

FINAL REPORT

WTFRC Project #PH-01-140

WSU Project #14C-4164-2419

Project title: Eating quality standards for apples
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Dr. Roger Harker, HortResearch (2001-2003)
Cooperators: Dr. Jill McClusky, WSU, and Dr. Cathy Durham, OSU FIC (2003-2004)

Objectives:

1. Increase consumer acceptance by providing information on consumer criteria for the acceptability and willingness to purchase apples of different firmness and sweetness levels.
2. Compare results from a revised testing protocol utilized in 2004 for Gala and Red Delicious apples to trends observed in earlier studies with these varieties.
3. Evaluate the relationship of non-destructive firmness instruments to consumer purchase intent for Gala and Red Delicious apples from data collected in 2004.

Significant findings:

From the 2004 test results the following was observed:

- Apple firmness level was the only measure that significantly impacted consumer purchase decisions. As apple firmness (measured by penetrometer) increased, there was a significant increase in the number of consumers willing to buy the fruit.
- Apple sweetness, as measured by percent soluble solids, did not significantly affect consumer purchase decisions. Most apples (85%) were rated as having acceptable sweetness.
- For Gala apples, none of the non-destructive firmness measures, Aweta Acoustical Firmness Sensor (Aweta), Greefa Internal Firmness Device (Greefa), or Sinclair Internal Quality Firmness Tester (SIQ), related in a consistent way to consumer willingness to buy. The destructive firmness measure (penetrometer) provided a better prediction of consumer buying response than its non-destructive counterparts.
- For Red Delicious apples, Aweta and SIQ provided a statistically valid relationship to consumer willingness to buy. These non-destructive measures were not as consistent in predicting consumer buying as firmness measured by penetrometer. The Greefa non-destructive firmness measure did not relate in a consistent way to consumer willingness to buy.
- Results of consumer response to apple firmness levels from 2004 tests for both Gala and Red Delicious were similar to trends observed for these same varieties in 2001-2003.
- Trends observed from consumer tests for other varieties in 2001, 2002 and 2003 are similar to results obtained for 2004 Red Delicious and Gala.

Materials and Methods:

A. *Apple sorting and treatment:*

1. In the 2001-2003 tests, apples were purchased from commercial suppliers and then stored in either regular air (RA) or controlled atmosphere (CA) storage until within 2 weeks of each consumer test. Apples were either placed in RA storage or removed to room temperature to provide very soft fruit for consumers to rate. Apples for consumer testing were then sorted using non-destructive technologies to give each consumer a wide range of apple qualities based on firmness and soluble solids. Prior to the consumer test each apple was tested for firmness

(penetrometer), then half of the apple was used for taste evaluation and the other half tested for soluble solids (SS) and acidity using standard destructive instruments (refractometer and titrator). None of apples tested had been treated with SmartFresh™. Varieties tested from 2001-2003 were as follows:

- Gala (November 2001 and April 2002)
- Red Delicious (January 2002)
- Golden Delicious (January 2003)
- Braeburn (April 2003)
- Fuji (May 2003)

2. In 2004, Gala and Red Delicious apples were obtained from several packinghouses and pre-sorted using the available laboratory models of the non-destructive firmness instruments, Aweta, Greefa and SIQ. Gala apples were sorted for sweetness prior to the consumer evaluations, but Red Delicious apples were not. It is possible that some of the apples had been treated with SmartFresh™. As in previous tests, some of the apples were removed from RA storage to room temperature to provide less firm fruit for consumer ratings. Just prior to testing, apples were tested for firmness and then cut in half for taste evaluation. The other half was destructively tested for soluble solids.

B. Consumer taste evaluations:

1. 2001-2003 protocol: From 2001 to 2003, consumer tests were performed in individual sensory taste booths at the Food Innovation Center Laboratory (OSU) in Portland. The sensory test design was developed to provide data to plot preference maps of consumer liking and apple instrumental measures for each apple variety tested. In these tests, 100 to 120 untrained consumers evaluated 6 or 8 apple halves for each variety. Consumer evaluations included scaled liking ratings, acceptability, and willingness to purchase.
2. 2004 protocol: In April 2004, consumer taste evaluations were conducted at an outside public venue, the Portland Saturday Market. Testing over 2 days drew 487 consumers for the Gala test and 283 consumers for the Red Delicious test. In 2004, each consumer tasted and rated slices from half of only one apple. Consumer data was collected on tablet and laptop computers using ballots presented in Compusense 4.5.2 data collection software. Agricultural economists assisted in designing this taste evaluation protocol. The objective for the 2004 test was to provide data that could be used for a predictive model to determine the relationship between apple firmness or sweetness measures to probability of consumer willingness to buy the apple. Consumer ratings included scaled liking ratings, acceptability for apple firmness and sweetness, and willingness to purchase at specific price points. Consumer demographic and apple eating habits were also obtained (data not shown).

