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ECONOMIC ANALYSIS OF SELECTED INSECT PEST MANAGEMENT PRACTICES FOR ALMONDS*

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Errors in fact found herein are, however, the responsibility of the author.

Navel orangeworm, Amyelois transitella (Walker) is considered the most important insect pest of almonds in California. Damages valued at $22 million were believed to exist in 1977 (Rice 1978). Research has shown that a combination of cultural practices and chemical control can dramatically reduce the damage from navel orangeworm (NOW).

Data from research conducted by the University of California show that orchard sanitation (removal and destruction of mummy nuts) and early harvest (just at or slightly after 100 percent hullsplit) and the use of an in-season spray occasionally, due to infestation of NOW from neighboring orchards, will dramataically reduce NOW damage.[1] Trials show that removing mummies and destroying them can easily reduce NOW damage by 50 percent and that early harvest can further reduce NOW damage by 40 percent.

Despite evidence from trials showing these cultural practices to be effective, growers usually like to see the economic feasibility of recommended practices demonstrated before steps are taken to adopt the new practices. Growers want to know:

(1) how much recommended practices will increase costs.

(2) how much benefits can be expected to increase.

(3) if unit costs are influenced by the size of the operation.

(4) how benefits and costs behave for varying levels of pest damage.

(5) how price received for the crop affects the feasibility of the recommended practices.

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[1]See, for instance, University of California Cooperative Extension (1980) and Engle and Barnes (1980).

The simplest way to provide the information growers want to know is through the use of partial enterprise budgeting. This technique allows one to relate changes in revenue and costs to changes in management practices and to impute the net benefits to the particular practices as they are added or removed from the budget.

Partial budgeting works especially well when the enterprise being studied is not competitive with enterprises in the firm. In the case of almonds in California, it is very common that almonds are the principal or only enterprise on the farm. Therefore, one can be reasonably sure that the use of market prices to value production inputs is a good measure of cost since there is no competing enterprise to give rise to internal or opportunity costs that differ from market prices.

The Model Production Unit

Feasibility analyses for the firm are usually easier to understand and more accurate if they are based on a model firm. A hypothetical almond producing operation was established to identify the scale of operation and to provide some basis for judging the reasonability of results. Per acre partial budgets were then prepared to reflect the results of using various insect pest management practices to deal with NOW damage.

The model unit is assumed to have the following characteristics.

1. All almond acreage is bearing.
2. All bearing acreage is treated with a dormant spray to control peach twig borer, Anarsia lineatella (Zeller).
3. There are 320 acres of trees planted at the rate of 75 trees per acre:

   (a) 214 acres are Nonpareil variety
   (b) 53 acres are Merced variety
   (c) 53 acres are Mission variety.

4. All trees are 12-15 feet in height. (The budgets do not apply to large trees that tend to be found in Northern California.)

5. Total meat yields at maximum nut removal are:

   (a) Nonpareil, 1500 lbs./acre
   (b) Merced, 1200 lbs./acre
   (c) Mission, 1500 lbs./acre

6. Harvesting equipment consists of

(a) self-propelled shaker	(2)
(b) self-propelled pickup unit	(1)
(c) rake	(2)
(d) cart	(6)

7. Shaker performance is 1-1/2 hours per acre. This will allow the Nonpareil harvest to take place in 13 days each 12 hours in length using 2 shakers.

8. New cost of harvest machinery is:[1]

(a) self-propelled shaker		$38,000
(b) self-propelled pickup machine		15,000
(c) rake		7,000
(d) cart	3 for	2,000

9. Estimated useful life of a new shaker is 3,000 hours with a salvage value of $10,000.

10. Harvest machinery depreciation is strictly proportional to use.

11. Wage rates are $5.60 per hour including social security and benefits. Employees are paid 1.5 times wage rate for time over 60 hours per week.

12. During harvest, the work week is 72 hours.

13. A May spray of Guthion, properly timed, will reduce NOW damage by 50 percent, along with a treatment for mites.

14. Sanitation through winter clean-up will reduce NOW damage 50 percent and will substitute for a May spray and probably mite treatment.

15. Early harvest at about 100 percent hullsplit will reduce NOW damage by 40 percent.

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[1]Taken from Kent Olson and Lynn Horel (1981) Extension Service, University of California, Davis, 1981.

