, growers receive higher prices for 'Valencia' oranges than for early and mid season varieties. 'Valencia' oranges require 13 to 15 months to fully mature, which means that during the entire harvest season (March to June) two crops hang on the trees – this year's mature fruit and next year's growing fruitlets. Late season 'Valencia' harvest occurs sometime after May 1st when next year's growing fruit reaches one-inch in diameter. Previous studies have estimated between 20 and 50% yield reductions in next year's crop when 'Valencia' fruit is mechanical harvesting with young fruit greater than one-inch diameter (Hedden and Coppock, 1971; Coppock et al., 1981; Roka et al., 2005; Whitney and Hedden, 1973). Mechanical harvesting systems are forced to shut down sometime during May, leaving an estimated 25% to 30% of Florida's mature 'Valencia' crop to be harvested by hand crews (FASS, 2005).

Abscission compounds offer a solution to the "late-season" problem by selectively loosening this year's mature fruit and reducing the required force to remove fruit. Harvesting equipment can operate with less mechanical force, and thereby minimize the inadvertent removal next year's young fruits. One compound, CMNP (5-chloro-3-methyl-4-nitro-1H-pyrazole) has attracted a significant amount of attention because it loosens fruit over a wide range of concentrations and does not affect tree health or yield (Burns, 2002).

Model and Data

A model was developed to compare an annual stream of benefits from mechanically harvesting late-season 'Valencia' oranges with CMNP application against the costs to develop and register CMNP. The model consists of two equations, one estimating economic benefits (B_A) and the other quantifying cost of developing and registering CMNP for commercial use (C_A). Economic viability of CMNP was evaluated by calculating the NPV of accrued costs since 1995 and anticipated benefits starting in 2010 and continuing through the 2018 season. A payback period was also calculated as additional measure of financial performance.

Equation (1) describes two benefits of abscission: 1) (V_A) The dollar value of fruit that would have been lost in the next season if the crop in the current season is mechanically harvested without CMNP application, and 2) (S_A) the harvest cost savings earned by extending the operation of a mechanical system in the current season.

$$B_A = \sum_{t=a}^{T}\left[\frac{V_A + S_A}{(1+r)^t}\right]$$

$$= \sum_{t=a}^{T}\left[\frac{\lambda * Q_{t+1}^{vls} * P_{t+1} * \gamma_t}{(1+r)^{t+1}} + \frac{\gamma_t * Q_t^{vls} * (HH_{\cos t/bx} - MH_{\cos t/bx} - A_{\cos t/bx})}{(1+r)^t}\right] \qquad (1)$$

The dollar value of fruit (V_A) is estimated by multiplying: 1) percent yield reduction in next year's crop (λ), 2) quantity of late season fruit to be harvested (Q_{t+1}^{vls}) and, 3) on-tree fruit price (P_{t+1}). The calculated value of lost fruit was constrained by the area over which CMNP will be applied (γ_t). Harvest cost savings (S_A) equals the unit cost savings multiplied by the projected number of boxes to be mechanically harvested during the late season, where ($\gamma_t * Q_t^{vls}$) is the maximum area treated by abscission compound application and the unit cost savings is calculated by subtracting mechanical harvesting ($MH_{cost/bx}$) and abscission application cost per box ($A_{cost/bx}$) from hand harvesting cost per box ($HH_{cost/bx}$).

Total cost of EPA registration is estimated to be between $7 and 11 million. In addition, the University of Florida-IFAS has spent between $500 and $700 thousand of public dollars annually since 1996 to research alternative abscission compounds and develop management strategies for the application of CMNP. As depicted in Equation (2), abscission expenditures are divided into two categories: 1) registration costs (Reg_t), and 2) R&D expenditures by FDOC ($R\&D_t^{FDOC}$), and UF/IFAS ($R\&D_t^{UF}$). For the purposes of this analysis, abscission R&D and CMNP registration costs were totaled from 1996 and are expected to continue until CMNP is fully registered for commercial use in 2012.

$$C_A = \sum_{t=a}^{T} \frac{C_t}{(1+r)^t} = \sum_{t=a}^{T} \left[\frac{\mathrm{Re}\, g_t + R\&D_t^{FDOC} + R\&D_t^{UF}}{(1+r)^t} \right] \qquad (2)$$

Results from field trials provided estimates of second year yield losses from mechanical harvesting without CMNP application. Two scenarios were developed around these results. A high-loss scenario (H%) assumes that yield reductions of 15% occur in early May harvest, increasing to 20%, 45% and 50% in late May, early June, and mid June dates, respectively. A low-loss scenario (L%) assumes yield reductions of 15% and 20% for the early and mid June harvest dates, respectively.

