76-Q2

Department of Plant Pathology
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TITLE: HULL ROT OF ALMONDS

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1. OBJECTIVES:

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

2. INTERPRETIVE SUMMARY:

Crop losses from hull rot are related directly to loss of almond nuts which cannot be harvested, extra labor to remove "sticktights" during the winter, and loss of fruiting wood from toxins. At this time no effective control measures are available.

The disease is caused by two fungi, the more common one is Rhizopus which is identified by the black growth usually found within opened hulls and some growers have called it "bread mold" and the second is Monilinia, the causal organism of blossom blight on almonds and apricots (Monilinia laxa) and of peach blossoms and fruit brown rot (Monilinia fructicola). Infections of almond hulls do not take place until hull split. Survey of orchards at hull split during 1975 and 1976 showed Rhizopus hull rot in all of the major almond-growing regions but somewhat less in Kern, Yolo, and Colusa counties. Hull rot caused by the brown rot organisms is less prevalent but M. fructicola infections were widespread in 1976 especially in the Central San Joaquin Valley after the August rains. Differences in varietal susceptibility have been shown with the paper-shelled variety most susceptible and the hard-shelled varieties least susceptible. As an example, NonPareil, Jordanolo, and IXL are very susceptible followed by Merced, Ne Plus Ultra, and Thompsons moderately susceptible and the Mission, Davey, and Drake showing little to no disease.

Moisture is required by both of these fungus pathogens for germination and infection but no correlation has been established from a single year's (1976) environmental studies that cultural programs such as irrigation and fertilization enhances disease development in the orchard. Studies in paired plots with previous histories of high and low hull rot showed that temperatures between the orchards were similar. Orchards with low disease incidence in fact had longer periods of relative humidity over 90% in Chico and Fresno, yet the reverse occurred in Turlock. Regardless, the moisture periods, relative humidity of over 90%, in both the low and high disease orchards were adequate for hull rot to develop.

3. EXPERIMENTAL PROCEDURE AND RESULTS

Survey of almond orchards to establish the pathogens involved.--Orchards in both the Sacramento and San Joaquin valleys were observed for hull rot, samples of 100 almonds were collected and the species of fungi involved evaluated. A sample evaluation form is attached. Farm advisors in the various counties participated in the survey program.

A brief summary is provided about the survey listing the numbers of orchards visited, the average percent of fruiting wood killed per tree, the fungus involved, and the differences in cultivar susceptibility.

Butte County.--In three orchards between Durham and Chico, the Non Pareil cultivar had the most hull rot with about 4% of the bearing wood killed. The fungi identified were primarily Rhizopus, Monilinia, and a combination of both. Hull rot fungi were found on other cultivars such as Ne Plus Ultra and Thompson yet very little bearing wood was killed. Another survey is needed to determine the relative importance and percent hull rot caused by the brown rot fungi compared to the Rhizopus species. Trees adjacent to avenues in the orchard were more severely diseased which could mean that Rhizopus spores or mycelium are carried in soil particles.

Yolo County.--Four Nonpareil orchards showed less twig blight than in Butte County with only a trace to 1% fruiting wood killed per tree. The fungus involved was almost all Rhizopus except for one Ne Plus Ultra orchard where Monilinia was found on 17% of the hulls. On cultivars such as Merced, Price, Butte, and Norman twig blight did not occur. Yolo County is an area with less twig blight than other counties and the reasons for this should be further studied.

Stanislaus County.--It is interesting that only two orchards with Nonpareil was included in the survey and these orchards showed high incidence of twig blight. Merced and Ne Plus Ultra cultivars also showed the twig blight. Both Rhizopus and Monilinia were found. The higher incidence of hull rot on the cultivars other than Nonpareil could be related to higher August rainfall in the San Joaquin Valley compared to the Sacramento Valley.

Merced County.--Twenty-five orchards were surveyed in Merced County and serious twig blight was found on Nonpareil, Merced, and Ne Plus Ultra cultivars. Twig blight was as high as 8% in some orchards. Again, both Rhizopus and Monilinia were commonly found.

