**Economic Value of an Abscission Compound for Mechanically Harvested Late-season ‘Valencia’ Oranges**

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This paper compares estimated economic values of mechanically harvesting ‘Valencia’ [*Citrus sinensis* (L.) Osb.] during the late season without adverse yield impacts, against the estimated cost of development and registration of the abscission compound, CMNP (5-chloro-3-methyl-4-nitro-1-H-pyrazole). The basis of this analysis is a “benefit-cost” model that compares the discounted cash flows of public expenditures against projections of future private benefits of extending mechanical harvesting into late May and June with CMNP application. The estimated net present value (NPV) of cash flows, over a 10-year planning horizon with an assumed interest rate of 10%, was $38 million. The public investment for CMNP registration and development had a positive internal rate of return (IRR) of 32.64% and a payback period of 4.8 years from 2008. Thus, benefits resulting from the application of abscission compound for mechanically harvesting late-season ‘Valencias’ more than offset the cost of R&D and registration.

More than 95% of Florida’s citrus crop is hand harvested. Hand harvesting costs continue to rise steadily with higher state and federal minimum wage rates and increasing regulatory requirements on work place safety. The Florida citrus industry needs to become more cost efficient to remain globally competitive. Brazil, the leading world citrus producer, enjoys at least a two-fold cost advantage with respect to harvesting (Muraro and Spreen, 2003). Since 1995 the Florida Department of Citrus (DOC) has been funding mechanical harvesting and abscission research. The DOC monies come directly from a tax on Florida citrus growers. Trunk and canopy shaking machines have emerged as commercially viable mechanical harvesting systems for the early and mid season orange varieties. Although mechanically harvested acreage increased to 35,000 during the 2006–07 season, which represents less than 7% of the total acreage, only a small percentage of growers are adopting mechanical harvesting equipment. This is in spite of the fact that these systems significantly improve labor productivity and when combined with economies of scale, should drive down the unit cost of harvesting to a more competitive level (Roka, 2007).

The most significant obstacle against the widespread adoption of mechanical equipment is harvesting “late-season” ‘Valencia’ sweet oranges [*Citrus sinensis* (L.) Osb.] Sometime after the first of May, next year’s growing fruitlets exceed 1 inch in diameter; a size correlated with a critical mass susceptible to mechanical removal. Vigorous mechanically harvesting at this time removes young developing fruit and negatively impacts next year’s yield (Roka et al., 2005; Whitney, 1975; Whitney and Hedden, 1973). Burns (2002) reported that the abscission compound CMNP selectively loosens mature fruit. CMNP can be utilized for late-season harvesting because it enables lower machine intensities to be used to selectively harvest loosened mature fruit without adversely affecting next year’s fruit yield (Burns et al., 2006). Since 1995, the DOC and the state of Florida through the University of Florida/IFAS, have invested more than $7 million of public funds into the research and development of abscission compounds. One compound, CMNP, has begun the formal Environmental Protection Agency (EPA) registration process. As of 1 July 2007, the DOC had spent more than $750,000 on the CMNP registration process. Grants from the federal government have provided $2.05 million toward CMNP registration. An estimated $6.5 million of additional funds will be required to complete the full registration process, which is anticipated to occur in Spring 2012 (Table 1). The question for this paper is do the private benefits of extending mechanical harvesting into late May and June with an abscission compound more than offset its public cost of development and registration?

**Materials and Methods**

Equation (1) defines two benefits anticipated from an abscission compound (Bₐ).

\[
B_i = (V_i + S_i) = \sum_{r=1}^{v} \left[ \frac{P_{i+1}}{(1+r)^t} \times tQ \times \%LF \times (HH_i - MH_i) \right] - A_i
\]

[Eq. 1]

