Ganoderma butt rot in California almonds

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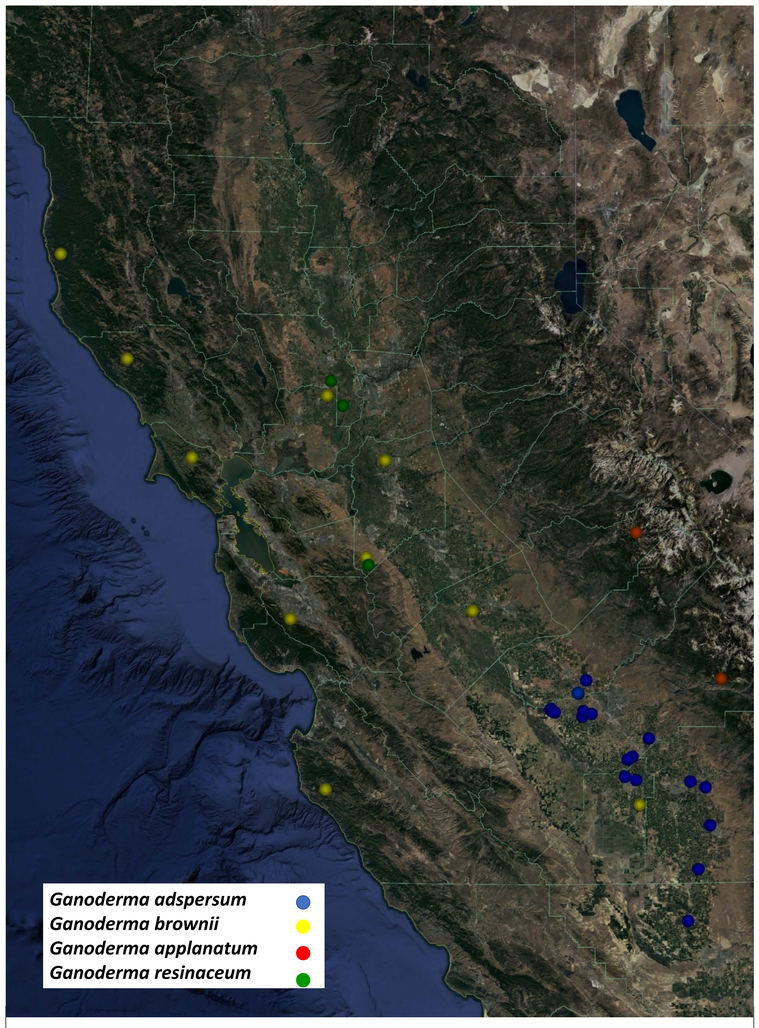


Figure 1. Geographic distribution of *Ganoderma* spp. collected during our surveys.

Introduction

- Butt rot is the most poorly understood of the wood decay types associated with almond and perhaps the most important.
- Windfall related to butt rot is one of the factors limiting almond orchard age to 20-25 years.
- Butt rot has long been known in California orchards, but was usually considered a problem of older orchards often associated with weak or already diseased trees.
- Surveys for wood decay in almond orchards began in late 2015, and identified *Ganoderma* species as the primary cause of decay in windfall trees.

***Ganoderma* species in almond**

G. brownii and G. lucidum (resinaceum)
- •Endemic to CA
- •Occur sporadically throughout orchard
- •Generally non-aggressive on healthy trees

G. adspersum
- •Previously unknown in CA and North America
- •Able to overcome tree response
- •Infection incidence tends to be high
- •Orchards as young as 6
- •Known range is limited
- •Potential to spread

Figure 3 above. From left. Windfall caused by *Ganoderma* butt rot. Active *Ganoderma adspersum* conk, notice bright white edge and reddish spores covering top surface. Inactive conk and trunk symptom indicated by red arrow.

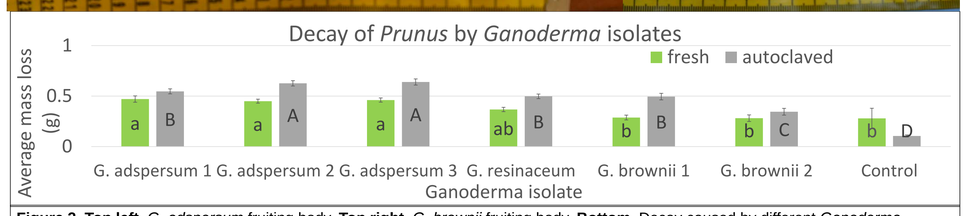
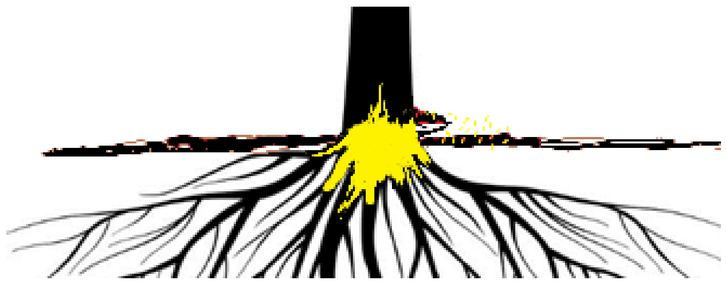


Figure 2. Top left. *G. adspersum* fruiting body. **Top right.** *G. brownii* fruiting body. **Bottom**. Decay caused by different *Ganoderma* isolates 12 weeks after inoculation. Lower case letters represent Tukey's grouping for fresh wood blocks, and uppercase letters represent Tukey's grouping for autoclaved wood blocks. Different letters indicate a significant difference.