16. A combination of sanitation and early harvest will reduce NOW damage by 70 percent.

17. All acres in the orchard are treated with a dormant spray for peach twig borer control.

18. All acres are at least 0.5 miles from external sources of NOW infestation.

19. Irrigation and other management practices are independent of insect pest management practices.

Insect Pest Management Scenarios

Five different scenarios depicting various insect pest management approaches to management of NOW were analyzed through the use of the partial enterprise budgets. A description of the scenarios is as follows:

I. Benchmark - The only pest management practice use is a dormant spray for peach twig borer and the usual disease control.

II. May spray and mite control - A May spray for NOW control and a mite spray added to the dormant spray.

III. Sanitation - Winter clean-up of mummies by hand poling with no poling after shakers. No sprays for NOW are used.

IV. Sanitation with early harvest - Winter clean-up of mummies by hand poling and early harvest of Nonpareils and Merceds with no poling after shakers. Assume Nonpareil yield reduced 2 percent.

V. Sanitation with early harvest and poling after shakers - Winter clean-up of mummies by hand poling, early harvest of Nonpareils and Merceds and poling after shakers. Assume that 2 percent yield of Nonpareils lost in IV is recoverd.

The scenarios show sanitation being substituted for a May insecticide treatment and a miticide treatment. Research by Engle and Barnes (1980) shows that if the mummy count is only two or three per tree, a May spray will likely not be needed. If the May insecticide treatment is avoided, the miticide treatment can also likely be avoided since predacious mites were not impacted by the May insecticide treatment.

Where early harvest is included, it was assumed that the removal of nuts just as 100 percent hullsplit occurs, will result in a loss of 2 percent in nut removal for Nonpareils. Work by Labavitch (1980) shows this to be a possibility.[1] Hand poling following the shaker can recover these nuts but at a cost. Therefore, the importance of monitoring the NOW population as hullsplit approaches becomes evident. If it appears that the NOW infestation is not developing very rapidly at 95-100 percent hullsplit (1/4 percent or less per day), then early harvest and the poling after the shaker might not be necessary with the savings in costs attendant to that decision.

Costs of Insect Pest Management Practices

The per acre costs of the various practices were developed as follows:

1. May spray for NOW control

Guthion 50wp at 4 lb/acre	$22.60
Grower ground application	12.50
Total	$35.10

2. Mite control (applied with May Spray)

Omite 30wp at 10 lb/acre	$38.00
Total	$38.00

3. Sanitation (winter mummy removal by poling)

7-3/4 man hrs. at $3.75/hr.	$29.00
mummy destruction	5.00
Total	$34.00

[1]The degree of nut removal at early harvest can be quite variable. The reasons are not fully understood, see Labavitch (1981).

4. Early harvest (costs of adding one shaker, one pickup, one rake and and three carts)

Interest on added shaker (1/2 new value at 15 percent divided by 320 acres) $\frac{38000}{2} \times .15 \times \frac{1}{320}$ =	$ 8.91
Interest on added associated equipment (1/2 new value at 15 percent divided by 320 acres) $\frac{24000}{2} \times .15 \times \frac{1}{320}$ =	5.62
Personal property tax/acre	.87
Total	$15.40

5. Early harvest with hand poling after shaking.

Added machine ownership costs from (4)	$15.40
Hand poling costs	29.00
Total	$44.40

It should be noted that the costs for sanitation and early harvest are especially scaled for the 320 acre operation because the fixed machine costs are spread over the 320 acres.

Budgeting Results

Using the assumptions, the scenarios and the costs of the selected insect pest management practices, partial budgets were computed for each scenario under conditions of varying prices and varying levels of NOW infestation in an untreated orchard. Revenues net of NOW related insect pest management practices were computed for meat prices of $1.00, $1.25 and $1.50 per pound and for untreated damage levels of 20 percent, 10 percent and 5 percent. This should give growers information about the effects of product prices and damage to be prevented on revenues net of NOW pest management costs.