One benefit of using an abscission compound is the dollar value of lost fruit during the late season due to mechanical harvesting without the abscission compound (*Vₐ*). This benefit equals the expected future fruit price (*Pᵢ₊₁*) multiplied by the projected quantity of ‘Valencia’ oranges harvested mechanically (*Qᵢ₊₁*). This value, in turn, is multiplied by the percentage of lost fruit (%LF). The second benefit (*Sₐ*) of abscission compound application comes from the unit cost harvest savings generated by mechanically
harvesting with abscission compound application after early May. Unit cost savings were calculated by subtracting the mechanical harvesting (MH) and CMNP application costs (A) from hand harvesting (HH) rates per box. Total harvest cost savings (\( S_t \)) was found by multiplying the unit savings times the projected number of boxes to be harvested during early-May, mid-May, early-June and mid-June. Net present values (NPV) of future benefits were determined using an interest rate of 10% (\( r \)).

Equation (2) defines the costs for research and development (R&D) and registration (\( C_a \)).

\[
C_a = \sum_{i=1}^{n} \sum_{t=2006}^{2018} \left[ \frac{R_{g, t} + R & D_{t, DOC} + R & D_{t, UF/IFAS}}{(1 + r)^t} \right] 
\]

The data on abscission compound expenditures were broken down by CMNP registration (\( R_{g, t} \)), DOC sponsored R&D (\( R & D_{t, DOC} \)), UF/IFAS sponsored R&D (\( R & D_{t, UF/IFAS} \)), and federal grants. To date, all (100%) federal grants have gone to fund abscission compound registration. A summary of abscission compound expenditures are presented in Table 1.

Determining a future value of abscission compound use in terms of mechanical harvesting ‘Valencia’ oranges after 1 May requires data to answer the following questions:

1. What are the expected weekly volumes of ‘Valencia’ oranges harvested during May (e.g., after 1 May) of a typical season?
2. What is the expected yield reduction next year if late-season ‘Valencia’ oranges are mechanically harvested this year?
3. What is the expected price of late-season ‘Valencia’ oranges?
4. What is the expected unit cost differential between hand harvest and mechanical harvesting systems?

The expected percentage of ‘Valencia’ oranges harvested after 1 May and on-tree fruit prices were based on the average of production and price levels over a 20-year period. The data used to calculate the means were obtained from the Florida Agricultural Statistics Service (FASS), Annual Citrus Summary (FASS, Annual Citrus Summary, 1985–86 to 2005–06). An average percentage of ‘Valencia’ orange production was calculated from total orange production. Further, a “typical” season of ‘Valencia’ orange harvest was apportioned by the four late harvest dates mentioned above (early-May, mid-May, early-June, and mid-June).

Production projections for the Florida orange crop have been developed by the Florida Department of Citrus (DOC) from 2008–09 through 2017–18 (Florida DOC, 2007). Specific projections of ‘Valencia’ production by harvest date were estimated using the percentages developed from the FASS historical data. All the data were tabulated and organized within an Excel spreadsheet.

The effect of mechanical harvesting and its anticipated adverse yield impact on next year’s crop were estimated from data collected from a late-season mechanical harvesting trial without abscission compound application. The trial was conducted in a commercial grove south of Immokalee from 2003 to 2005 during four harvest periods (early-May, mid-May, early-June, and mid-June). First-year results were reported in Roka et al. (2005). Canopy and trunk shakers operated under three frequency and shake duration treatments, respectively, without abscission compound application. Treatment results were compared to a handpicked control treatment. Yield differences by harvest method and date were analyzed using the Statistical Analysis System ANOVA software package (SAS Institute, Inc., Cary, NC).

An experimental use permit (EUP) is expected for CMNP by Spring 2010. The EUP requests that up to 25,000 acres be mechanically harvested with CMNP. For the purposes of this analysis, it was assumed that late-season ‘Valencia’ orange acreage treated with CMNP would increase to 25,000 acres over the course of 4 years (increasing 25% each year). It is feasible that the entire 25,000 acres, if granted by the US EPA, could utilize CMNP immediately. However, in the interest of developing conservative benefit/cost estimates, this analysis phases-in CMNP acreage over a 4-year horizon. An average yield per acre for ‘Valencia’ orange between 1985–86 and 2005–06 was calculated in the analysis. This value multiplied by 25,000 acres represents a constraint to the projected quantity of ‘Valencia’ orange to be mechanically harvested during the late season over the next 10 years.

