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LEMON PITTING IN THE CENTRAL VALLEY

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Project Summary

Lemon pitting is an issue first observed at packinghouses in California's Central Valley in 2015, and the impact from this disorder has been seen with increasing frequency in more recent growing seasons. The Citrus Research Board (CRB) initiated a project in April 2023 that gathered a group of University of California experts from all relevant disciplines to find the cause and solution for this emerging issue (Mayorquin and Klein 2023). Since April 2023, we have been monitoring 12 orchards as part of project activities to determine the cause of the issue; and this year, we have started to carry out some field treatments. Our 2023 survey data showed that the damage to the fruit occurs right after petal fall, typically during the first week of May, with some of the damaged fruit recovering as the season progresses. However, it might not be noticed until the fruit becomes larger later in the season. We implemented a trapping system and established analysis protocols during the 2023 growing season that are continuing through 2024. Monitoring of insect populations at field sites started last year, and further microscopic analysis is being conducted to gain more insight into the nature of the damage. No fungal or bacterial organisms have been isolated from symptomatic tissue to date. Based on initial leaf nutrient results and the initial survey, field treatments were initiated in the 2024 season to reduce the incidence of lemon pitting. The potential role of pruning activities and further observations of rough rind are also being reviewed this growing season.

Introduction

In 2015, growers started seeing lemon fruit with pitting. The issue was initially observed in the Ivanhoe and Orange Cove areas with later finds south in the Arvin area of Kern County. There have been no reports of this issue outside the Central Valley. Lemon pitting is characterized by the development of undulating and depressed areas on the fruit's surface (**Figure 1**). Fruit with this condition loses its fresh marketability and is sent for juicing, resulting in significant economic loss for growers due to the difference between the price of fresh market versus juicing.

The cause of lemon pitting is presently unknown; possible hypothesized causes include insect damage, pathogen damage, physiological factors such as nutrient deficiency or abiotic stress, any other factors that disturb the cuticle layer, or interactions between two or more of these factors. The current


Figure 1. Appearance of lemon pitting in Lisbon lemons at harvest. The disorder appears as undulating and depressed areas on the fruit's surface. *Photo by Ashraf El-kereamy*

project was initiated by the CRB last year to address this issue and find a solution to control lemon pitting.

Project Goals

The objective of this project is to identify the factors associated with lemon pitting and provide growers with guidelines to effectively manage and control this condition in California through the following activities:

1. Reviewing information from three growing seasons from 2022-24 for the groves in the survey.
2. Identifying common factors/differences among the affected orchards.
3. Characterizing fruit growth rate and identifying the stage where damage occurs.
4. Conducting regular pathological tests, insect surveys and histological studies.
5. Quantifying environmental conditions – temperature, relative humidity and wind speed - across the surveyed citrus fields exhibiting lemon pitting.
6. Determining the nutritional content of leaves and fruit throughout the growing season at 12 surveyed citrus fields exhibiting lemon pitting.
7. Testing field treatments to reduce the incidence of lemon pitting.

Current Project Results

We collected grove histories and initiated monitoring of 12 orchards in the Central Valley during the 2023 season. Orchard information is presented in **Table 1**. One of the orchards is

Table 1. Summary of information collected from the 12 orchards (R1-11) under study and the damage percentage during the 2022 and 2023 seasons.

	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R10B	R11
Rootstock	Carrizo, C35	Carrizo	Carrizo	Carrizo	Carrizo	Trifoliate	Carrizo	Trifoliate	Trifoliate	Carrizo	Carrizo	Unknown
Variety	Lisbon	Lisbon	Lisbon	Lim 9A	Lisbon	Lisbon	Lisbon	Lisbon	Lisbon	Lisbon	Lisbon	Lisbon
Age (Years)	60 & 8	18	6	7-10	20	14	5	8	15	18	18	70
Planting Density	11x20	18x20	20x20	20x20	20x20	20x20	20x14	20x17	20x20	22x20	22x21	20x18
Soil Type	Clay	Clay Loam	Heavy top 3ft and sand below	San Joaquin Loam	Clay Loam	San Joaquin Loam	Cometa Loam Moderate Drainage	176 Yettem Sandy Loam, 0 to 2 percent slopes	Clay Loam	Clay Loam	Clay Loam	Exeter Loam
Adjacent Crops	Blood orange, Tango, Seedless lemon, Pistachio	Orange, Lemon, mandarin	Rio Red Grapefruit, Navel orange	Tango, Clementine, Navel	Lemon/ Oranges	Citrus	Minneola/ Kirkwood/ Tango	Lisbon lemon and Valencia orange. The rest is open pasture.	Citrus	Citrus	Citrus	Lemons, Navel, Valencia
2022 damage (%)	5	80	90	40	70	20	20	23	80-90	30	0	10
2023 damage (%)	1	21	26	42	6	8	23	0	3	0	2	0

