Quantitative and Qualitative Impacts of Windfall on Almond Yield and Quality

Project No.: **HORT40.Brown**

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A. Summary

By 2025, the California almond community commits to reduce dust during almond harvest by 50%. One option is transition to alternative off-ground harvest systems like catch-frames. Even though a transition to catch-frames would reduce harvest passes and subsequently dust, there is a potential unknown loss of marketable yield in the form of windfall that would not be picked up if ground harvest is abandoned. Additionally, windfall is a concern for current harvest systems since windfallen nuts that lie on the orchard floor for extended periods might disproportionately affect crop quality. Out research addresses the quantity and quality of windfall in relation to variety, location, and timing. Preliminary analysis from the 2019 season show windfall from 0 to 1%, with the majority of sites showing <0.4% (0-15 lbs per acre). Fruit falling before 4 weeks of normal harvest were very poor quality. Quality and size of kernels is not compromised with potential 2-4 weeks early shake. However, kernel moisture was found to be 10-15% higher at >2 weeks early shake. Analysis of regional and cultivar data is ongoing.

B. Objectives

This project is divided into two separate yet integrated projects. The first project aims to estimate the quantitative impact of windfall and the second project aims to estimate the qualitative impact of windfall. The main goal of this proposal is to understand the windfall dynamic and estimate both the relative volume and quality of nuts that fall prematurely from almonds trees (windfall) compared to those harvested by tree shaking.

Objectives

- Characterize the windfall dynamic and estimation of relative importance to the rest of the harvest in relation with environmental, biological and management factors.
- Assess the quality of the windfallen nuts collected from regions of the Central Valley.
- Determine incubation period of windfallen nuts in multiple environments.

Milestones

- Monitor environmental, biological and management factors in orchard across the Central Valley in a controlled time interval to determine influences on windfall.
- Develop a multivariate regression model to determine significant windfall factors.
- Analyze windfallen nuts for quality characteristics
- Estimate loss of yield and quality from windfall.
- Subset data and data from the quantitative analysis to determine the potential yield and value loss due to windfall under a variety of climactic and management scenarios.

C. Annual Results and Discussion

Activities and outputs - Quantitative project

The initial phase of the project consisted on establishing communication with many industry partners and collaborators to enroll the orchards for summer monitoring. During this time, different designs for sampling kits (strings with barcodes attached) were tested with final construction of over 550 sampling kits before spring. Software algorithms were developed by Dynamic Ventures/CountThings to aid in the image analysis and nut counting.

During Spring, personnel met all collaborators to identify final sites to be monitored and establish logistics. During this time, recruits were interviewed and trained before first orchard visit. By the end of Spring, each recruit was assigned a number of orchards to visit and a unique sampling kit was assigned and attached to each participating tree.

Image collection started during the first month of Summer. Each participating orchard cultivar in the entire state was visited in at least 4 instances, which resulted in over 12, 000 images and more than 300 fruit samples collected. Image collection terminated in Fall.

Starting in Fall, all barcodes and any other equipment used was collected from each orchard. Data sorting and analysis started in November and image analysis began in December. Preliminary results were obtained on December 6th, 2019 to be presented during the Almond Conference. Image analysis of regional and cultivar data is continuing during January 2020.

Progress toward goals - Quantitative project

Preliminary analysis from the 2019 season show windfall from zero to 1% percentage, with the majority of sites showing <0.4% (0-15 lbs per acre). It was also observed that wind speed greatly increases the incidence of windfall during the last two weeks prior to harvest.

Activities and outputs - Qualitative project

The windfall projects team met regularly to harmonize the experimental design. It was agreed that the detailed sequential observations on windfallen nuts is required to assess quality. Two locations in the Central Valley including Kern County-Bakersfield site in the south and Butte County- Chico in the north were selected. Each location was in full production phase (7-12 years), irrigated using microsprinklers and we focused on the Nonpareil variety.

Our experimental design RCBD at both sites with 6 blocks, 6 pseudo-repetitions each with 20 nuts. Out treatments were the incubation time of the nuts on the orchard floor. The treatment were **T6** - six weeks prior to harvest, **T4** - 4 weeks pre-harvest incubation and T2 - Two weeks

pre-harvest incubation and **T0 -** regularly harvested nuts that serve as the control. During the planning phase, we used the hull split prediction model to predict hull split. There was a 7-10 days delay this year compared to the mode. Thus, we had to adjust our field observations based on the progress of the hull split. Microsprinkler irrigation was selected due to the creation of a uniform wet zone with a potential greater impact on quality.

We placed a light nylon mesh-trap on top of each incubation site in order to avoid contamination with other windfallen nuts. We visited each site bi-weekly to lay successive treatments and monitor the hull-split. All the nuts were collected on the eve of the harvest day. We returned prior to the sweeping operation to collect T0. All the collected nuts were stored at 4-5^{o}C. The following quality parameters were assessed whole nut integrity (insect or NOW damage), mold formation on the hull and kernel, kernel moisture, kernel weight, kernel Color , Free Fatty Acids (FFA) and Peroxide Value (PV). The preliminary analysis of composite samples from both sites sent to the JL Lab in Modesto are reported below (Table 1).