The Florida Department of Citrus (FDOC) forecasted future production and season average prices for all round oranges from 2009 to 2018. Figure 1 outlines the steps used to convert the total FDOC estimates to the expected quantities of ‘Valencia’ oranges harvested during the four late-season dates. Proportions were estimated using the historical FASS data from 1985-86 through 2005-06 (FASS, 2007). The harvest date percentages were used to apportion forecasted 'Valencia' production between 2008 and 2018 by the four late season harvest dates (Table 1). Same methodology was applied to forecasting on-tree 'Valencia' prices.

An average yield per acre was calculated for 'Valencia' oranges. This value was applied to the acreage constraint to project the number of boxes that will be available for mechanical harvesting with abscission during the late season ($\gamma_t * Q_t^{vls}$). FASS production data from 1985-86 through 2005-06 season was used to calculate an average yield per acre for 'Valencia' oranges. 'Valencia' blocks averaged 305.09 boxes per acre, a 12.61% reduction in average yield per acre from all round oranges. This percentage differential was applied to the FDOC projected yield per acre for all round oranges for seasons 2007-08 through 2017-18 and, converted to boxes by multiplying the number of acres allowed by EUP (Table 2).

The model allocates CMNP on the basis of one harvest date at a time. That is, if the entire EUP acreage allotment, converted to boxes (Table 2), can be consumed during the first harvest date where abscission is needed to eliminate a subsequent reduction in yield, i.e. early May of 2010-11, in scenarios with high percentage of yield reduction and high production, 8.73 million boxes (Table 2) will be sprayed with CMNP and can be fully allocated in early May where 11.66 million boxes (Table 1) are available, then no mechanical harvesting with CMNP will be applied during the rest of the season.

Four scenarios were developed and analyzed to determine if the private benefit of extending mechanical harvesting into late May and June with abscission agent application more than offset the public costs of development and registration (Table 3). These scenarios examined changes with respect to four variables: price, production, percentage of lost fruit and the amount of fruit allotted by the experimental use permit (EUP) to be sprayed with CMNP.

The nominal and discount dollars spent on registration and R&D of CMNP since 1996 are listed in Table 4. Expenditures on registration began in 2004 with federal grants. Federal government funding stopped in 2006 and provided a total of $2.054 million toward CMNP registration. FDOC expenditures on CMNP registration are projected to be nearly $6.0 million by 2009. By 2005, The FDOC spent almost $4.00 million on abscission R&D. Since 2005, the University of Florida/IFAS has spent $1.32 million on screening alternative abscission compounds and on CMNP field management strategies. Table 4 summarizes R&D and registration costs.

The cost/benefit analysis in this paper uses the 2007-08 season as the initial reference point, that is t = 0. Even though, benefits from abscission will continue on indefinitely, projected net cash flows were calculated over a 10-year planning horizon for CMNP due to availability of projected production and price estimates from FDOC. Registration and R&D expenditures from 1996 to 2007 were combined and discounted using Equation 2, to 2007-08 dollars for all four scenarios, totaling an initial investment of $19.10 million. The model applied the same interest rate (r = 10%) used to discount future cash flows, as well as to calculate the present value of past costs.

Results and Discussion

The estimated NPV of CMNP public investment from 1995 through 2018 under high price and low production expectations ranged from $72 to $79 million. Under low price and high production expectations, NPV estimates over the same time frame ranged between $60 and $66 million. In any of the four scenarios considered the NPV of CMNP investment with 25,000 of treated “late-season” acreage turned positive by the 2012 season, four years from 2008, the reference year of this study (Table 5).

Results by scenario suggest that on-tree price will have a bigger influence on CMNP returns than production levels. The effect of changing production assumptions is relatively small compared to the effect of price changes. In high production scenarios, the total number of boxes mechanically harvest in the late season within 25,000 acres of EUP is greater than in low production scenarios, resulting in higher savings. A low price assumption embedded with high production levels, however, resulted in a lower value of preserved fruit, offsetting gains in harvest savings.

