Project Number 75-Q

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Department of Plant Pathology
University of California, Davis
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TITLE: Hull rot of almonds

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I. OBJECTIVES:

The last extensive studies on hull rot disease of almond were made in 1961. Studies at that time were on the causes of the disease and toxins produced by Rhizopus circinans. Current studies are on 1) identification of the specific hull rot pathogens in almond-growing regions, 2) determination of environmental factors which favor infection and disease development and 3) disease control.

II. ABSTRACT:

Crop losses from hull rot are related to direct loss of almond nuts which cannot be harvested, extra labor to remove "sticktights" during the winter, and loss of fruiting wood from toxins. The loss of fruiting wood can be as much as 25%. Navel orange worm overwinters in the "sticktights."

The fungi Rhizopus and Monilinia are the causal agents of hull rot. Rhizopus is identified by the black growth usually found within opened hulls and growers have called it "bread mold." Rhizopus hull rot was found throughout the almond-growing areas and more than one species was isolated. Monilinia is known to the fruit industry as the brown rot organism. Monilinia hull rot caused by M. laxa was more prevalent in the Sacramento Valley than in the San Joaquin Valley orchards. Further studies are needed to determine which hull rot organisms are most important in the various almond-producing areas. Almond varieties vary in susceptibility to hull rot pathogens. The most susceptible are varieties such as Nonpareil, Jordanolo, and IXL, followed by Merced, Ne Plus Ultra and Thompson. The varieties such as Mission, Davey, and Drake have shown little to no hull rot or twig blight. Vigorously growing orchards providing less air movement appeared to have more hull rot. Although free moisture is required for germination and growth of Rhizopus and Monilinia, no differences were observed between sprinkler-irrigated and furrow-irrigated orchards. The first infections were observed in split hulls of fruits with aborted embryos. Infection appeared to start on the outer shell of the nuts and quickly moved into the hulls. This was followed by movement of toxins into twigs and possibly branches and death of these parts.

Disease control will be difficult because hulls do not split all at once and split hulls are the infection sites. Any cultural modifications to increase air movement will help reduce hull rot, especially in orchards with large vigorous trees with dense foliage. Chemical sprays during hull split are being investigated. Regardless, the control measure will be a "Hard Nut to Crack."

III. EXPERIMENTAL PROCEDURE:

Field research was done in Fresno County at the Freeman and Boos orchards; Kearney Horticultural Field Station; in Yolo County at the University of California experimental orchard; and in Butte County at the Knottleman orchard. Fungal isolations were made from soil, twigs, and hulls. Sprays for residue analyses were applied in orchards in Fresno County and harvested almonds were hulled by a commercial operator. Laboratory studies were done in the Department of Plant Pathology laboratory at University of California, Davis.

IV. RESULTS:

Causal organism: Isolations made from the Freeman orchard on July 1, 1975, from 10 twigs showed no *Rhizopus* within the dead tissues and 4 soil samples yielded two isolates of *Rhizopus* which grew at 25 C but not at 36 C. On July 17, isolations from 12 healthy hulls collected from the tree had 6 isolates of *Rhizopus* which grew at 36 C but not at 25 C, and 3 samples from the soil yielded three cultures which grew at 36 C. No natural infections were observed at this time. Inoculations of Nonpareil hulls by first injuring them showed they were susceptible but inoculations of spur and stem gave no infections. On August 5, the first indications of hull rot and twig blight were observed on almonds with aborted embryos. At Freeman, the pathogen isolated was *Rhizopus* while at Knottleman the pathogen was *Monilinia laxa*. At this time 32 apparently healthy fruit were collected from the Knottleman orchard and incubated for one week at 22 C. Twenty-one of the fruit developed *M. laxa* decay and one *Rhizopus* decay. Forty-six apparently healthy fruit were collected from Freeman orchard and incubation showed 10 *M. fructicola* and two *Rhizopus*. By September, hull rot was prevalent in many orchards. On the 6th of September, 100 sticktights at Freeman orchard showed 38% with *Rhizopus*, 9% with *Monilinia*, and 1% *Botrytis* and 52% with no sporulation or indication of infections. The 52% were probably sticktights because they were on shoots killed by the toxin produced from hull rot.