First, note the revenues net of NOW pest management costs. These results are shown in Table 1. In addition to showing the effects of various pest management practices, the results in Table 1 demonstrate the significance of the financial losses growers can suffer from rejects due to insect damage from whatever source. They also demonstrate what growers might be able to spend

TABLE 1. REVENUE PER ACRE NET OF INSECT PEST MANAGEMENT COSTS FOR NAVEL ORANGEWORM CONTROL FOR SELECTED SCENARIOS, ALMOND PRICES AND UNTREATED DAMAGE LEVELS, CALIFORNIA, 1980.

Scenarios \ Prices/lb.	$1.00	$1.25	$1.50
	Untreated Damage Level 20 Percent		
I. Benchmark	$1,112.93	$1,412.06	$1,711.19
II. May spray plus mite spray	1,212.96	1,541.90	1,876.90
III. Sanitation	1,252.06	1,581.00	1,915.90
IV. Sanitation with early harvest	1,283.13	1,619.20	1,955.26
V. Sanitation with early harvest plus poling after shakers	1,272.72	1,613.49	1,954.24
	Untreated Damage Level 10 Percent		
I. Benchmark	$1,286.06	$1,615.00	$1,950.00
II. May spray plus mite spray	1,293.55	1,637.46	1,981.19
III. Sanitation	1,332.65	1,676.56	2,020.29
IV. Sanitation with early harvest	1,338.87	1,683.61	2,028.60
V. Sanitation with early harvest plus poling after shakers	1,329.50	1,678.98	2,028.82
	Untreated Damage Level 5 Percent		
I. Benchmark	$1,366.65	$1,710.56	$2,054.30
II. May spray plus mite spray	1,350.27	1,701.63	2,053.00
III. Sanitation	1,384.37	1,740.73	2,092.10
IV. Sanitation with early harvest	1,382.82	1,732.09	2,081.35
V. Sanitation with early harvest plus poling after shakers	1,374.09	1,728.28	2,082.46

per acre to reduce these losses. For instance, the difference in revenue per acre for the model operation at 20 percent rejects and 5 percent rejects is $253.72 even with good meat priced at $1.00 per pound ($1,366.65-$1,112.93). Table 1 also shows the relation of the different practices at different damage potentials and almond good meat prices.

The relative financial standing of the pest management practices is best seen in Table 2 where the benchmark revenue is subtracted from the revenue net of IPM costs for each scenario. The May spray plus mite spray (scenario II) is clearly inferior to the others and when untreated damage levels are as low as 5 percent, this practice is not justified even assuming that the practice reduces rejects by 50 percent. Scenario III, sanitation in the form of winter mummy removal and destruction, is better than scenario II by about $39.00/acre in each case. This suggests that growers might be able to pay as much as $73 per acre for winter cleanup and be as well off as if they had used the May spray and mite spray strategy. Since the mite spray adds about $39 to the chemical alternative, clearly if the mite spray is not needed, the May Guthion spray and the winter cleanup scenarios could be expected to give about equal results.

When early harvest is added to sanitation (scenario IV) financial results are improved relative to sanitation alone as long as the potential damage is high enough. In Table 2, scenario IV was not as profitable as scenario III when the expected untreated damage was 5 percent. This is because early harvest was assumed to give a reduced yield and the improved quality could not offset both the loss of nuts and the added costs of early harvest.

In considering scenario V, where an attempt is made to recover the nuts left on the tree by the shaker at early harvest, Table 2 shows that this set of practices is very sensitive to meat prices and damage levels. With lower

TABLE 2. ADDED REVENUE PER ACRE NET OF NAVEL ORANGEWORM IPM COSTS FOR SELECTED SCENARIOS, ALMOND PRICES AND UNTREATED DAMAGE LEVELS, CALIFORNIA, 1980*

Scenarios \ Prices/lb.	$1.00	$1.25	$1.50
	Untreated Damage Level 20 Percent		
II. May spray plus mite spray	$100.03	$129.84	$165.71
III. Sanitation	139.13	168.94	204.71
IV. Sanitation with early harvest	170.20	207.14	244.07
V. Sanitation with early harvest plus poling after shakers	159.79	201.43	243.05
	Untreated Damage Level 10 Percent		
II. May spray plus mite spray	$ 7.49	$ 22.46	$ 31.19
III. Sanitation	46.59	61.56	70.24
IV. Sanitation with early harvest	52.81	68.61	78.60
V. Sanitation with early harvest plus poling after shakers	43.44	63.98	78.82
	Untreated Damage Level 5 Percent		
II. May spray plus mite spray	-$ 16.38	-$ 8.93	-$ 1.30
III. Sanitation	22.72	30.17	37.80
IV. Sanitation with early harvest	16.17	21.53	27.05
V. Sanitation with early harvest plus poling after shakers	7.44	17.72	28.16