The four scenarios described in Table 5 evaluate how different price and production assumptions combined with percentage levels of lost fruit from mechanical harvesting late season ‘Valencia’ oranges without abscission affect the NPV of CMNP. These results by scenario provide a basis to evaluate minimum threshold levels for unit harvest cost savings and EUP acreage. Figures 2 depict NPV surface for scenario 1. The vertical axis shows the NPV in million dollars for ranges of unit cost savings due to mechanical harvesting and EUP acreage limits. The bottom right axis represents different levels of unit cost savings that range from $0.00 to $0.80 per box, the unit cost differential used in this analysis. The bottom left axis represents different levels of EUP acreage ranging from 0 to 25,000 acres, the amount being requested in the EUP application with U.S. EPA. In each scenario the NPV surface decreases as both EUP acreage and unit cost savings decrease. The surface allows threshold points to be identified where the NPV is no longer positive.

NPV surfaces suggest that the NPV is influenced by the EUP acreage constraint. For high price/low production scenarios (S1 and S2), mechanical harvesting less than 5,733 acres with a unit cost savings of $0.80 will result in negative values of NPV over the timeline of the analysis (i.e 2018). If unit cost savings are only $0.10 per box, then mechanically harvested areas with

CMNP application will have to increase to more than 8,403 acres or NPV will be negative. In more conservative scenarios, points on the NPV threshold were similar. Annual mechanically harvest areas of less than 6,534 acres, with a unit cost savings of $0.80, will result in negative values of NPV. If unit cost savings are $0.10 per box, then mechanically harvested areas with CMNP application of less than 10,318 acres will also result in negative values of NPV (Table 6).

Table 7 depicts the minimum acreage of CMNP application to achieve a payback period within 6 years by selected unit cost harvest savings (i.e. Cumulative NPV=0 by 2013-14). If unit cost savings are $0.10 per box annual mechanically harvest areas of less than 12,625 acres will result in negative values of NPV in high price/low production scenarios. On the other hand, low price/high production scenarios will yield negative NPV if unit cost savings are $0.10 per box and mechanically harvested areas with CMNP application are 14,890 acres.

Concluding comments

Results by scenario provide a basis to evaluate minimum threshold levels for two critical variables: unit harvest cost savings and EUP acreage. These threshold levels are useful to visualize the implications of changes in these two variables and their effect in the outcome of this investment. Reductions in the gap between hand harvesting cost per box and mechanical harvesting plus the application of CMNP cost per box, referred to as the unit harvest cost savings, have a negative impact on the NPV. If this gap is reduced to zero, the NPV of CMNP will still be positive, but the industry would have no incentive to implement mechanical harvesting. The overarching objective of mechanical harvesting with abscission agent application are to reduce harvesting costs and increase growers' on-tree returns.

The EUP constrained the model by setting a limit on acreage of CMNP application during the late season. If this constraint is removed and more acres receive CMNP application with mechanical harvesting, then more acres realize the estimated benefits. Returns will increase as well as the NPV of CMNP. On the other hand, a threshold exists for total acreage receiving CMNP, below which the NPV of CMNP is negative. The likelihood that the public investment into CMNP will be positive is very strong. The minimum acreage threshold to achieve a positive NPV on CMNP investment within 6 years is less than 15,000 acres, 10,000 acres less than the requested experimental use permit. This minimum acreage further assumes that net savings from mechanical harvesting will only be 10-cents per box less than hand harvesting. The ability that CMNP has in enhancing efficiencies of mechanical harvesting can be tied back with the fact that with economies of scale unit savings should increase, and thus, the overall benefit of CMNP should be greater.

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Table 1. Projected late-season 'Valencia' oranges by harvest dates, low and high production scenarios (million boxes), for seasons 2007-08 through 2017-18.