Table 1. Preliminary Results on composite samples in Bakersfield and Chico

Treatments	*Moisture (%)*	*Aflatoxin (ppb)*	*Free Fatty Acids (%)*	*Peroxide Value (meq/kg)*
	Bakersfield			
T6	33.1	<0.4	12.1	<0.5
T4	20.9	<0.4	3.9	<0.5
T2	18.3	<0.4	3.4	<0.5
T0	5.4	<0.4	0.3	<0.4
	Chico			
T6	6.1	<0.4	0.2	<0.3
T4	6.1	<0.4	0.2	<0.3
T2	5.8	<0.4	0.2	<0.3
T0	3.6	<0.4	0.2	<0.3

Progress toward goals - - Qualitative project
These preliminary results indicate for the Bakersfield site that the T6 nuts had a higher moisture content and showed higher mold formation both on the hull and the kernel. The FFA % as oleic acid was higher which indicates a decline in quality similar to reduced shelf life. We are carrying out analysis to determine more accurately the timing threshold for nut quality.

D. Outreach Activities

Field Day, March 14th 2019, Fresno, CA., Recruitment session, 25 Farmers and 1 Advisor

Field Day, March 19th 2019, Modesto, CA., Recruitment session, 30 Farmers and 1 Advisor

Field Day, March 26, 2019, Chico, CA., Recruitment session, 20 Farmers and 1 Advisor

Preparing for Harvest, In-the-orchard CASP Events, June 11, 2019., Hughson, CA., Windfall Recruit session, 12 farmers and 8 ABC members

Preparing for Harvest, In-the-orchard CASP Events, June 12, 2019., Orland, CA., Windfall Recruit session, 12 farmers and 5 ABC members

Almond Conference Poster Session, December 10, 11, 2019., Sacramento CA., Windfall Poster presentation, 1000 farmers.

E. Materials and Methods

Quantitative project approach

Multiple regions in the Central Valley were selected for windfall monitoring by our research team. We selected the number of orchards to maximize the number of cultivars, tree age and management combinations for the quantity portion. Each orchard was marked with GPS. Sampling kits using polyester string and four barcodes were placed at the trunk of selected tree. Barcodes were laid at 0.5 m, 1.5 m, 2.5 m, and 3.5 m away from the trunk. Each barcode will then be considered the center of a data collection point across the orchard. Commencing at 5% hull split, each data collection point was pictured weekly until 95% hull-split prior to and at normal tree harvest. Using the actual windfall data, we will estimate windfall percentage.

Quantitative project challenges

Recruitment of hundreds of orchards across the state using help from collaborators was difficult but, a final number of 60+ orchards was achieved. Due to limited collaboration, we were unable to arrive to each data point before windrowing in many cases. Another challenge with our approach is the difficulty of the counting software to recognize the almonds in a picture. The software needs to be trained in order to recognize what it should and count.

Qualitative project approach

Using a RCBD, two orchards were selected from the two extreme locations in the almonds growing region. One site was in Bakersfield in Kern County and the other in Chico in Butte County. Each orchard received three timing treatments, where almond fruit will be placed on the ground at 4 different equally spaced timeframes prior to harvest; six (T6), four (T4) and two (T2) weeks prior to harvest with a control (T0) for standard timing of harvest. Each orchard utilized microsprinkler irrigation for maximum wetting of during incubation. There were 6 pseudo repetitions represented by individual trees within a single row.

We simulated windfall by shaking tree branches and collecting fully split nuts. Twenty nuts were placed under a nylon mesh trap and left to incubate until harvest prior to assessment of moisture content, peroxide values, kernel weight, kernel color, insect damage, mold formation, free fatty acid composition, aflatoxins, and changes in USDA grading scale. We also used a Watermark sensors to monitor soil moisture and temperature in the top 5 inches of soil.

An ANOVA statistical model will be used to assess differences between incubation treatments. Two separate models will be run per orchard site. We expect the combination of quantitative and qualitative results will allow us to estimate the potential yield loss from windfall.

Qualitative project challenges

The initial challenge we faced was the 8-10 delay observed in hull split compared to the prediction model. We had to readjust the treatment times based on the actual hull split

observed on the field. The second challenge was that we did not have adequate windfall fruits so, we needed to select split nut and lay them on the floor for incubation.

F. Publications that emerged from this work

Windfall Analysis

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Project ID: HORT40-Brown

Background

- Almond harvest is characterized by the use of heavy machinery that can produce large amounts of dust for about three consecutive months.
- It is estimated that California almond harvest produces 11, 220 tons of dust.
- Harvest in one almond orchard can produce 41 pounds of PM10 per acre, while other crops such as wheat produce about 5.8 pounds of PM10 per acre.
- Almonds exposed to soil can be contaminated by pathogens and toxins such as aflatoxins.
- Current harvest practices are unsustainable in the long run, due to the soil conditions required for harvest.
- Off-ground harvest can reduce dust to virtually zero.
- Off-ground harvest can also reduce the use of pesticides, fertilizers, and it can also increase soil health and increase tree longevity.
- Windfall is a phenomenon that has not been studied.