*Values in the table represent the difference between the value for the benchmark in Table 1 and the values for Scenarios II through V in Table 1.

prices and high potential damage, poling after the shaker does not appear financially justified. This is because with cheaper prices and high levels of rejects, the nuts salvaged by hand poling (here assumed to be 2 percent of 1,500 pounds) won't offset the cost of hand poling after the shaker, a cost that does not vary with quality or price. In Table 2, one can see that with meat prices at $1.50/lb. and untreated damage levels at 5 or 10 percent there is a slight financial gain from poling after the shaker because the good nuts are worth more and damage is low. That is, there are more good nuts to be salvaged.

It should be noted that scenario V includes hand poling both after the shaker and in the winter to provide a very clean orchard. Situations will vary such that the poling after the shaker will so reduce the level of mummies as to preclude the need for winter cleanup. If that was the case then $34 per acre could be added to the values for scenario V in Tables 1 and 2. This adjustment would make a scenario of "early harvest plus poling after the shaker" superior to any other at all meat prices for all levels of untreated damage.

Adapting Analysis to Specific Grower Conditions

Obviously, the analysis presented above will not fit every almond grower in California. Each grower will need to carry out an analysis for his own operation for each season. Only in this way can the grower decide what will likely be best for him.

To facilitate growers doing this type of analysis, a programmed worksheet has been developed with an example giving all of the steps in computing the net benefits of application of winter cleanup. This worksheet is shown in Table 3. Growers, pest control advisors, extension personnel and others can

TABLE 3 (Continued)

Steps	Example	My Operation
8. Gross revenue/acre after added insect control practice. (Repeat step 4)		
(a) Each variety yield x reject level	(a) 1500 x .10 = 150 1200 x .10 = 120 1500 x .01 = 15	
(b) Subtract results in (a) from variety yield to give good meat yield.	(b) 1500 - 150 = 1350 1200 - 120 = 1080 1500 - 15 = 1485	
(c) Multiply good meat yields by expected price.	(c) 1350 x 1.50 = 2025 1080 x 1.50 = 2027.50 1485 x 1.50 = 2227.50	
(d) Add or subtract premium or penalty for each variety.	(d) (2¢/lb.) 2025 - 30 = 1995 1620 - 24 = 1596 2227.50 - 0 = 2227.50	
(e) Multiply results of each variety in (d) by fraction of the orchard represented by each variety.	(e) 1995 x .666 = 1328.67 1596 x .1625 = 259.35 2227.50 x .1625 = 361.96	
(f) Sum results in (e) to give weighted acreage gross revenue per orchard acre.	(f) 1328.67 + 259.35 + 361.96 = $1949.98	
9. Subtract 4(f) from 8(f) to give revenue change due to new practice.	1949.98 - 1711.18 = 238.80	
10. Added cost of practice.	$34.00	
11. Net benefits (losses) from added practice (9-10).	$204.80	

adapt this sheet to any pest management practice for use as a planning device in grower decision making. This study demonstrates dramatically that there are enough dollars involved in navel orangeworm damage to almonds to justify considerable analysis.

Summary and Conclusions

This study has demonstrated the following points:

1. Navel orangeworm damage to almonds is a serious problem for individual growers and the industry.
2. Two cultural practices--winter clean up and early harvest--are effective in reducing navel orangeworm damage.
3. Winter clean up may be a profitable substitute for a May "in season" spray.
4. Winter clean up (sanitation) and early harvest seem to give the best financial rewards for all levels of untreated damage and at meat prices ranging from $1.00 to $1.50 per pound.
5. If early harvest and sanitation are combined with hand poling after the shaker, the poling after the shaker would likely only be profitable at untreated damage levels of 5 percent or less and with meats prices of more than $1.50 per pound or with large quantities of nuts left on the tree such as 40 or 50 pounds per acre.
6. If poling after the shaker to salvage nuts at harvest will leave low enough mummy counts to preclude winter clean up then the practice will likely be profitable over a wide range of meat prices and levels of untreated damage.
7. As the level of navel orangeworm infestation is reduced, the use of sanitation in the form of winter clean up improves in profitability

relative to a scenario that also includes early harvest. This is due to the losses in yield that can result from early harvest.