Fresno County.--Twenty orchards were surveyed in Fresno County and the percent blight of fruiting wood was estimated to be as high as 15%. The cultivars affected were Nonpareil, Merced, and Ne Plus Ultra with Thompsons also showing considerable hull rot. Even a few Rhizopus hull rot was shown on the Mission cultivar but twig blight did not occur.

Kings County.--Only one orchard was surveyed and hull rot was minimal with only a few twigs blighted. Only Rhizopus was found.

Kern County.--Three orchards were surveyed. Only a trace of hull rot was observed except Rhizopus was found on hulls that had become wet and lying on the ground. Monilinia was not found.

In summary, the survey showed that hull rot is most important on the Nonpareil cultivar and in 1976 severe infections were observed on Ne Plus Ultra and Merced. With two unseasonal rains some hull rot was observed on all cultivars but twig blight was not serious except on Nonpareil, Ne Plus Ultra, and Merced. Continuation of this survey is needed to establish why some orchards have more disease than others and why toxins move into the twigs and cause blight. Water stress to trees was not indicated in tests made by Lonnie Hendricks, Farm Advisor, Merced County. Also, the effect of blighted twigs and leaves on death of branches must be assessed.

Susceptibility of hulls to infection by Rhizopus and Monilinia.--Among the three paired locations (Table 1) with previous high and low incidences of hull rot, no marked differences were noted in susceptibility of hulls to the two hull rot organisms. The percent infection was higher when Rhizopus inoculations were made into split hulls while with Monilinia, no differences were shown. Both M. fructicola and M. laxa were equal in their ability to infect hulls and cause twig blight.

Thus the differences in degree of hull rot from natural infections could be related to factors other than host resistance.

Environmental influences.--Temperature and relative humidity were monitored in paired orchards in three almond-growing counties. The paired orchards were similar in most respects except one had high and the other low disease incidence (Fig. 1, 2, and 3).

Total hours of moisture were different in the paired orchards as noted in Table 2, but the temperatures were approximately the same. For example, Montgomery, 302 hours, 62°F while Birdseye, 435 hours, 64°F.

Disease incidence was low until after the mid-August rain. Orchards with a history of high disease developed significantly more hull rot than orchards with low disease.

Wind velocity and soil moisture data were taken in one paired orchard in Merced County. Tensiometer readings indicated adequate moisture in both Suguira north and south orchards. Anemometer readings indicated very little wind during the season and showed no differences between the north and south orchards.

Conclusion.--Temperatures were very similar but moisture periods were different in the paired orchards. Orchards with low disease incidence had longer moisture periods except for Suguira south. It appears that moisture periods in both low and high disease orchards were adequate for hull rot to develop. Factors other than temperature and relative humidity appear to affect disease development. Inoculum levels and period of infection in the orchard may be the determining factor in disease levels.

Suppression of Monilinia fructicola inoculum.--Early and midwinter applications of sodium pentachlorophenate (SPCP) and benomyl plus oil were applied in large scale plots replicated four times to determine if either chemicals would reduce the population of M. fructicola and whether SPCP would reduce navel orange worm population. Test plots were sprayed by Todd Browne, Fresno County Farm Advisor, and disease data read by J. M. Ogawa. Navel orangeworm data was obtained by Dr. Dick Rice. The plot was located in southern Fresno County in the Otis Freeman orchard. Varieties in the plot were Merced, Nonpareil, and Mission. Counts of hull rot caused by M. fructicola were taken before the rain in August and again after the rain. No differences in the amount of hull rot caused by brown rot were shown. SPCP was also applied in the Boos orchard in Fresno County near the city of Sanger and in the Nottlemann orchard in Butte County near the city of Chico. In these two plots, the chemical was applied to control M. laxa blossom blight and hull rot. Neither plot developed sufficient blossom blight to obtain control data.

Judging from this data and other information on prunes, the effect of benomyl and oil or the use of sodium pentachlorophenate for suppression of M. fructicola inoculum is questionable. Yet conclusions on the efficacy of SPCP or benomyl cannot be drawn because of insufficient information on inoculum source.

Control with Botran.--Koepsell and Rough (unpublished data) showed that two Botran applications during the summer were promising in the control of Rhizopus hull rot. Residue analyses showed the presence of Botran in the meats from a single Botran application after hull split. During 1976, Botran was applied to obtain performance data as well as residue samples. The Upjohn Company was interested in obtaining animal feeding studies to permit the use of Botran-treated crops for animal feed.

