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Improving Almond Shell Seal with Cultural Practices to Reduce Kernel Damage by Insects

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Almond shell seal has been identified as a major factor determining resistance to Navel Orangeworm (NOW) and ant feeding on almond kernels. The almond shell is composed of three distinct layers, but the seal or "openness" of the innermost layer appears to be most important for deterring insect feeding. Past research has shown that shell seal varies greatly between almond varieties. This project was funded and initiated in late summer of 1998. Our project has three main objectives:

1. To identify cultural factors that cause shell seal quality to vary within a variety, and determine the range of that variability.

2. To determine how shell seal quality affects damage potential from NOW and ants.

3. To determine if shell seal quality can be predicted after shell hardening but before hull split, and to develop a field method of rating shell seal quality.

During the 1997 harvest, we collected Nonpareil almonds from orchards in Merced, Fresno, and Kern Counties. There was a tremendous range in shell seal quality, but overall, seal quality was good and insect damage levels (from NOW and ants) were low. In 1998, we collected almond samples from selected orchards and from UCCE research trials involved with varying rates of nitrogen, potassium, and irrigation. The shell seal quality was much poorer in 1998 compared to 1997. Nut samples were tested for shell seal quality (SSQ) and stored for later use to correlate with damage levels due to NOW and ants.

We are comparing different methods to measure shell seal. In the 1970's, the USDA used a seal quality meter that measured airflow through any openings in the shell. The seal quality meter would be impractical to use in the field, but is very useful as a research tool to measure differences. It also represents an objective standard that we can use to develop a field measurement tool. In addition to that method, we are also measuring other factors such as the width of the shell opening, and the overall shell width and length. Measurements obtained from other methods will be correlated with values from the seal quality meter. For example, the width of the shell opening can be measured with devices such as spark plug gauges.

We obtained nut samples from research plots involved with nitrogen rates (Kern County—Mario Viveros) and with nitrogen, potassium, and irrigation rates (Colusa County—Rollie Meyer). In addition, we obtained nut samples from selected orchards in Fresno and Merced counties that were sampled in 1997. In total, over 135 samples were obtained (with at least 200 nuts in each sample).

The Seal Quality Meter used was originally developed for use with large packages to test the "air tightness" or seal. One researcher from the Fresno office of USDA reported on the use for almond shell seal back in 1977. We consulted with that office and with researchers (Gradziel, Kester) at UC, Davis, on how the meter was modified for use with almonds. We then developed our own system for testing almond shell seal that is listed below. We are also working with Dr. Carlos Crisosto, KAC, on testing procedures. He works in post-harvest research, especially with peaches.

1. To identify cultural factors that cause shell seal quality to vary within a variety, and determine the range of that variability.

   A. Calibrating Seal Quality Meter
   B. Varietal Differences
   C. Effect of Cultural Differences on Shell Seal Quality (SSQ)

   A. Calibrating Seal Quality Meter
   Procedure for Testing Almond Shell Seal Quality: 1998, Fresno UCCE

   Objective testing of almond shell seal quality was done with the Fiberboard Seal Quality Meter. The meter is based on the principle that the rate of air flow into a sealed package at a known internal air pressure varies with the tightness of the package. So, a low air flow indicates a good seal, a high air flow indicates a poor seal. The meter has a small pump that generates air at a low pressure, and the air flows through a flexible tube through a small needle for flow-rate control. This meter also contains a low pressure gauge that is connected to a second flexible hose and small needle.

   We modified the meter by combining the two hoses into a "Y" shaped tube and using a 1/16 inch inflator needle (used for inflating sport balls). The orifice diameter was 0.055 inch. With this procedure, one hole only was needed instead of two holes, and we used a smaller diameter hole. Thus, less shell damage (cracking) occurred. A 1/16 inch hole was drilled through the almond shell (one side only), the needle was inserted, and a standard meter pressure of 30 psi (inches of water) was used. Measurements of air flow were taken in values of cc/minute. With these modifications, the procedure only required one smaller hole to be drilled. Measurements were taken quicker and with less shell breakage than with two larger holes drilled (with the previous measurements). With our modified procedure, we obtained consistent results when re-testing the same nuts.