8. Growers, pest control advisors and extension personnel can perform this analysis on a block by block basis to aid decision making in insect pest management for almonds.

Reference List

Engle, C. E. and M. M. Barnes (1980), "Relationship Between Almond Mummy Sanitation and Navel Orangeworm Infestation," in Barnes, M. M. et al. "Investigations on Control of the Navel Orangeworm and Mites on Almonds - 1980," Department of Entomology, University of California, Riverside, 67pp. mimeo.

Labavitch, John (1981), "Early Harvest Trials 1980," Preliminary summary of research, Pomology Department, University of California, Davis, mimeo.

Olson, Kent and Lynn Horel (1981), "Farm Machinery Costs," Division of Agricultural Sciences, University of California, Leaflet 2263, May 1981, 19pp.

Rice, Richard E. (1978), "Insect and Mite Pests of Almonds," in Almond Orchard Management, Division of Agricultural Sciences, University of California. Publication 4092, viii-150pp.

University of California Cooperative Extension (1980), "Summary of 1979 Almond Integrated Pest Management Trials," mimeo.

APPENDIX TABLE 1. COMPUTATION OF ANNUAL COSTS OF ALMOND SHAKING MACHINES, AND ASSOCIATED EQUIPMENT 1980

Assumptions:

1.	Self-propelled shaker new cost		$38,000
2.	Estimated useful life		3,000 hours
3.	Salvage value		$10,000
4.	Performance rate (75 trees per acre)		1-1/2 hours per acre
5.	Size of operation		320 acres
6.	Operating cost		$ 10.17 per hour
	Fuel and oil	$ 1.63	
	Repairs	8.54	
		$10.17	
7.	Wage rate (including overtime, social security and fringe benefits)		$ 6.05 per hour
8.	Depreciation (new cost less salvage value divided by useful life in hours)	38000 - 10,000 = 28000/3000 = $9.33 per hour	
9.	Personal property tax (1% of average cash value using 15-year life with 10% salvage value)*	$38000 - 3800 = 34,200/2 = $17,100 x .01 = $171 per year	
10.	Interest on investment (new cost divided by 2 at 15%)	38000/2 = 19000 x .15 = $2,850 per year	
11.	New cost of associated equipment		$24,000
	(1) self-propelled pickup	$15,000	
	(1) rake	7,000	
	(3) cart	2,000	
		$24,000	
12.	Interest on investment of associated equipment (New cost divided by 2 at 15%) 24000/2 = 12000 x .15 =		$ 1,800 per year
13.	Personal property tax on associated equipment (1% average cash value using 15 year life with 10% salvage value)* 24,000 - 2400 = 21600/2 = $10,800 x .01 = $108 per year		
14.	Hours to shake	320 acres x 1.5 hrs/acre = 480 hours.	

*Based on schedule from Yolo County Assessors Office, March 1981.

COSTS OF SHAKING AND ANNUAL COSTS OF
ASSOCIATED EQUIPMENT FOR 320 ACRES OF ALMONDS, 1980

Item	2 Shakers		3 Shakers	
	Total	Per Acre	Total	Per Acre
Operating cost ($10.17 x 480 hrs.)	$ 4,882	$15.26	$ 4,882	$15.26
Labor ($6.05 x 480 hrs.)	2,904	9.07	2,904	9.07
Depreciation ($9.33 x 480 hrs.)	4,478	13.99	4,478	13.99
Total variable costs	$12,264	$38.32	$12,264	$38.32
Interest on average investment ($2,850 + $1,800) x no. of shakers	$ 9,300	$29.06	$13,950	$43.59
Personal property tax ($171 + $108) x no. of shakers	558	1.74	837	2.61
Total annual costs	$ 9,858	$30.80	$14,787	$46.20
Total costs (variable + annual)	$22,122	$69.12	$27,051	$84.52
Per acre cost of adding one shaker and associated equipment	$84.52 - $69.12 = $15.40 per acre			