Another Botran spray application plot was set up at the Sugiura orchard in Turlock after considerable hull rot had already developed. This plot was set up to determine if further hull rot can be stopped and if twig blight could be reduced from such sprays. Table 3 gives the results. Sprays at this time significantly increased the Rhizopus rot but reduced brown rot. This indicates that protective sprays for hull rot are ineffective when applied after disease develops.

The effectiveness of Botran as a protective spray before infection was tested in three locations. Table 4 shows that Botran sprays applied at hull split reduces twig blight caused by hull infections by Rhizopus and Monilinia.

4. DISCUSSION:

Discussion and summary is included with the section on results. Studies during the last 2 years have related to understanding the disease and providing information necessary to give direction to plans for control measures. Judging from data obtained on environmental influences, cultural methods of control do not appear feasible nor does information on host susceptibility. Thus control measures should be directed at protecting the hulls during the time of hull split from Rhizopus and Monilinia infections. The chemical Botran which is registered for use as postharvest

treatment on stone fruits, but not on almonds, have provided some benefits and will be tested under large scale field tests. Also, judging from the variability in hull rot between orchards the inoculum levels and their origins needs explanation. Field sprays will be tested in attempts to reduce the population of fungal spores of Rhizopus and Monilinia as well as other fungal spores including that of Aspergillus.

5. PUBLICATIONS:

Browne, L. Todd, J. M. Ogawa, and B. Gashaira. 1977. Search continues for almond hull rot control. California Agriculture 31(1):16-17.

Table 1. Susceptibility of almond hulls to infection from Rhizopus and Monilinia before and after hull split.

Orchard[a]	Organism[b] Hulls	Percent infected		Percent infected hulls showing twig blight	
		Closed	Split	Closed	Split
Freeman	M. fructicola	50	40	73	58
	R. stolonifer	33	80	57	77
Cunha	M. fructicola	30	33	33	62
	R. stolonifer	27	57	57	50
Birdseye	M. fructicola		83		80
	R. stolonifer		37		63
	M. laxa		83		72
Montgomery	M. fructicola		93		75
	R. stolonifer		43		83
	M. laxa		87		90
Sugiura (North)	M. fructicola	90	93	75	71
	R. stolonifer	47	93	50	79
Sugiura	M. fructicola	70	93	54	68
	R. stolonifer	27	67	70	75

[a]Nonpareil trees inoculated before and after hull split.

[b]Inoculated with spore suspension of organisms using hypodermic needle. on July 27, 28, and August 3, 1976, and data taken 21 days later before harvest of crop.

Table 2. Temperature, relative humidity and hull rot in Nonpareil almond orchards.

County/Grower	Total hours above 90% RH	Avg. Temp During Moisture Period °F	Total No. Days Monitored	% bearing wood killed/tree Days evaluated		
Butte						
Montgomery[a]	302	62	70	0.08	0.40	3.14
Birdseye	435	64	70	0.35	0.44	1.15
				8/9	8/17	9/1
Merced						
Sugiura North[a]	352	60	91	0.04	0.06	0.57
Sugiura South	195	59	91	0.05	0.07	0.85
				8/9	8/18	8/30
Fresno						
Freeman[a]	386	63	75	0.06	0.58	1.39
Cunha	457	64	75	0.00	0.17	0.54

[a]History of high disease incidence

Table 3. Control of brown rot and Rhizopus hull rot with fungicides

Treatment	Amount per 100 gal	Percent of hulls Healthy	Rhizopus	Brown rot	Rhizopus and brown rot	Average No. twig blight[b]
Control	--	10	17 C	61 B	12	43 A
Botran	1.3 lb	22	21 B	48 AB	9	41 A
Botran + Benlate + Oil	1.3 lb .5 lb	18	26 A	41 A	15	35 A

[a]Sugiura orchard, Turlock, sprayed 9/14/76 with handgun on Ne Plus Ultra almond (7 replications). Disease at time of spray was 59% healthy, 34% brown rot, and 7% Rhizopus. Stat. Sig. 5% level.