Results:

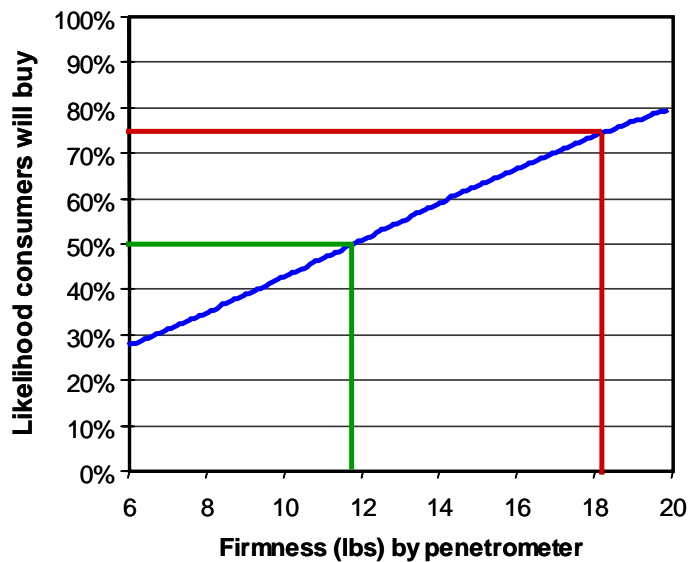
I. April 2004 test results for Gala.

A. Prediction of consumer purchase intent from firmness and sweetness:

The relationship of apple firmness measured by penetrometer and sweetness (SS) to consumer purchase intent was evaluated from the instrumental measures on each apple consumers were given and their response to the question, “Would you buy this apple to eat fresh for \$0.99/lb.?” The consumer demographics information revealed that 58% of the consumers tested usually paid \$0.99 or more per pound for apples. Results for the Gala apples sampled by 487 consumers are as follows:

- For the quality range (10-16% SS and 7-23 lbf) of Gala apples served, 71% of consumers indicated that they were willing to buy and 29% of consumers were not willing to buy fruit of that quality, regardless of price.
- At \$0.99/lb., 58% of consumers indicated that they were willing to buy the fruit.
- Apple firmness level (penetrometer) was the only measure that significantly affected consumer purchase decisions. Most apples (80%) were rated by consumers as having acceptable firmness. As Gala apple firmness increased, there was a significant increase in the number of consumers willing to buy the fruit.
- Gala apple sweetness level, measured as soluble solids, did not significantly impact consumer purchase decisions. Most apples (83%) were rated by consumers as having acceptable sweetness.
- The likelihood of a consumer buying at any firmness level can be determined from the consumer responses for all Gala apples evaluated in 2004 (Figure 1). This graph represents a model relating consumer purchase behavior to Gala firmness (penetrometer). For example, at 11.8 lbf firmness level (penetrometer) the likelihood that consumers will choose to buy the apple or not buy the apple is the same (50% YES, 50% NO), and 18.4 lbf is the firmness level by penetrometer where the likelihood that consumers will choose to buy the apple is 75% YES, 25% NO.
- The other non-destructive firmness measures, Aweta, Greefa, and SIQ, did not relate to consumer willingness to buy in a consistent way. The destructive firmness provided a better prediction of consumer buying response than its non-destructive counterparts.

Figure 1. April 2004 model of the likelihood that consumers will buy Gala apples at a given firmness level.