   There was an apparent problem with air leakage between the needle and the nut shell on occasion. A small pad was added to the outside of the needle that assisted in blocking that air flow. Also, light hand pressure (pressing down on the needle) was used to achieve a better air seal. Almond shells with extremely poor seal (at the suture) would require more pressure downward on the needle. Usually, those shells had air flow values of 500 cc/min or greater. We dealt with that problem by giving values of 500 +. Our hypothesis was that any shell openings of 500 or greater would be equal in terms of insect damage. We plan to test that hypothesis later.

We arbitrarily established five categories of air flow values (in cc/min): 1 – 99, 100 – 199, 200 – 299, 300 – 399, 400 – 499, and 500 +. These categories were based upon thousands of shells measured and our thoughts regarding differential levels of insect damage. Initially, the lower values would mean better shell seal, or sutures that are mostly closed. These categories may change after the experiments that include exposure of in-shell nuts to insects.

There are differences between varieties with respect to shell layers, and those differences can impact SSQ measurements. For example, the Butte shell has significant air space between the first-second layers and the second-third layers. To accurately measure SSQ, we removed the outer two layers so that the pad (around the needle) rested against the inner shell layer. Other varieties may differ from Nonpareil also.

B. Varietal Differences

There were differences in the shell and suture characteristics between almond varieties, particularly the shell layers. Those differences required that we modify the testing procedures for different varieties for SSQ. Our standard measurements included SSQ (in cc/min), width of suture opening, and overall shell width and length. There were regional differences noted for the same variety also.

Nonpareil nuts were tested first and had the widest range of values. Almost all visible shell seal leaks were located at the suture area; either at the top or bottom of the "wing". Many of the visible leaks were located at the "dip of the suture" just above the shell point (end opposite of the stem attachment). Please see figure 1. Poorly sealed Nonpareil nuts could often be predicted based upon how the "wing" is attached to the rest of the shell (figure 2). This observation is similar to the situation with split pit in peaches. Nut samples from some of the BIOS orchards in Merced/Stanislaus counties had lower SSQ values (better seals). One orchard had 81% of the nuts contained in the 1 – 99 category of SSQ. The SSQ was highest with the smallest sized nuts. For example, many of the nuts with a SSQ of 100 or less were averaging 0.77 x 1.13 inches (width x length). Nuts with SSQ of 400 and higher were longer and wider.

With Nonpareil, there is some difference in the adhesion of the husk to the shell. With some nuts, the outer shell layer was removed when the husk was removed, causing a larger shell leak. It was interesting that this problem occurred less often with nuts from the BIOS orchards. Nuts with the best shell seal reading (lower air flow) tended to have a harder outer shell layer with better adhesion to the middle shell layer. Nuts with unequal joining of the outer shell to the wing had larger shell leaks (figure 1) as did shell with larger wings. Shell leaks usually appeared on the short side of the nut when the wing did not join at the same height with the outer shell layer.

Sonora shells are often poorly sealed. The outer shell layer is thin and variable. The hull to shell adhesion is strong, and thus easy to damage the shell layer. When leaks occur, they are large and occur most often in the suture area.

The Thompson shells were the poorest sealed, with over 30% of nuts testing above 500 on the flow meter. Most of the leaks occurred in the suture area. Many leaks were 1/8 inch wide, and found through the entire length of the shell.

The innermost layer of Butte variety shells were generally much better sealed than Nonpareil shells. However, the three shell layers are more separated, with more air space between them compared to Nonpareil (figure 3). This created a problem with the SSQ meter values obtained. Air flow from the needle would enter between the outer shell layers and give false (high) readings. We modified the testing procedure as listed above. Butte shells had a better attachment of the wing to the shell also, compared to Nonpareil shells.

C. Effect of Cultural Differences on Shell Seal Quality (SSQ)

We collected nut samples from three sources. A nitrogen rate trial from Kern County supplied 30 samples. A nitrogen/potassium/irrigation trial from Colusa County supplied 91 samples. Nut samples from selected orchards supplied another 15 samples. A summary sheet listing results from some of the selected orchards is enclosed (table 1). We are trying to find correlations between our SSQ meter readings and other measurements such as suture width, and shell length and width. Those other measurements can be done in the field with micrometers. The results are not fully analyzed yet.