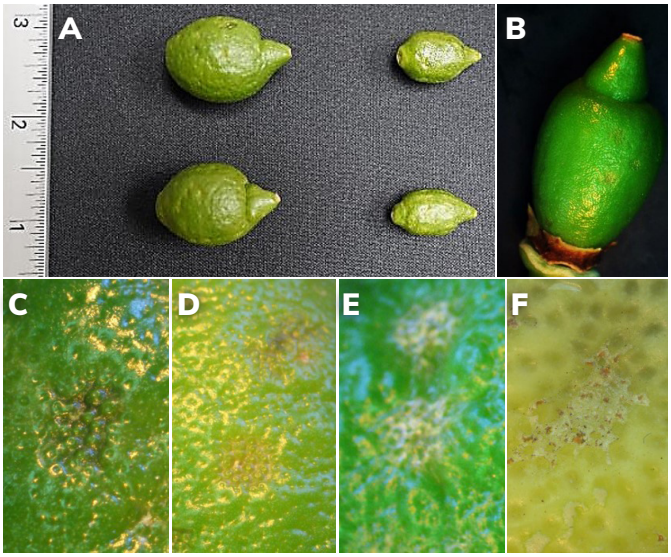

Figure 2. Occurrence and progress of lemon pitting in Lisbon lemons through the growing season. A and B fruit affected at early stages of development. C-F development of the affected area through the season from petal fall to harvest. *Photo by Ashraf El-kereamy.*

located in the Arvin area of Kern County, three in Porterville and eight in Ivanhoe and Orange Cove areas. Two of these fields belong to the same grower and are treated similarly; however, one exhibits a higher rate of damage compared to the other. The survey results showed that the damage is occurring on Lisbon lemons grown on various rootstocks, with tree ages ranging from 4-70 years. These orchards are planted in different types of soil, and there are no other crops adjacent to them, only citrus species surrounding all orchards under study except for Ranch #1, which has pistachio as an adjacent crop. The topography of the land does not show any specific pattern with symptoms on the fruit. The percentage of damage to the fruit varies significantly, ranging from 5-80 percent. Our data showed that the damage occurs right after petal fall, typically during the first two weeks of May, and appears as a darker depressed spot on the fruit surface. These darker depressed spots develop into pitting by the end of the season (**Figure 2**). Some of the damaged fruit can recover as the season progresses. Investigating the damage and healthy rind revealed that the damage is superficial and limited to the waxy cuticle layer, with no further damage detected in the flavedo or the albedo tissue (**Figure 3**).

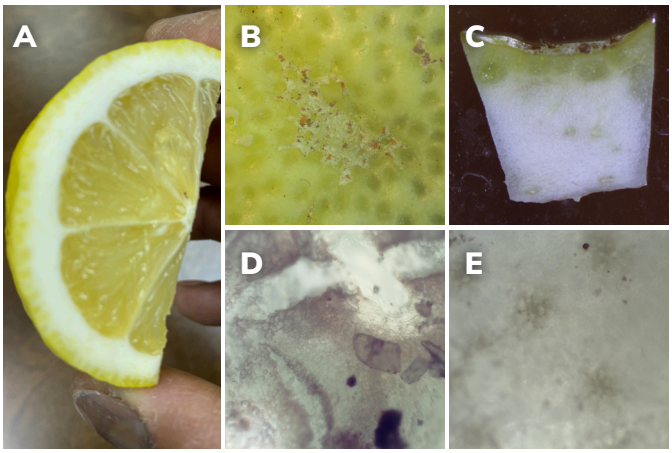

Figure 3. Lemon pitting peel damage appears superficial, with no damage underneath the peel (A, B and C). The cuticle layer looks broken on damaged fruit peels under 10X magnification (D), compared to healthy peels (E). *Photo by Ashraf El-kereamy.*

Biotic and Abiotic Factors

To understand the possible role of insects and pathogens in causing this rind damage, we have been monitoring these orchards continuously with twice monthly field visits/inspections since April 2023 and have installed various insect traps seasonally in all 12 orchards. Review of damage by project entomologists suggests there is no indication of insect damage or signs of insects on the fruit. It is important to note that the damage does not appear to be related to pesticide sprays, since rind damage is seen in all groves, both before and after the petal fall spray. Examination by project plant pathologists revealed no pathogenic organisms. Classical pathology tests and advanced genomic analysis revealed the presence of some epiphytic fungi (fungi on the surface) that are present in branches carrying both healthy and damaged fruit.

We tried to study the pattern of the damage in the orchard and in individual trees to see if there is any correlation between a specific direction in the field or a specific side of the tree and the damage. It does not seem that the damage is associated with any specific direction in the orchard or in the tree. However, we noticed that the damage can be localized in a specific branch on the tree in a clean orchard with no association with any direction. Examination of these branches revealed a discoloration in the vascular system of these branches, which could be due to other abiotic stress factors that remain under investigation.