[b]Average number of twig blight per 200 ft of fruiting wood per tree.

Table 4. Control of hull rot with Boran spray applied at hull split on Nonpareil almonds.

Orchard[a]	Number of twigs blighted per 100 ft of fruiting wood	
	Control	Botran spray[b]
Birdseye[c]	56	24
Montgomery	53	36
Sugiura	42	11
Freeman	59	24
Cunha	23	4

[a]Birdseye and Montgomery orchards located in Butte County, Sugiura orchard located in Merced County, and Freeman and Cunha orchards located in Fresno County.

[b]Branches sprayed with spray concentrations of 2 lb. of Botran 75W in 100 gal of water. Each limb sprayed with handgun sprayer. Total fruiting wood on each branch ranged from 12 ft to 30 ft with the total fruit wood in five replications providing about 100 ft of fruiting wood.

[c]Inspection of almond hulls showed that in the control Rhizopus was found in 4.3% and Monilinia on 9.5% of the hulls and in the Botran-treated sample Rhizopus was found in 0.5% and Monilinia in 1.6%.

ALMOND HULL ROT SURVEY

Estimator_____ Date_____ County_____

Grower: (Name, address and location)

Name_____

Address_____

City_____

N

(St)

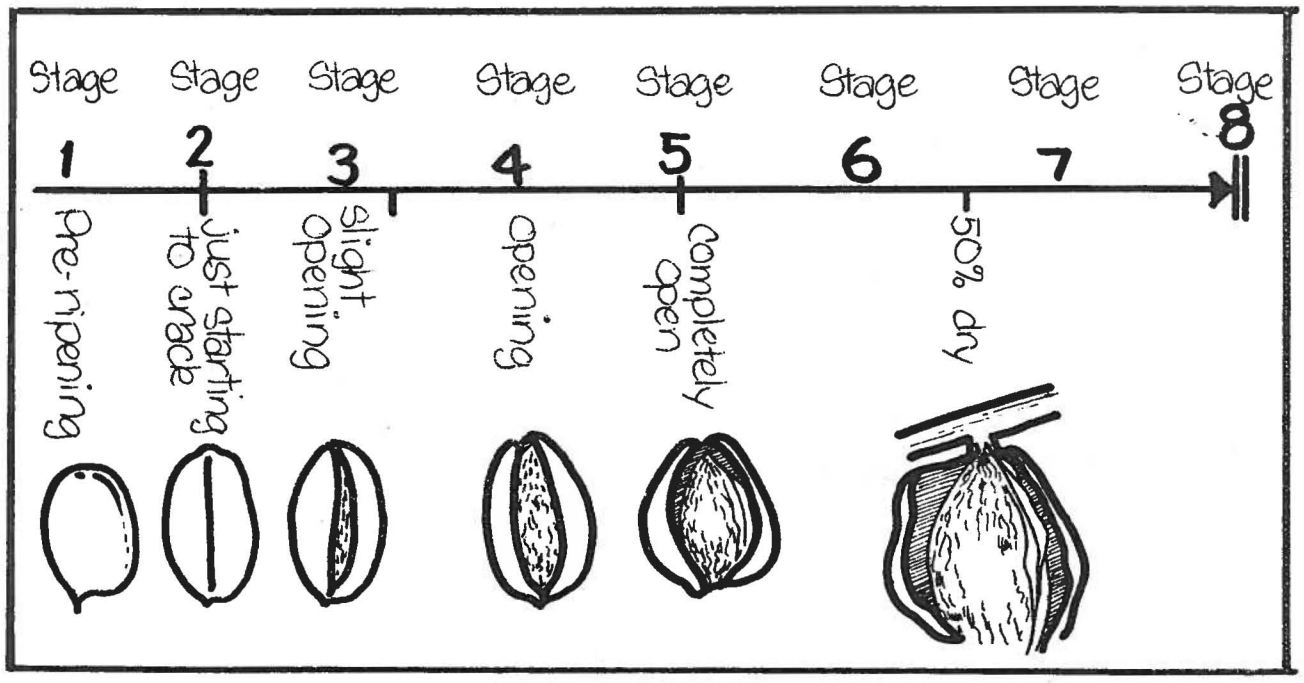
(St)