The nitrogen rate plot in Kern County was discontinued. We have analyzed all the Nonpareil samples, but are discussing the data with M. Viveros and W. Bentley.

There were 91 samples (replications) obtained from the potassium, nitrogen, and irrigation trial in Colusa county (R. Meyer). With each sample, 25 nuts were tested for SSQ, suture opening, and shell width and length. Since the plot design is complicated, we gave our results to R. Meyer for analysis and are awaiting the results. The enclosed tables show the totals for each replication (Table 2).

When all this data is analyzed, we will file an updated report with the Almond Board.

2. To determine how shell seal quality affects damage potential from NOW and ants.

For objective 2, almonds of known shell seal quality will be exposed to Navel Orangeworm (NOW) and ant infestation under controlled conditions. We are trying to determine what the minimum level of shell seal that will allow kernel damage from NOW and from ants.

We also want to determine if damage levels increase with progressively poorer shell seal. We are working with Dr. Judy Johnson, USDA in Fresno, who supplies NOW eggs weekly. We had to "customize" exposure chambers for the NOW infestation, and now have the system operating. Fifty nuts (with different SSQ) are located in individual cups on a tray under slightly humid conditions (to increase NOW survival). Eggs are introduced to each cup in week one and three, and then the in-shell nuts will be rated for infestation after week four.

In the past, southern fire ants have not attacked in-shell almonds until May. So, we will be placing nut samples (with varied SSQ in a randomized pattern) near ant colonies in May.

3. To determine if shell seal quality can be predicted after shell hardening but before hull split, and to develop a field method of rating shell seal quality.

   This work was scheduled to start in spring of 1999. We are working with Dr. Gradziel and Crisosto to plan field and laboratory observations and research. Both of them are very familiar with the problem of split pit in peach, and have access to laboratory tools, which can assist us in observing the shell formation of almond. This third objective will be done using techniques developed for monitoring split pit in peaches and determining reference date (shell or tip hardening). We will work in selected orchards that will be predicted to have varying ranges of shell seal due to crop load, tree age and vigor, etc. We will cut across the nuts before and after shell hardening, and correlate those observations with shell seal at harvest. The ultimate goal is developing a forecasting system to help determine if hull-split sprays or if summer ant control sprays are needed.