Ganoderma Butt Rot

- Butt rot fungi decay the tree from the bottom up and from the inside out and often cause no obvious external symptoms on the host. See image below.
- Reduce structural stability resulting in windfall.
- Requires wounding
- Signs and symptoms include windfall trees, *Ganoderma* fruiting bodies,flat strip of bark on tree (Figure 3).
- Other symptoms may include shallow rooting, leaning trees and loss of vigor.



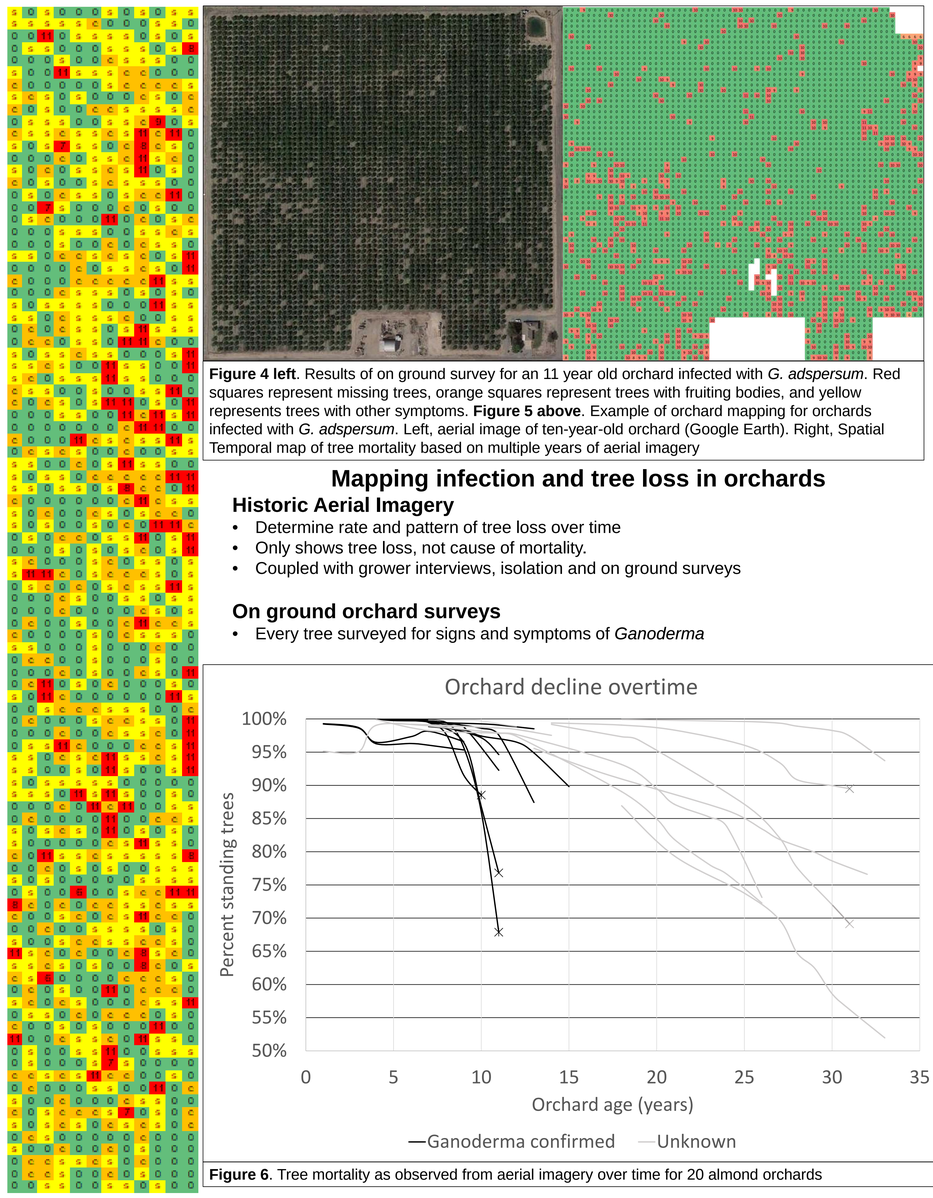


Figure 4 left. Results of on ground survey for an 11 year old orchard infected with *G. adspersum*. Red squares represent missing trees, orange squares represent trees with fruiting bodies, and yellow represents trees with other symptoms. **Figure 5 above**. Example of orchard mapping for orchards infected with *G. adspersum*. Left, aerial image of ten-year-old orchard (Google Earth). Right, Spatial Temporal map of tree mortality based on multiple years of aerial imagery