FASS data documents average “on-tree” fruit prices by early and late-season varieties. A percentage difference between the ‘Valencia’ and all round orange on-tree prices was estimated from historical price data (1985–86 through 2005–06). This expected price differential was applied to the projected FDOC estimates to project the ‘Valencia’ price from 2008 through 2018.

**Results and Discussion**

Yield results from the mechanical harvesting trials without CMNP application were mixed. In one year, significant production losses were attributable to mechanical harvesting in early and mid-May. In the second year of the trial, yield reductions did not occur during the May harvest dates. In keeping with a conservative approach of this analysis toward valuing abscission compound benefits, it was assumed that no negative yield effect would occur from early and mid-May mechanical harvesting.

A 15% and 20% yield reduction was calculated for early and mid-May. In the second year of the trial, yield reductions were attributable to mechanical harvesting in early and mid-May. In the second year of the trial, yield reductions were attributable to mechanical harvesting in early and mid-May. In the second year of the trial, yield reductions were attributable to mechanical harvesting in early and mid-May.

Annual cash flows are presented in Table 3 from the 2007–08 through the 2018–19 season. The 2007–08 season is used as the reference year to compare costs and benefits. Registration and R&D expenditures from 1996 to 2007 are combined and discounted to 2008 dollars, totaling $19.10 million. Nearly a million dollars will be spent in 2008–09 according to the FDOC abscission compound registration budget. Another $0.48 million in R&D sponsored by UF/IFAS, adding up to $1.47 million in expenditures on CMNP for the 2008–09 season. The analysis assumes that by Spring 2010 an EUP will be issued by the USEPA. Although the citrus industry is asking for 25,000 acres, there is no certainty that the EPA will grant such a large EUP. For that reason, and to
allow for the possibility that manufacturing capability may not be sufficient to accommodate the full 25,000 acre request, CMNP application in Spring 2010 will be limited to 25% of 25,000 acres. CMNP-applied acreage will increase to 50%, 75%, and 100% during 2011, 2012, and 2013, respectively.

In 2009–10, benefits of $1.44 million due to harvest cost savings will accrue to abscission compound application. Note that the value of lost fruit will not be captured until the following season (2010–11), when the negative effect on subsequent yields is eliminated due to CMNP application. During 2010–11, abscission compound application net benefits total $10.13 million, $7.7 million of benefit from capturing more of the crop that was mechanically harvested in the previous year and $2.87 million of harvest cost savings from mechanically harvesting 50% of the allotted 25,000 acres, minus $0.44 million of development and registration cost. In 2011–12, 75% of the 25,000 acres will be harvested resulting in a $12.39 million of net benefits. In the next season (2012–13), all of the 25,000 acres will be harvested by mechanical means with CMNP the estimated positive benefit is $14.20 million. Estimated inflows for the following 5 years will continue to slightly decline from $14.13 to $13.79 million, reflecting a decline in FDOC citrus production forecasts.

Annual estimated cash benefits of abscission compound application were discounted using an interest rate of 10%. The last line in Table 3 presents the annual net present value of CMNP application benefits. When summed across the 10-year planning horizon, the estimated net present value (NPV) of net cash flows resulted in a positive $38 million. Based on the production, price, and discount rate assumptions embedded in this analysis, the investment in CMNP registration and R&D had an internal rate of return (IRR) of 32.64% and a payback period of 4.80 years. The assumptions of this analysis have been purposely conservative. A discount factor based on a 10% interest rate may be considered high given that a risk-free investment alternative return for U.S. Treasury Bills is 4.19 (USDT, 2007). A higher interest rate, of course, lowers the net present value of a future benefits.