	Early May (million boxes)		**Mid May (million boxes)**		Early June (million boxes)		Mid June (million boxes)	
Season	Low	High	Low	High	Low	High	Low	High
2007-08	11.99	12.25	10.86	11.10	5.72	5.84	3.86	3.95
2008-09	11.73	12.12	10.63	10.98	5.59	5.78	3.78	3.90
2009-10	11.40	11.86	10.33	10.74	5.44	5.66	3.67	3.82
2010-11	11.07	11.66	10.03	10.57	5.28	5.56	3.57	3.76
2011-12	10.68	11.46	9.68	10.39	5.09	5.47	3.44	3.69
2012-13	10.42	11.40	9.44	10.33	4.97	5.44	3.36	3.67
2013-14	10.22	11.33	9.26	10.27	4.87	5.41	3.29	3.65
2014-15	10.09	11.27	9.14	10.21	4.81	5.37	3.25	3.63
2015-16	9.96	11.33	9.02	10.27	4.75	5.41	3.21	3.65
2016-17	9.96	11.40	9.02	10.33	4.75	5.44	3.21	3.67
2017-18	9.96	11.40	9.02	10.33	4.75	5.44	3.21	3.67

Source: Blanco, 2008.

Table 2. EUP acreage constraint converted to total boxes of 'Valencia' orange for seasons 2007-08 through 2017-18 under two production scenarios (Low and High).

	All oranges avg. yield* (boxes/acre)		'Valencia' avg. yield** (boxes/acre)		'Valencia' (million boxes)	
Season	Low	High	Low	High	Low	High
2007-08	388.04	388.29	339.09	339.31	8.48	8.48
2008-09	389.05	389.72	339.97	340.56	8.50	8.51
2009-10	394.29	393.22	344.55	343.62	8.61	8.59
2010-11	400.66	399.82	350.12	349.39	8.75	8.73
2011-12	388.10	390.02	339.14	340.82	8.48	8.52
2012-13	375.80	380.49	328.39	332.50	8.21	8.31
2013-14	365.43	371.24	319.33	324.42	7.98	8.11
2014-15	355.99	361.95	311.08	316.30	7.78	7.91
2015-16	345.14	356.48	301.60	311.51	7.54	7.79
2016-17	337.63	350.88	295.04	306.62	7.38	7.67
2017-18	337.63	350.88	295.04	306.62	7.38	7.67

Source: Blanco, 2008.

Notes:*FDOC (Brown, 2007)"All round oranges" estimates, **Yield differential calculated from FASS historical production data applied to FDOC estimates, ***'Valencia' avg. yield converted to boxes in 25,000 acres.

Table 3. Scenario description in terms of price, production, percentage of lost fruit and EUP assumptions.

Scenario	Price	Production	% lost fruit	EUP acres	Date of CMNP application	% preserved fruit
1	High	Low	High	25,000	Early May	15%
2	High	Low	Low	25,000	Early and mid June	15% and 20%
3	Low	High	High	25,000	Early May	15%
4	Low	High	Low	25,000	Early and mid June	15% and 20%

Table 4. Abscission registration and R&D expenditures (million $) from 1996 to 2008 discounted to 2008 dollars to determine initial investment in 2008.

Year	FDOC R&D* (million $)	UF/IFAS R&D (CI) (million $)	FDOC Registration (million $)	Federal Grants (million $)	Nominal total (million $)	Inflation factor	Nominal totals inflated to 2008 dollars (million $)
1996	0.05	0.00	0.00	0.00	0.05	3.14	0.16
1997	0.08	0.00	0.00	0.00	0.08	2.85	0.21
1998	0.43	0.00	0.00	0.00	0.43	2.59	1.11
1999	0.61	0.00	0.00	0.00	0.61	2.36	1.44
2000	0.49	0.00	0.00	0.00	0.49	2.14	1.06
2001	0.67	0.00	0.00	0.00	0.67	1.95	1.30
2002	0.51	0.00	0.00	0.00	0.51	1.77	0.90
2003	0.46	0.00	0.00	0.00	0.46	1.61	0.74
2004	0.50	0.00	0.00	0.07	0.57	1.46	0.84
2005	0.20	0.38	0.05	0.65	1.28	1.33	1.70
2006	0.00	0.42	0.71	1.33	2.46	1.21	2.98
2007	0.00	0.53	3.92	0.00	4.44	1.10	4.89
2008	0.00	0.48	1.30	0.00	1.78	1.00	1.78
					Total in 2008 dollars		$19.10

Source: King and Roka, 2008.
Notes: *FDOC R&D expenditures include only abscission. Does not include funds spent on equipment design.