Mapping infection and tree loss in orchards

Historic Aerial Imagery

- Determine rate and pattern of tree loss over time
- Only shows tree loss, not cause of mortality.
- Coupled with grower interviews, isolation and on ground surveys

On ground orchard surveys

- Every tree surveyed for signs and symptoms of *Ganoderma*

Figure 6. Tree mortality as observed from aerial imagery over time for 20 almond orchards

Inoculum sources

Spores

- Somatic compatibility pairings of isolates from infected trees, suggest that spores are main source of inoculum.
- An average sized *Ganoderma* fruiting body can produce more than a trillion spores in a year.
- Sporulating fruiting bodies have been observed year round in orchards

Infected tissue

- Test of inoculum survival in soil reveal *G. adspersum* remains viable within infected tissue after seven months buried in the soil.
- Survival rate decreased with decreasing size of infected material.

Figure 6. Sporulating *G. adspersum* fruiting body. Note rust colored spores on and around fruiting body.

Harvest most likely drives infection and spread

- Shaking results in wounding on trunk and in roots at or below the soil line.
- Sweeping and pickup operations help to disperse spores throughout orchard and neighboring blocks.
- Irrigation and rain help percolate spores into soil.
- Moisture hastens spore germination and infection.

Acknowledgements

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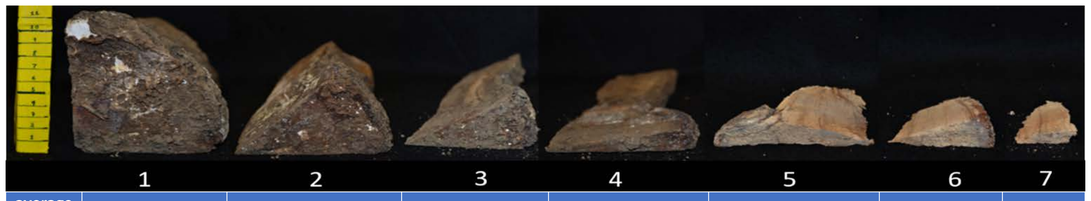

average volume (cm^3)	1820	910	455	228	114	57	28
recovery at 7 months	50%	36%	25%	21%	4%	0%	0%

Figure 7. Stump pieces colonized with *G. adspersum* following seven months buried in the soil. **Table 1.** Re-isolation percentage of *G. adspersum* from colonized pieces of stump following seven month buried in the soil.

Root stock susceptibility to decay

- All known infections of *Ganoderma adspersum* have been grafted on Nemaguard peach rootstock.
- Preliminary laboratory decay studies suggest that varieties with plum parentage are most easily decayed while those with almond parentage are least easily decayed.
- Laboratory decay studies with dead wood, are not representative of a living tree in the field
- Other characteristics that may affect ease of wounding including: bark thickness, malleability, and healing time are all being investigated.

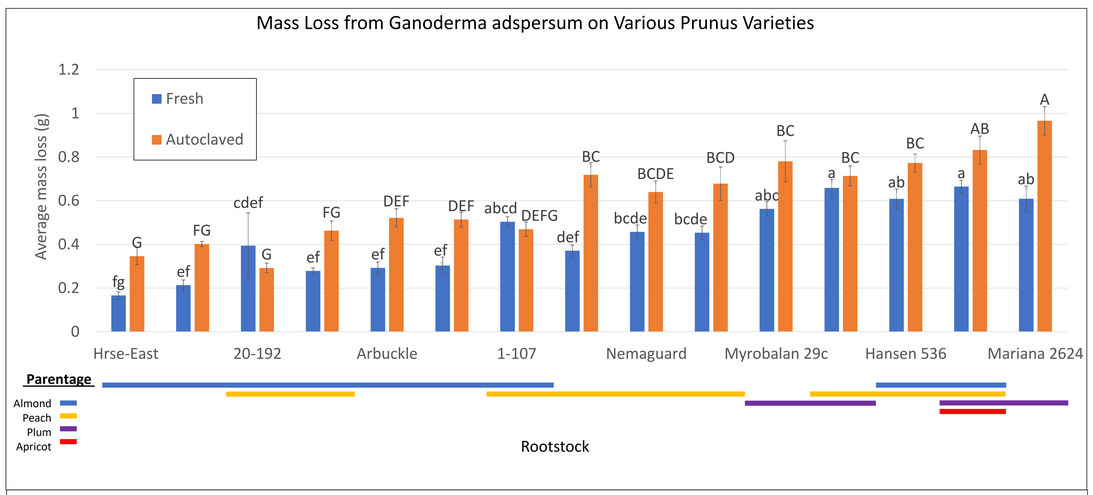

Figure 12. Average decay among different Prunus rootstocks three months after inoculation. Lower case letters represent Tukey's grouping for fresh wood blocks, and uppercase letters represent Tukey's grouping for autoclaved wood blocks. Different letters indicate a significant difference.