Figure 3

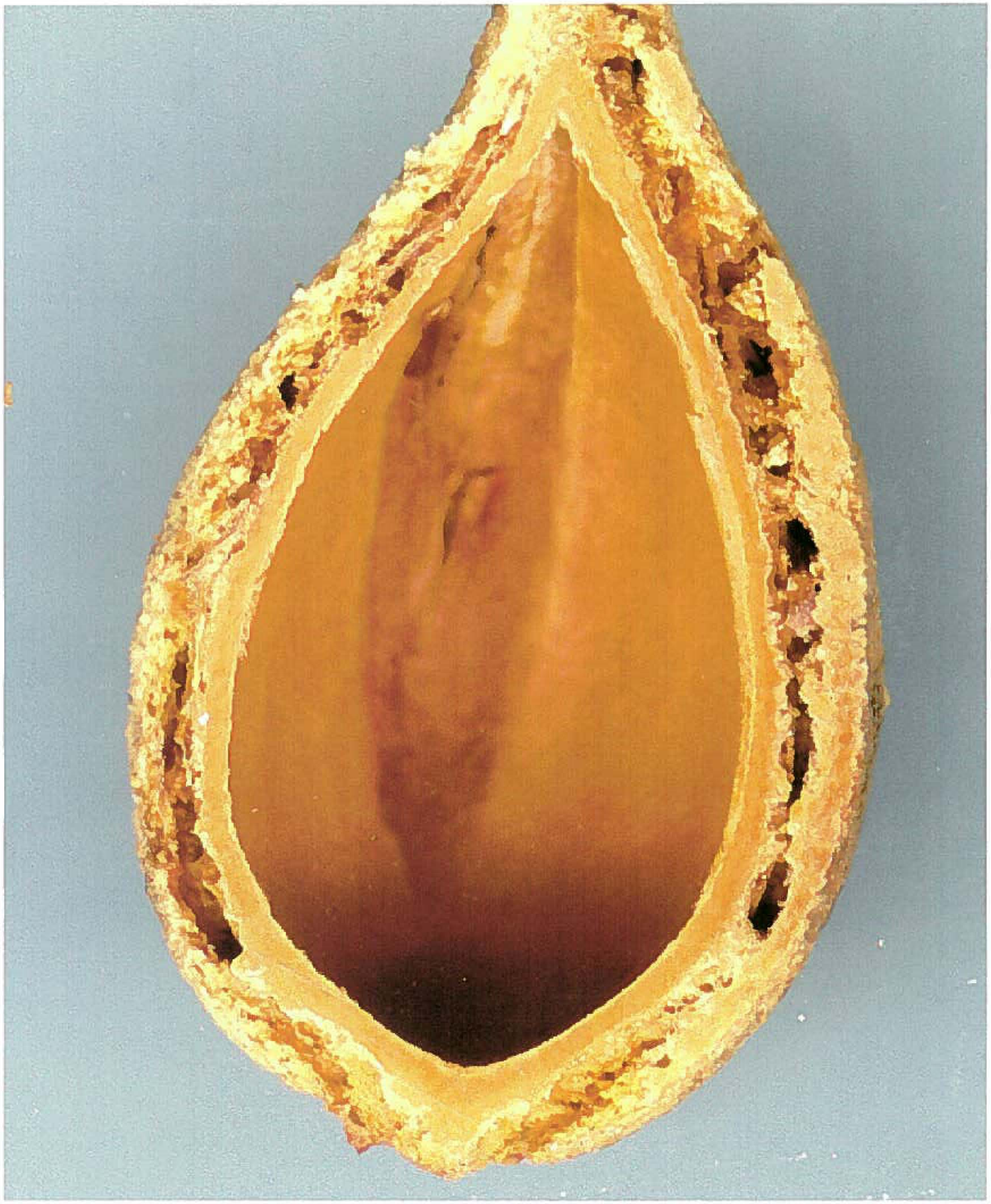

Figure 2.

Nonpareil:

Well-sealed

Poorly-sealed

Figure 1

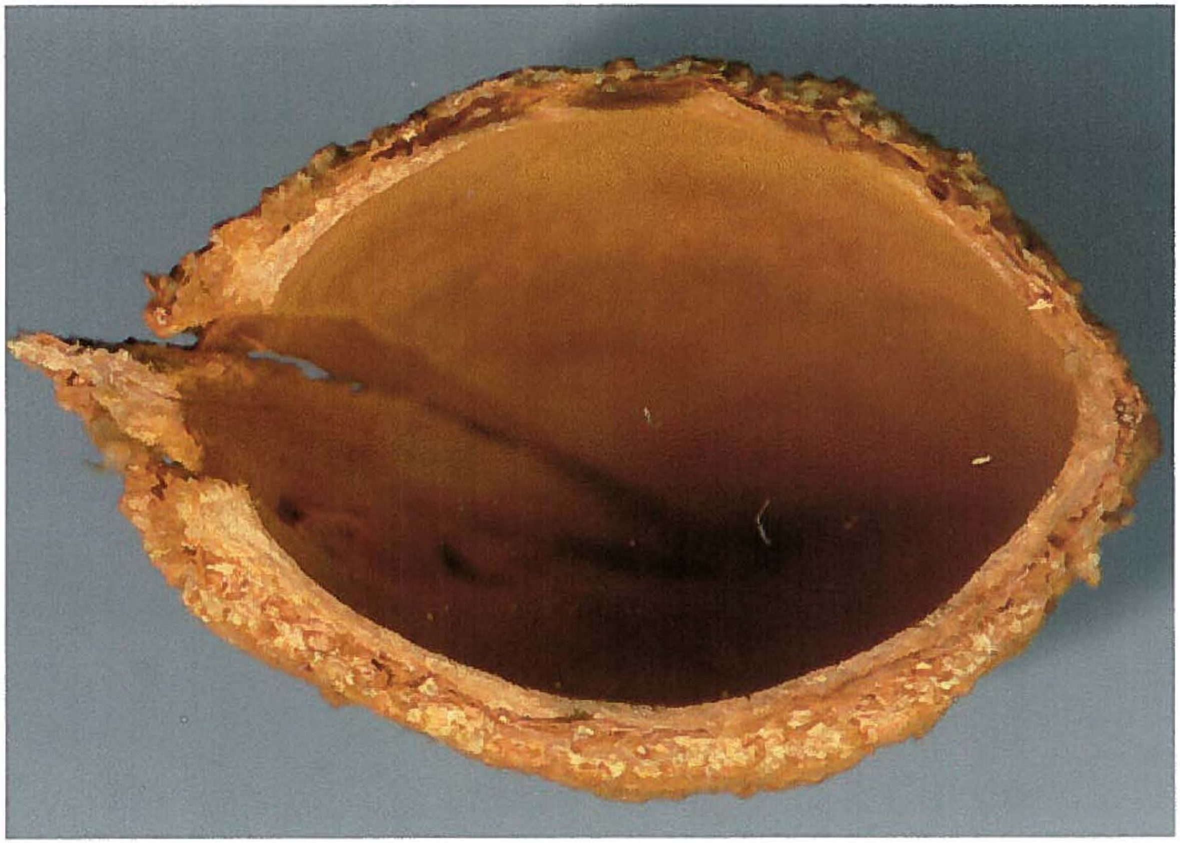

Table 1

SHELL SEAL TEST 1998						HARVESTED 9/10/98			
SOUTH CALIF. N. TRIAL NONPAREIL SAMPLE ORANGE 1									
			FREE	LEAK	LEAK	LEAK	SHELL SIZE		
NUT NO.	CC/M	COMP	NEEDLE	WIDTH	LENGTH	AREA	WIDTH	LENGTH	
1	500		30	0.1	0.91	0.091	0.85	1.38	
2	500		30	0.04	0.85	0.034	0.76	1.25	
3	500		30	0.05	0.71	0.0355	0.74	1.31	
4	500		30	0.07	0.98	0.0686	0.95	1.43	
5	500		30	0.08	0.93	0.0744	0.86	1.33	
6	500		30	0.04	1.01	0.0404	0.86	1.37	
7	500		30	0.12	1	0.12	0.87	1.34	
8	500		30	0.1	0.89	0.089	0.87	1.48	
9	500		30	0.05	0.76	0.038	0.76	1.43	
10	500		30	0.05	0.84	0.042	0.85	1.35	
11	500		30	0.12	0.96	0.1152	0.77	1.16	
12	500		30	0.12	0.97	0.1164	0.69	1.3	
13	500		30	0.11	0.85	0.0935	0.7	1.28	
14	400		17	0.002	0.97	0.00194	0.87	1.41	
15	440		21	0.03	0.75	0.0225	0.78	1.25	
16	500		30	0.15	0.86	0.129	0.75	1.39	
17	500		30	0.08	0.91	0.0728	0.85	1.31	
18	470		25	0.04	0.17	0.0068	0.81	1.36	
19	500		30	0.04	0.71	0.0284	0.76	1.37	
20	500		30	0.09	0.97	0.0873	0.85	1.34	
21	480		27	0.05	0.74	0.037	0.89	1.33	
22	410		14	0.02	0.74	0.0148	0.87	1.34	
23	460		23	0.03	0.07	0.0021	0.85	1.31	
24	500		30	0.06	0.86	0.0516	0.81	1.36	
25	500		30	0.06	0.99	0.0594	0.8	1.35	
Average:	**486**			**0.068**	**0.816**	**0.059**	**0.82**	**1.34**	
0-99	**100-199**	**200-299**	**300-399**	**400-499**	**500**	cc/m at .30 inches of water			
0	0	0	0	6	12	number of nuts		avg cc/m	486.4
LEAK WIDTH									
0-.0009	**0.001**	**0.002**	**0.01**	**0.02**	**0.03**	**0.04**	**0.05**		total
0	0	1	0	1	2	4	4		12
0.06	**0.07**	**0.08**	**0.09**	**0.1**	**0.11**	**0.12**	**0.13**	**.14+**	
2	1	2	1	2	1	3	0	1	13