**Conclusions**

Utilizing abscission compounds, specifically CMNP, should allow mechanical harvesting systems to achieve a high percentage of mature fruit removal during the ‘Valencia’ orange late season with no significant impact on yield for the following season crop (Burns et al., 2006). A spreadsheet model with static future production and price expectations was developed to determine the net present value (NPV) of abscission compound application in terms of late-season ‘Valencia’ orange harvesting. A positive NPV of $38 million was calculated over a 10-year planning horizon where the total use of CMNP was restricted to a maximum of 25,000 acres. A positive NPV indicates that the benefits resulting from the application abscission compound for mechanically harvesting late-season ‘Valencias’ more than offset the cost of R&D and registration. In addition to harvesting late-season ‘Valencia’ orange without adverse yield effects, abscission compound application allows for increased harvesting speeds of the equipment, making the equipment more cost efficient. Higher

Table 2. Projected total benefit of CMNP application for season 2010–11 in terms of total value of lost fruit plus harvest cost savings against CMNP research and registration costs, in million dollars.

<table>
<thead>
<tr>
<th>Quantity of lost fruit</th>
<th>Value of lost fruit</th>
<th>Total value of lost fruit</th>
<th>Hand harvesting cost</th>
<th>Mechanical harvesting cost</th>
<th>Application cost</th>
<th>Harvest cost savings</th>
<th>CMNP cost (R&amp;D and registration)</th>
<th>Benefit of CMNP (million $)</th>
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<tbody>
<tr>
<td>million boxes</td>
<td>million $</td>
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<td>$/boxes</td>
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<tr>
<td>0.00</td>
<td>0.00</td>
<td>7.70</td>
<td>2.5</td>
<td>1.5</td>
<td>0.2</td>
<td>2.87</td>
<td>0.44</td>
<td>$10.13</td>
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CMNP net benefit (19.10) (1.47) 0.90 10.13 12.48 14.20 14.13 14.03 13.88 13.79 13.79
Discount factor 0.909 0.826 0.751 0.683 0.621 0.564 0.513 0.467 0.424 0.386
Net Present Value (19.10) (1.36) 0.74 7.62 8.46 8.82 7.97 7.20 6.48 5.85 5.32
Total NPV: 2007–2019 38 M

Table 3. CMNP-related projected net cash flows (in million $) from 2007–08 through 2018–19.

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<tr>
<td>Years</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>10</td>
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<tr>
<td>Registration cost</td>
<td>9.12 (0.99)</td>
<td>0.09 (0.09)</td>
<td>0.09 (0.09)</td>
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<tr>
<td>R&amp;D by IFAS/UF</td>
<td>2.07 (0.48)</td>
<td>0.45 (0.35)</td>
<td>0.35 (0.35)</td>
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<tr>
<td>R&amp;D by FDOD</td>
<td>7.92 (0.99)</td>
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<tr>
<td>Value of lost fruit</td>
<td>0</td>
<td>7.70</td>
<td>8.51</td>
<td>8.45</td>
<td>8.38</td>
<td>8.28</td>
<td>8.13</td>
<td>8.05</td>
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<td>Savings</td>
<td>1.44</td>
<td>2.87</td>
<td>4.31</td>
<td>5.75</td>
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<td>CMNP net benefit</td>
<td>(19.10)</td>
<td>(1.47)</td>
<td>0.90</td>
<td>10.13</td>
<td>12.48</td>
<td>14.20</td>
<td>14.13</td>
<td>14.03</td>
<td>13.88</td>
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<td>Discount factor</td>
<td>0.909</td>
<td>0.826</td>
<td>0.751</td>
<td>0.683</td>
<td>0.621</td>
<td>0.564</td>
<td>0.513</td>
<td>0.467</td>
<td>0.424</td>
<td>0.386</td>
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fruit removal percentages and decreasing cosmetic tree damage from mechanical harvesting equipment are two other potential benefits associated with the use of abscission compounds. Hence, the benefits estimated in this paper are likely to be conservative. Future work in this analysis will involve analyzing different scenarios and conduct of sensitivity analysis of the assumptions used in the model.

**Literature Cited**


Gainesville, FL.