Figure 1: Typical almond harvest in California.

Figure 2: Almonds are left in windrows for certain amount of days to dry almonds. During this time almonds are exposed to pathogens, insects, and pesticide residues.

Objectives

- Over the next season identify how much windfall occurs in the state.
- Identify where the windfall occurs.
- Identify the effect of location cultivar, and date.
- Determine the effect of windfall date on quality of final harvest.
- Determine effect of harvest date on nut quality.

Methods

- Divide the state in three regions: South, Central, and North.
- Survey orchards with different cultivars, rootstocks, and age.
- Select trees of same variety in a transect.
- Use barcodes as reference and take pictures every week along row (0°) and across row (90°).
- Make weekly visits to over 280 sites across the state from 5% Hull split to the eve of harvest.

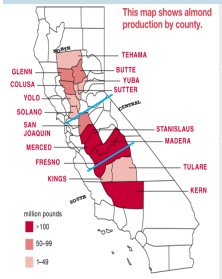
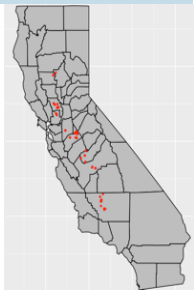


Figure 3: Almonds orchards divided by region.



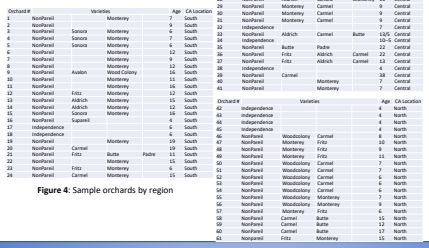


Figure 4: Sample orchards by region

Results

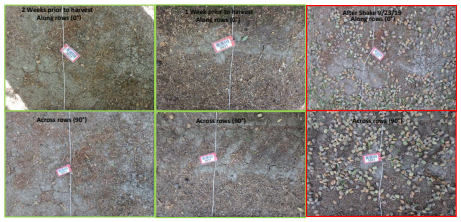
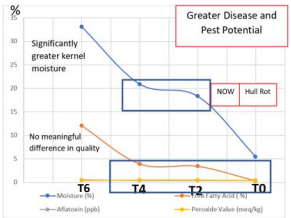


Figure 5: EXAMPLE Quantitative Observations (Low Windfall 0-0.1% 2-3 lbs)



Kern-Bakersfield	T6	T4	T2	T0
Moisture (%)	33.1	20.9	18.3	5.4
Free Fatty Acid (%)	12.0	3.9	3.4	0.3
Aflatoxin (ppb)	0.5	0.4	0.4	0.4
Peroxide Value (meq/kg)	0.4	0.5	0.5	0.4

Figure 6: Preliminary analysis of composite samples from Bakersfield shows Moisture and FFA percentages **gradually decreasing** from T-6 (6 weeks before harvest) to T-0 (nuts at harvest) while aflatoxin concentration and peroxide value remained constant.

Conclusion

- Preliminary analysis shows windfall from zero to 1% percentage, with the majority of sites showing <0.4% (0-15 lbs.).
- Fruit falling before 4+ weeks of normal harvest are very poor quality.
- Quality and size of kernels is not compromised at 2-4 weeks early shake.
- Kernel moisture is 10-15% higher at > 2 weeks early shake.
- The potential for NOW and Hull Rot is greatly increased with fruit maturity.
- Analysis of regional and cultivar data is continuing.
- Repeat studies in 2020 with added 1) high aflatoxin sites and 2) high Navel Orange Worn/Hull-Rot sites will be conducted.

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Impact of windfall on almond yield and quality

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The Almond Board of California and UC Davis are interested in assessing the quantity and quality of the windfall nuts or the hull-split nuts that fall pre-harvest from almond trees across California. We believe this information can be very valuable to the growers.

The driving questions are:
- What is the percentage or amount windfall almond relative to the total yield?
- Are these nuts mature enough?
- What is the effect of longer exposure of this group of nuts to insect damages and/or varying conditions to their quality?

We would like to answer these questions together.
Thank you in advance for joining the Windfall project.
Please ask for the sign-up sheet!!

Procedures

Grower:

1. Get grower permission to enter their fields.
2. Get as much orchard information as possible (variety, age, spacing, irrigation frequency, etc.)
3. Communicate with us of any spray and Irrigation schedules.

UC Davis personnel:

1. Randomly choose 3 average-looking trees per variety in an orchard.
2. Attach one sampling kit per tree (chord with barcodes) as in picture below.
3. Take pictures every 7 days of each barcode starting at 5% hull-split.
4. Collect sampling kits at 95% hull split.

Explanation Video: Type “Windfall Sampling Kit” on YouTube or https://bit.ly/2HqInrv

Picture 1: Sampling along the row.