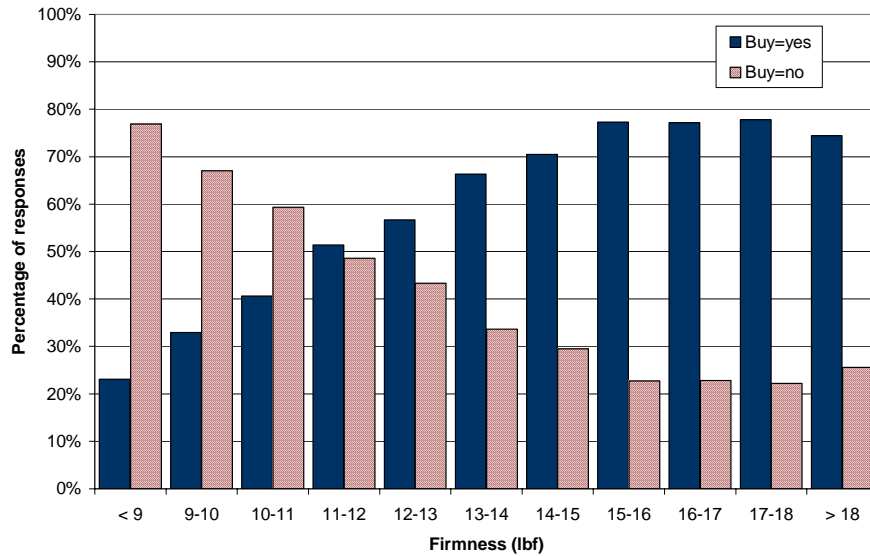
B. Comparison of April 2004 Gala test results to previous Gala results (April 2002):

- The April 2002 test protocol was 100 consumers sampling 8 apples each (resulting in 800 responses) compared to the 2004 test protocol of 487 consumers sampling one apple each.
- The 2002 results were evaluated using exploratory methods to describe the data trends. The new test design used in 2004 substantiated the trends from the 2002 test.
- The relationship between firmness and purchase intent for the 2002 Gala data can be visualized using a histogram as shown in Figure 2. The histogram gives the percentage of

“yes” and “no” consumer responses as to whether they would purchase the fruit at a given firmness range. All the apple firmness levels tested with these consumers were between 6 and 20 lbf, but the majority of apples tested were in the 10-16 lbf range.

- The two tests provided similar results. For example, the 2002 test determined that at 11-12 lbf firmness, more consumers were willing to buy than not (51% YES, 49% NO). This is similar to the 2004 Gala study where 50% of consumers said that they would buy the fruit at 11.8 lbf firmness.

Figure 2. April 2002 consumer willingness to buy Gala at different firmness levels.



II. April 2004 test results for Red Delicious.

A. Prediction of consumer purchase intent from firmness and sweetness:

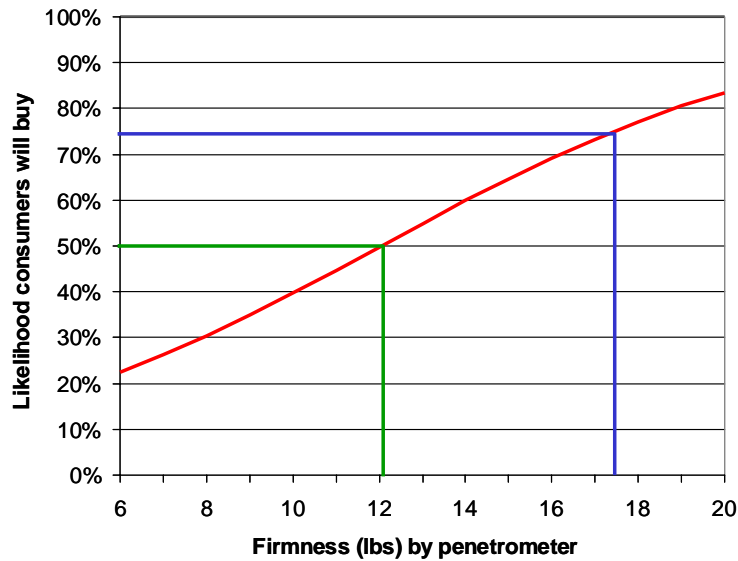
The relationship of apple firmness measured by penetrometer and sweetness (SS) to consumer purchase intent was evaluated from the instrumental measures on each apple that consumers were given and their response to the question, “Would you buy this apple to eat fresh for \$0.99/lb.?” The consumer demographics information revealed that 58% of the consumers tested usually paid \$0.99 or more per pound for apples. Results for the Red Delicious apples sampled by 290 consumers are as follows:

- For the quality range (11-16% SS and 6-19 lbf) of Red Delicious apples served, 69% of consumers were willing to buy fruit and 41% consumers were not willing to buy fruit of that quality, regardless of price.
- At \$0.99/lb., 59% of consumers indicated that they were willing to buy the fruit.
- As Red Delicious apple firmness (penetrometer) increased, there was a significant increase in the number of consumers willing to buy the fruit. Most apples (77%) were rated by consumers as having acceptable firmness.
- Red Delicious apple sweetness level, measured as soluble solids, did not significantly affect consumer purchase decisions. Most apples (86%) were rated by consumers as having acceptable sweetness.
- The likelihood of a consumer buying at any firmness level can be determined from the consumer responses for all Red Delicious apples evaluated in 2004 (Figure 3). This graph represents a model relating consumer purchase behavior to Red Delicious firmness (penetrometer). For example, 12.1 lbf is the firmness level by penetrometer at which the

likelihood that consumers will choose to buy the apple or not buy the apple is the same (50% YES, 50% NO), and 17.4 lbf is the firmness level by penetrometer where the likelihood that consumers will choose to buy the apple is 75% YES, 25% NO.