Death of apparently healthy twigs: On June 27, twigs which appeared healthy suddenly started to die. Examination of 44 trees showed 167 new dead twigs giving an average of about 4 twigs per tree. Isolations did not yield fungi which were pathogenic on reinoculation of twigs. These twigs could have been weakened by the toxin the previous year and could not support growth for the following year.

Kill of fruiting wood from toxins: On September 6, three typically diseased trees of the Nonpareil variety were examined for kill of fruiting wood by hull rot; 200 feet of fruiting wood on the lower part of the trees were examined. Of the four quadrants inspected, the northeast corner showed the least amount of dead shoots with 16% killed followed by the northwest corner with 23% and the southeast and southwest corners had 29% killed; in general there appears to be little variation among the four corners of the tree except where more nuts were present more hull rot was observed.

Susceptibility of almond blossoms to *M. laxa*: There is the question as to whether all varieties of almonds should be sprayed to reduce the *M. laxa* inoculum in the orchard. Inoculation tests were made by injection of spores of *M. laxa* into unopen blossoms. Evaluation of blossom blight gave the following results:

Variety	Number Inoculated	Percent blighted
Drake	69	89.9
Ne Plus Ultra	46	80.4
Nonpareil	76	68.4
Jordanolo	32	43.8
Mission	110	54.5
Davey	53	32.1

These data show that all varieties tested, including Mission and Davey, are susceptible to blossom blight. Recent observations show considerable problem with *M. laxa* blossom blight on the Mission variety in both the Sacramento and San Joaquin valleys.

Susceptibility of almond hulls to Rhizopus and Monilinia: Late season inoculations of hulls were made on the Merced and Mission varieties on the Davis Campus. Table 1 gives the data on percent infection of hulls, peduncle and twig symptoms. *M. fructicola*, *M. laxa*, and *R. stolonifer* infected hulls of Merced and Mission variety at hull split stage but the fungus invaded the peduncle and caused symptoms only on the Merced variety.

Control: Chemical control program with Botran and Benlate was started by evaluating these chemicals on harvested hulls. Table 2 shows promise of using Botran for control of *R. stolonifer* and Benlate for *M. fructicola*. *M. laxa* control requires reduction of inoculum during the winter so test plots have been set up at the Boos and Freeman orchards in Fresno and Knottleman orchard in Chico. In these tests the effect of sodium pentachlorophenate will be evaluated against *M. laxa*, *M. fructicola* and *Rhizopus*.

In anticipation that chemicals could be the solution to disease control, almond trees were sprayed with chemicals and nuts were shelled commercially. Samples of kernels, shell, and hulls are presently being separated for residue analyses of Botran and Benlate. If no chemicals are detected in the kernels, larger-scale spray tests are anticipated by combining the fungicide with the insecticide spray for application at hull split.

V. DISCUSSION:

Judging from the data on the causal agents, hull rot control measure must be directed at *Monilinia laxa*, *M. fructicola*, and the *Rhizopus* species. The *Monilinia laxa* control could possibly be solved by use of a dormant fungicide plus a blossom spray. The *M. fructicola* could possibly be controlled by use of Benlate during hull split. Survey of *M. fructicola* spore dispersal should be made by sampling spores in the orchards as well as harvesting almonds during the growing season and incubating them.

The benefit to be obtained for the growers would be to determine the varietal differences in susceptibility to hull rot, orchard or environmental conditions conducive to disease, and chemical or cultural control measures. This information is required for growers to plan for new orchards as well as to prevent hull rot.