We installed 12 weather stations in the 12 orchards included in the study, commencing operations on December 1, 2023. These local weather stations provide hourly data on air temperature, humidity and wind speed. Data from the weather stations will be extracted and analyzed soon. In the fall of 2023, we collected leaf samples for nutritional analysis. Our data showed that all nutrients are within the optimal level; however, phosphorus levels were at the threshold for deficiency in most of the orchards under study (**Table 2**). The leaf phosphorus level varied from 0.11 to 0.13 percent, which is only slightly higher than the cut-off point for phosphorus deficiency. Phosphorus is crucial for plant growth and development and is involved as a key factor in producing energy molecules. Phosphorus also affects cuticle thickness and helps plants manage temperature stress. Phosphorus deficiency in citrus results in deformed fruit and rough rinds. Our observation showed that, most of the damaged fruit had rough rinds, and we currently are working on getting more leaf analyses during the season to confirm this observation and to investigate involvement of the nutrients in the occurrence of damage.

At harvest, during December 2023 and January 2024, we collected 800 fruit randomly from all over the orchard and used

Table 2. Fall leaf nutrient content in the orchards under study and the damage percentage as determined during harvest of the 2023 season.

	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Zn (ppm)	Mn (ppm)	Fe (ppm)	Cu (ppm)	B (ppm)	Na (%)	Damaged fruit (%)
Ranch # 1	2.47	0.12	0.72	4.51	0.28	190.3	28.7	72.3	136.7	148.3	0.01	1
Ranch # 2	2.27	0.13	0.92	5.16	0.27	24.5	26.0	123.0	12.3	187.3	0.00	21
Ranch # 3	2.25	0.11	0.93	5.15	0.26	123.3	29.7	119.0	83.0	94.7	0.00	26
Ranch # 4	1.80	0.11	1.03	4.12	0.32	195.3	52.0	78.3	127.3	148.7	0.01	42
Ranch # 5	1.86	0.10	0.58	5.40	0.40	167.7	68.7	196.3	22.0	31.6	0.00	6
Ranch # 6	2.16	0.10	0.70	4.77	0.34	115.0	27.3	83.7	85.3	77.0	0.00	8
Ranch # 7	2.04	0.10	0.80	4.87	0.31	118.9	53.7	162.7	104.7	122.7	0.00	23
Ranch # 8	2.08	0.13	0.61	5.33	0.32	301.0	80.7	121.7	132.3	92.7	0.00	0
Ranch # 9	2.00	0.12	0.61	3.46	0.39	134.0	19.0	87.7	88.3	57.2	0.01	3
Ranch # 10	2.10	0.11	0.73	5.01	0.38	135.0	12.0	57.3	114.0	149.7	0.01	0
Ranch # 10B	2.34	0.11	0.59	5.35	0.34	121.7	17.0	56.7	107.0	111.7	0.01	2
Ranch # 11	1.93	0.12	0.57	3.65	0.37	25.6	30.3	96.3	10.0	65.0	0.01	0
Optimum range	2.6-2.8	0.12-0.21	0.7-3.6	3.0-5.5	0.26-0.60	25-200	25-300	60-200	5.0-40	31-300	<0.16	---

them to measure the percentage of the damage, which has varied among these orchards, ranging from none to 40 percent.

We have been continuing to monitor these orchards during the 2024 season; however, we are visiting the orchards more frequently to collect sticky traps for insect monitoring Additionally, we have started field experiments to study the effect of nutritional, hormonal or stress mitigators in three orchards that showed a high percentage of damage during the 2023 season. Treatments include gibberellic acid treatments at a low rate of 10 ppm – a treatment that could have a positive effect on improving rind quality and reducing pitting without delaying fruit maturation. Other treatments include a group of chemicals that can make the fruit more resilient to environmental stress, such as Vapor Gard®, Parka®, Haven® and Silicon. All treatments were carried out per manufacturers' recommendations starting at the petal fall stage. The three orchards receiving additional treatments are located in Arvin, Ivanhoe and Orange Cove, covering the area where the damage was observed. These data will be available by the end of the 2024 season and will be communicated in coordination with the CRB.

Current Finding Conclusions

Lemon pitting issues seem to be localized in Tulare and Kern counties and are only observed in Lisbon lemons grafted on various rootstocks. The damage is initiated just after petal fall in May, and the damaged area on the fruit surface becomes depressed and the wax layer breaks, causing the pitting symptoms. We are monitoring 12 orchards for insect populations, pathogens, nutrients and environmental conditions throughout the season to determine the cause of the issue. Additionally, we have conducted some field applications to study their effect on the percentage of the damage. From our field observations, it seems that significant pruning after harvest had some positive effect, though we are working to confirm this observation. It is worth noting that we are not excluding any factors that could cause this pitting – including insects, physiological or environmental causes. It is possible that changes in the environment (e.g., cold weather during early fruit development) or cultural practices (e.g., heavy oil applications) have made the fruit of the Lisbon variety more susceptible to other factors, causing this issue to emerge.

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References

Mayorquin, J.S. and M. Klein. 2023. Lemon Pitting: A recurring issue in the San Joaquin Valley. *Citrograph* 14(4):34-36.

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