- For Red Delicious apples (2004), two non-destructive firmness measurements, Aweta and SIQ, provided a statistically validated relationship to consumer willingness to buy. The penetrometer measure provided a better prediction of consumer response than the Aweta or SIQ non-destructive firmness measures. Greefa, the other non-destructive firmness instrument, did not relate in a consistent way to consumer willingness to buy.

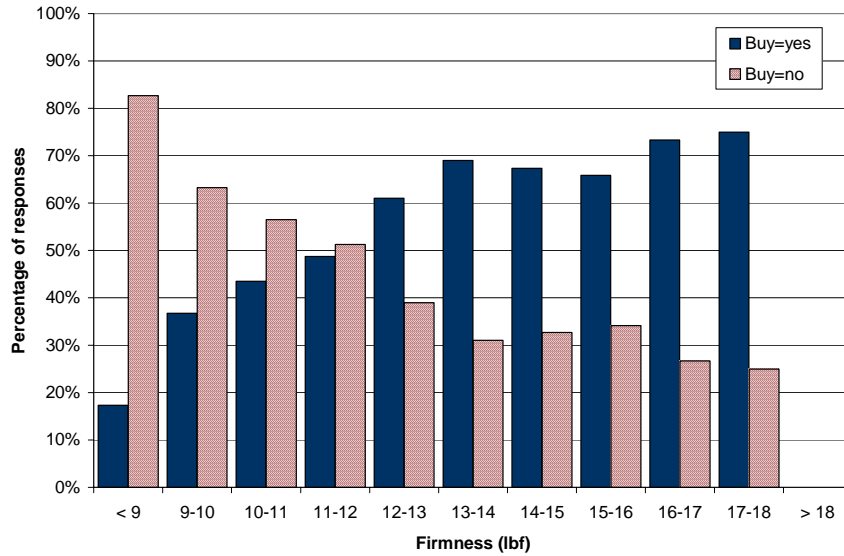
Figure 3. April 2004 model of the likelihood that consumers will buy Red Delicious apples at a given firmness level.



B. Comparison of Red Delicious test results from April 2004 to January 2002:

- The January 2002 Red Delicious consumer trial was conducted with 109 consumers evaluating 8 apples each, compared to the 2004 testing protocol of 290 consumers sampling one apple each.
- Exploratory methods were used to describe the 2002 data trends. The new test design used in 2004 substantiated the trends from the 2002 test.
- The relationship between firmness and purchase intent for the 2002 Red Delicious data can be visualized using a histogram as shown in Figure 4. The histogram gives the percentage of “yes” and “no” consumer responses as to whether they would purchase the fruit at a given firmness range. All the apple firmness levels tested with these consumers was between 6 and 20 lbf, but the majority of apples tested were in the 8-15 lbf range.
- The two tests provided similar results. For example, at 12-13 lbf firmness, more consumers were willing to buy than not willing to buy (61% YES, 39% NO). This is similar to the results of the 2004 Red Delicious study where 50% of consumers said they that would buy the fruit at 12.1 lbf firmness.