TABLE 1. Susceptibility and kill of twigs by late season inoculation of almond hulls on Merced and Mission varieties

Variety and pathogen	Percent infection or disease[1] Hull	Peduncle	Twig symptoms
MERCED			
M. fructicola	24	22	8
M. laxa	24	20	12
R. stolonifer	17	24	6
MISSION			
M. fructicola	18	0	0
M. laxa	16	0	0
R. stolonifer	11	0	0

[1]Three replications of 10 fruits with hulls just beginning to split were inoculated with 70,000 spores/ml with M. fructicola, 100,000 spores/ml with M. laxa, and 232,000 spores/ml with R. stolonifer. Inoculations were made by injection into the area between the hull and shell on October 7 and data taken on October 15.

TABLE 2. Effect of Botran and Benlate and their combination on suppression of R. stolonifer and M. fructicola development on detached hulls.

Chemical treatment lb/100 gal spray: Active Botran	Active Benlate	Percent infection from[1] R. stolonifer	M. fructicola
2/3	-	19	17
1.0	-	0	42
1 1/3	-	0	50
	0.5	-	0
	0.25	-	0
	0.125	-	44
2/3	0.5	0	0
2/3	0.25	6	0
2/3	0.125	25	0

[1]Four replications of 4 hulls in each except the Botran evaluation of M. fructicola had three replications of 4 hulls. Inoculated non-chemically treated hulls all came down with respective disease.

ALMOND HULL ROT SURVEY

Estimator____________________ Date________________ County__________

Grower: (Name, address and location)

Name ____________________

Address ____________________

City ____________________

(st) (st) ↑N

(indicate distance in miles)

Variety	Stage of Maturity (refer to chart on reverse side)	Anticipated harvest date	Yield per acre
1. Nonpareil	0 1 2 3 4 5 6 7 8 9	______	______
2. ______	0 1 2 3 4 5 6 7 8 9	______	______
3. ______	0 1 2 3 4 5 6 7 8 9	______	______

DISEASE & PATHOGEN OR COMPLEX

Variety	Percent hull rot caused by:[1] Rhizo-pus	Moni-linia	R & M	Others unknown	Inches of killed bearing wood/50 ft of fruiting area/tree quadrant[2] N	E	S	W
1. Nonpareil								
2. ______								
3. ______								

[1]Collect random samples of 100 fruit picked from the tree or ground on 1-3 trees of each variety, evaluate for disease and send same samples to: J. M. Ogawa, Department of Plant Pathology, University of California, Davis 95616 for isolations.

[2]Count is most easily taken by 2 people. One evaluator measures and calls out fruiting and diseased area while the other records total footage on counter and records inches of diseased on form. Surveys during the winter should include numbers of scaffolds killed and attacked by insects.

History of hull rot in orchard: Chronic______ Occasional______ 1st time______

Percent navel orangeworm 1. Nonpareil ______ 2.______ 3.______

Cultural conditions:

Tree: Age______; Rootstock______; Planting distance______

Vigor of orchard: Very______ So-so______ Weak______

Crop density: Heavy______ Medium______ Light______

Fertilizer rate: ______ lbs. of ______ per acre

Irrigation frequency (June through August): 2 wks______ 3 wks______ 4 wks______

Irrigation method: Flood______ Furrow______ Sprinkler______

Soil characteristics: Deep______ Shallow______ Sandy______ Medium______ Heavy______