Table 2

Plot	CC/M	Leak W.	Shell W.	Shell L.
K1	149.6	0.00568	0.7576	1.1324
K10	293.2	0.01644	0.7608	1.1416
K10	293.2	0.01644	0.7608	1.1416
K11	171.6	0.00532	0.74	1.144
K12	249.8	0.01444	0.73	1.1676
K17	264.4	0.01172	0.7616	1.1636
K18	312.8	0.01844	0.7492	1.1144
K19	269.2	0.01324	0.756	1.1572
K2	289.6	0.01444	0.7548	1.1728
K20	269.2	0.01324	0.7272	1.1392
K25	246.8	0.01652	0.7508	1.174
K26	186	0.00764	0.7636	1.1492
K27	237.6	0.01248	0.7424	1.1392
K28	230	0.02324	0.7392	1.1548
K3	271.2	0.01132	0.726	1.1512
K33	210.8	0.01204	0.77	1.17
K34	239	0.01208	0.776	1.1824
K35	191.2	0.01164	0.7492	1.168
K36	276	0.0148	0.7516	1.168
K4	444.4	0.04044	0.7592	1.1832
K41	334.8	0.01732	0.7752	1.2124
K42	231.6	0.01204	0.7484	1.1456
K43	224.8	0.0192	0.7492	1.2416
K44	96.2	0.0064	0.7412	1.2072
K49	245.2	0.01056	0.7532	1.132
K50	361.2	0.0276	0.734	1.1608
K51	299.6	0.02	0.7324	1.1828
K52	286.4	0.02644	0.7232	1.1624
K57	92.56	0.006	0.7284	1.1676
K58	92.8	0.0072	0.7	1.14
K59	103.32	0.00408	0.7608	1.176
K60	397.2	0.03204	0.742	1.1664
K65	208.4	0.00816	0.7164	1.4924
K66	210.4	0.00976	0.7036	1.1284
K67	143.08	0.00692	0.7112	1.1644
K68	227.4	0.01444	0.7604	1.17952

Plot	CC/M	Leak W.	Shell W.	Shell L.
NI10	99.2	0.00208	0.7292	1.0988
NI21	235.6	0.00852	0.7096	1.1036
NI21	235.6	0.00852	0.7096	1.1036
NI22	146.4	0.00724	0.7424	1.1308
NI23	156.6	0.008	0.736	1.1132
NI24	140.8	0.00804	0.7316	1.118
NI25	120.8	0.00248	0.7304	1.1584
NI36	139.2	0.00684	0.7424	1.1116
NI37	174.8	0.0092	0.726	1.1148
NI38	107.8	0.0032	0.7352	1.1144
NI39	159.32	0.0064	0.7272	1.1204
NI40	78.4	0.00132	0.7196	1.1124
NI51	157.8	0.00572	0.7476	1.1256
NI52	105.32	0.0032	0.7296	1.0852
NI53	96	0.00364	0.7248	1.128
NI54	89.32	0.00204	0.7392	1.1036
NI55	134.88	0.0058	0.7032	1.0888
NI6	140.6	0.00884	0.7352	1.1044
NI7	167.2	0.00928	0.6904	1.0456
NI8	79.2	0.00324	0.708	1.0536
NI9	85.8	0.0032	0.7136	1.0792
avg	**136**	**0.005562**	**0.725276**	**1.10543**

Plot	CC/M	Leak W.	Shell W.	Shell L.
AS10	223.2	0.00824	0.7548	1.1912
AS21	294	0.01292	0.788	1.2056
AS21	294	0.01292	0.788	1.2056
AS22	299.52	0.0184	0.7432	1.1616
AS23	277.2	0.0166	0.7452	1.178
AS24	235.6	0.01084	0.736	1.1124
AS25	236.6	0.01016	0.77	1.2324
AS6	181.6	0.00928	0.74	1.1756
AS7	267.64	0.01452	0.7472	1.1544
AS8	270.8	0.0176	0.73	1.1436
AS9	215	0.01048	0.7728	1.214
avg	**254**	**0.012905**	**0.755927**	**1.17949**

North CA
Butte Variety