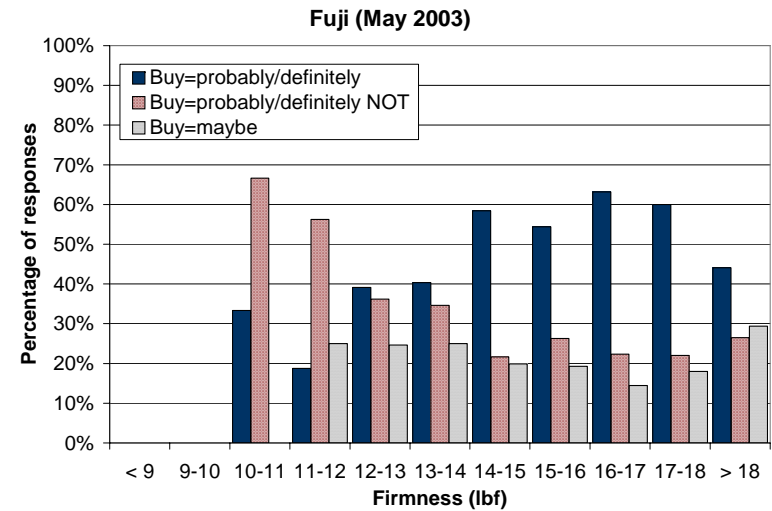
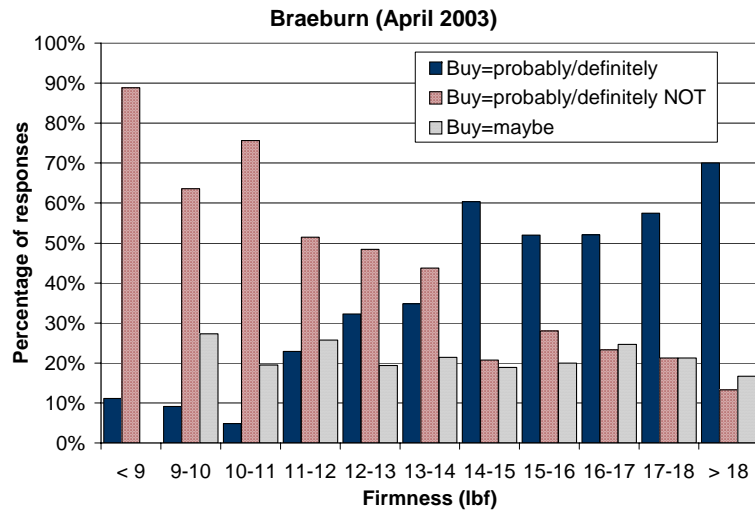
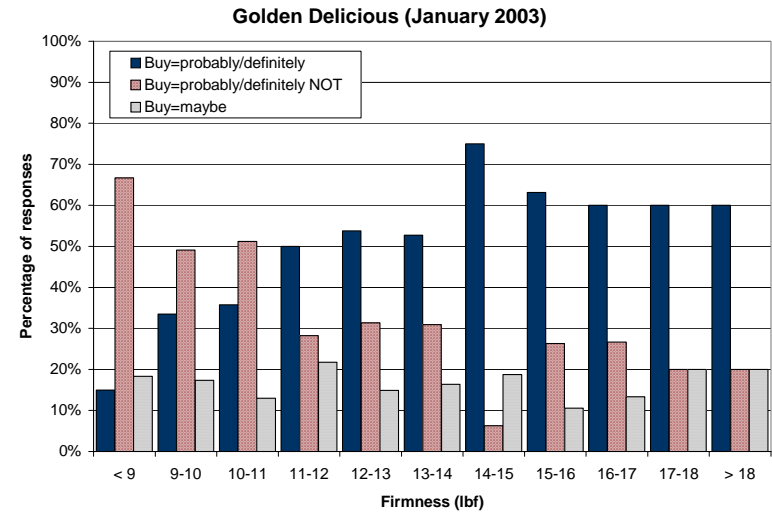
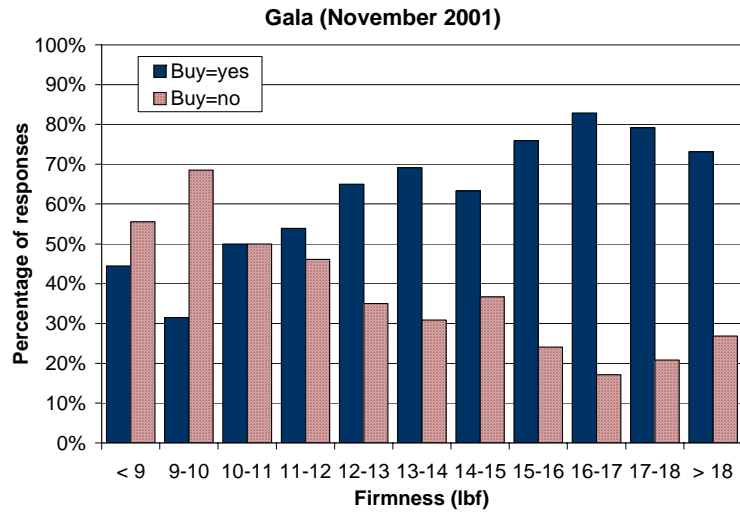
Figure 4. 2002 consumer willingness to buy Red Delicious at different firmness levels.