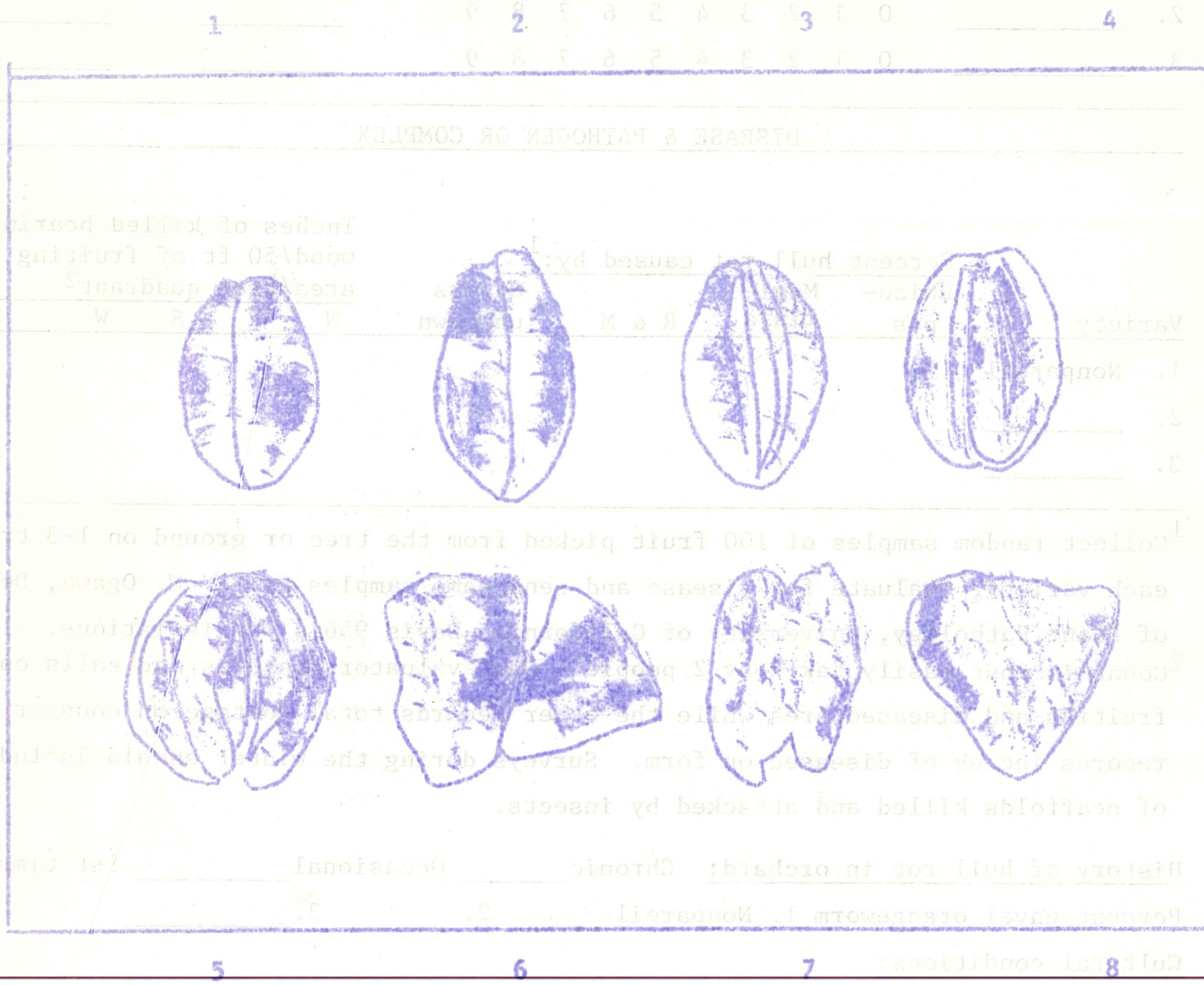
Rain - time & amount: July______ August______ September______

Other diseases or pests: (Circle or write in)

Blossom brown rot Shot hole Scale insect ____________

Leaf blight Scab Borers ____________

ALMONDS REPRESENTING MATURITY CLASSES
BASED ON DEGREE OF HULL DEHISCENCE AND DRYING



Class 0 = premature dehiscence because of aborted embryo

Class 9 = almonds collected after normal harvest

Form prepared by Browne, Ogawa and Gashaira (1975)