Table 5. Summary of scenario results, Cumulative NPV ($), payback periods (years from 2008), 1995 through 2018. Acreage receiving CMNP – 25,000 and unit cost savings of 80-cents per box to mechanically harvest.

Scenario	Total NPV (2008 million $)	Payback period (Years)
S1: high price/low production – high fruit loss	72.28	3.73
S2: high price/low production – low fruit loss	79.93	3.67
S3: low price/high production – high fruit loss	60.79	3.80
S4: low price/high production – low fruit loss	66.09	3.75

Source: Blanco, 2008.

Table 6. Minimum acreage of CMNP application by selected unit harvest cost savings to achieve positive NPV for each scenario by the end of the 2017-18 season.

	Unit harvest cost savings			
Scenario	80-cents	40-cents	20-cents	10-cents
	Acreage			
S1: high price/low production – high fruit loss	5,733	7,005	7,879	8,403
S2: high price/low production – low fruit loss	5,733	7,005	7,879	8,403
S3: low price/high production – high fruit loss	6,534	8,266	9,530	10,318
S4: low price/high production – low fruit loss	6,534	8,266	9,530	10,318

Source: Blanco, 2008.

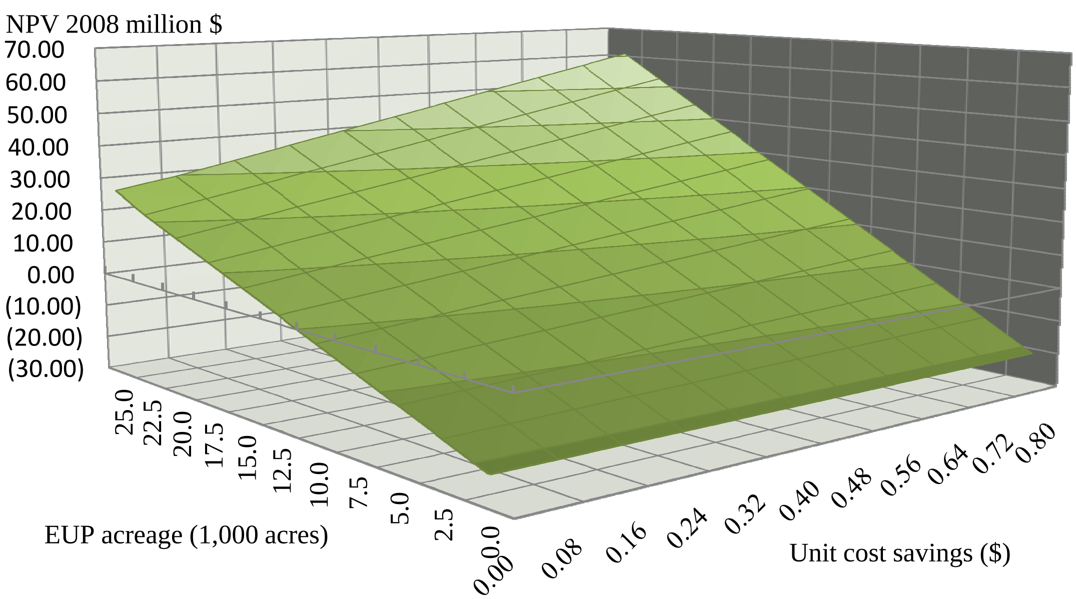
Table 7. Minimum acreage of CMNP application to achieve a "payback" period within 6 years by selected unit harvest cost savings.

	Unit harvest cost savings			
Scenario	80-cents	40-cents	20-cents	10-cents
	Acreage			
S1: high price/low production – high fruit loss	8,165	10,250	11,750	12,625
S2: high price/low production – low fruit loss	8,165	10,250	11,750	12,625
S3: low price/high production – high fruit loss	9,025	11,648	13,625	14,890
S4: low price/high production – low fruit loss	9,025	11,648	13,625	14,890

Source: Blanco, 2008.

Figure 1. Steps and data to convert FDOC production and price forecasts into estimates of annual ‘Valencia’ production by four late season harvest periods.

Figure 2. NPV surface by EUP acreage and unit cost savings under high price and low production scenario.



Source: Blanco, 2008.