III. Trends for other apple varieties from 2002 to 2004 based on consumer purchase intent at different levels of apple firmness.

- As in the Gala and Red Delicious studies in 2002, consumer trials for the other varieties tested in 2001, 2002 and 2003 were conducted with 100-110 consumers evaluating 6 or 8 apples each.
- Histograms showing the relationship between firmness (penetrometer) and purchase intent for Gala (November 2001), Golden Delicious (January 2003), Braeburn (April 2003) and Fuji (May 2003) are shown in Figure 5.

Figure 5. Relationship between firmness (penetrometer) and purchase intent for Gala (November 2001), Golden Delicious (January 2003), Braeburn (April 2003) and Fuji (May 2003).



Discussion:

The 2004 trials using Gala and Red Delicious provided additional insight and refined the results obtained in previous trials, not only with these varieties but with others as well. The most discriminating measure of consumer satisfaction is the determination whether the apple being evaluated is one that the consumer is willing to buy. The “willingness to buy” measure (“Would you be willing to buy an apple of this quality?”) was determined to be superior to asking questions about acceptability (e.g., overall liking, firmness liking, sweetness liking, etc.).

The 2004 trials were also conducted to evaluate the usefulness of consumer intercept testing in a public place vs. inviting consumers to test apples in a sensory laboratory. The testing protocol was simplified by asking fewer questions. One fruit was served per person, rather than 6 to 8 apples allowing us to increase the number of consumers tested. The new testing system works well for this type of sensory research.

Firmness is the key edible quality component that reflects consumer willingness to buy. Firmness was highlighted by Dr. Harker in his review of literature three years ago as the most important edible measure determining consumer acceptance. These studies confirm this observation.

What these studies have done is to establish the relationship between willingness to buy and firmness levels for five varieties grown in Washington (see Figures 2, 4 and 5). Each variety has slightly different firmness levels at which consumers are willing to buy. These figures are being used today by a number of marketing organizations as a basis of discussion with retailers (and growers) about the value of quality control programs that guarantee certain levels of firmness. Simply, higher firmness level standards will be reflected in more consumers willing to buy apples.

The most reliable and precise measure of firmness is the penetrometer. Unfortunately, most non-destructive instruments do not yet correlate well with consumer willingness to buy. The lack of correlation to consumer perception may be due to the mechanics of how non-destructive instruments measure firmness. The velocity at which the fruit is tapped or hit may not be sufficient to accurately measure fruit firmness (Dr. Marvin Pitts, personal communication).

Soluble solids is a measure of apple sweetness and in these studies does not correlate well with consumer willingness to buy. The use of near infrared radiation (NIR) as a non-destructive measure of sweetness correlates fairly well with the refractometer.

Data about consumer willingness to buy and firmness have been presented at numerous industry meetings (Hort. Assn. annual meeting, Traffic Association, Pom Club, Grade and Pack, etc.) and have are being used by several marketing organizations.

Analysis is still in progress for the 2004 tests data to evaluate the impact of consumer apple eating and buying habits and demographics on purchase intent. These results will be presented in the poster and oral presentations in July.

Budget:**Project title:** Eating quality standards for apples**PI:** Dr. Eugene Kupferman**Project duration:** 2001-2003**Overall cost:** \$181,950**Overall budget:**

Year:	Year 1 (2001)	Year 2 (2002)	Year 3 (2003)
Kupferman, WSU	20,645	31,300	6,000
Marin, OSU	32,149	46,910	14,000
Harker (NZ)	15,698	15,698	0
Total	68,042	93,908	20,000

Kupferman (WSU) Allocation:

Item	Year 1 (2001)	Year 2 (2002)	Year 3 (2003)
Salaries	8,000	10,500	
Benefits (39%)	3,120	4,100	
Wages	3,500	7,000	
Benefits (16%)	560	1,120	
Equipment	0	0	
Supplies	3,465	4,580	
Travel	2,000	4,000	
Miscellaneous	0	0	
Total	20,645	31,300	6,000

Marin (OSU) Allocation:

Item	Year 1 (2001)	Year 2 (2002)	Year 3 (2003)
Salaries	10,448	11,823	
Benefits (40%)	4,507	4,787	
Wages	1,840	11,100	
Benefits (10%)	184	1,100	
Equipment	5,000	6,300	
Supplies	2,000	1,800	
Travel	1,000	1,000	
Miscellaneous	7,170	9,000	
Total	32,149	46,910	14,000