(indicate distance in miles)

Variety	Stage of Maturity[1] (refer to chart below)	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	_____	_____

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

ALMONDS REPRESENTING STAGES OF MATURITY
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)

TEMPERATURE AND RELATIVE HUMIDITY OF TWO ALMOND ORCHARDS IN BUTTE COUNTY

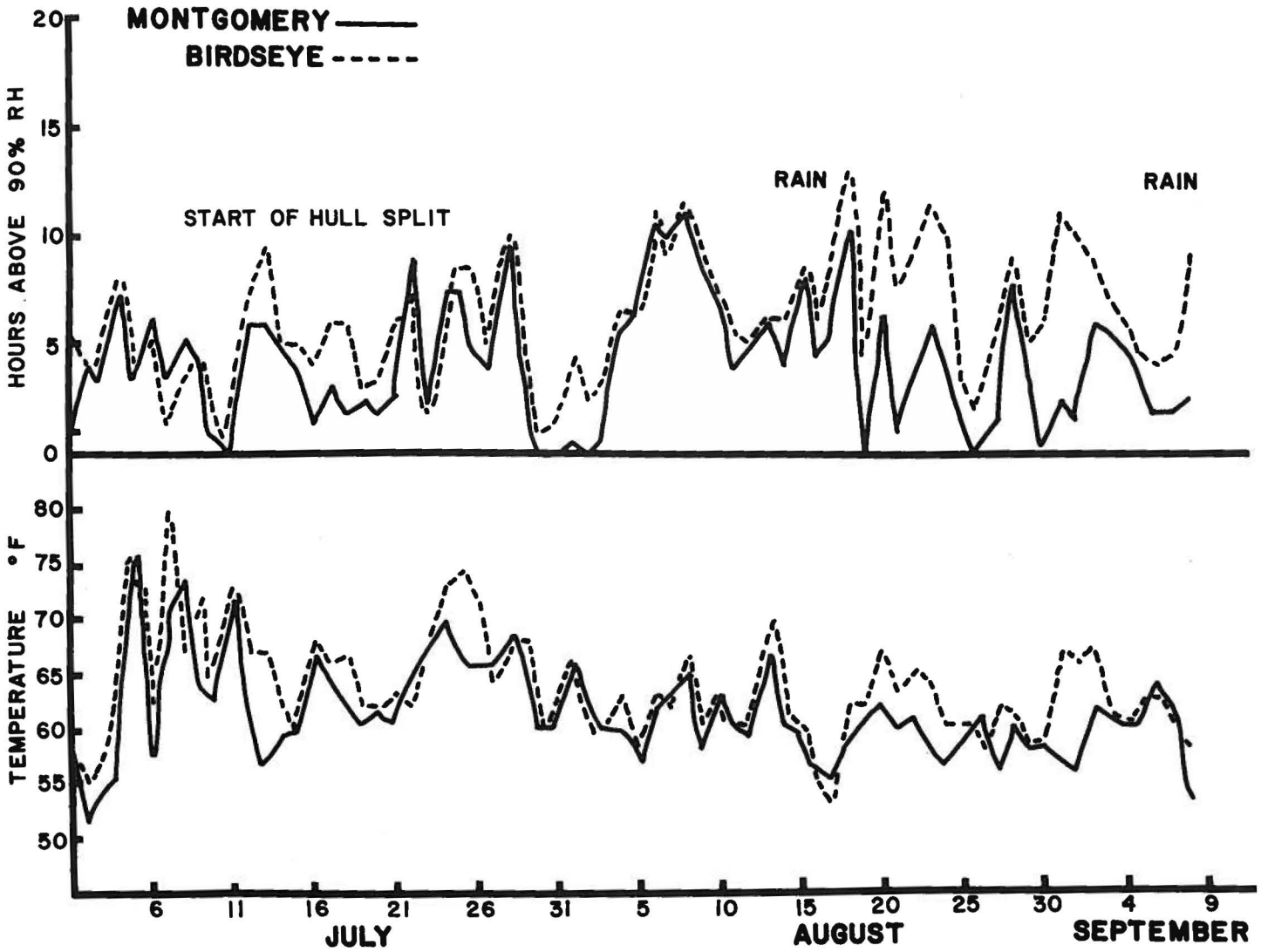


FIG 1

TEMPERATURE AND RELATIVE HUMIDITY OF AN ALMOND ORCHARD IN MERCED COUNTY

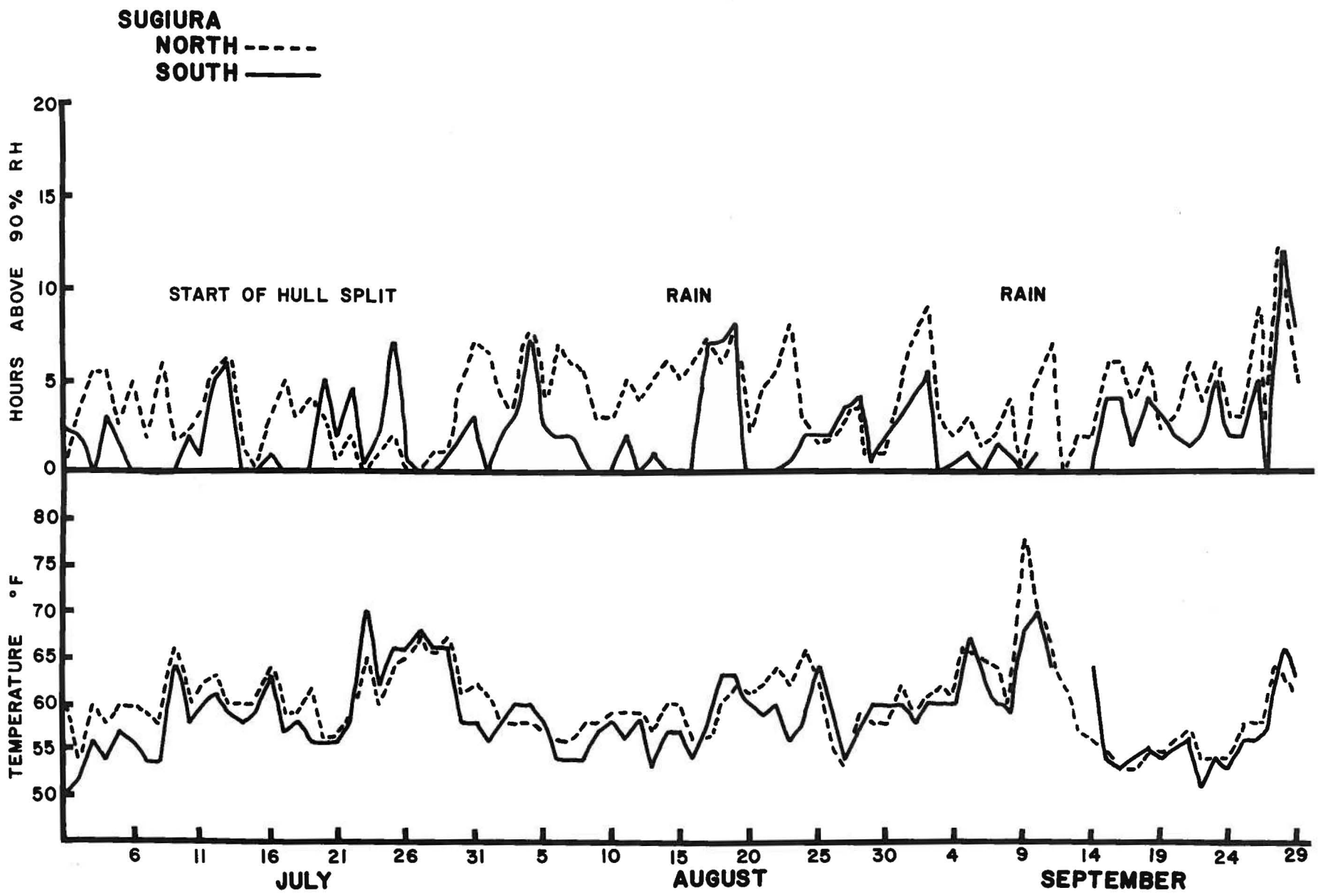


FIG 2

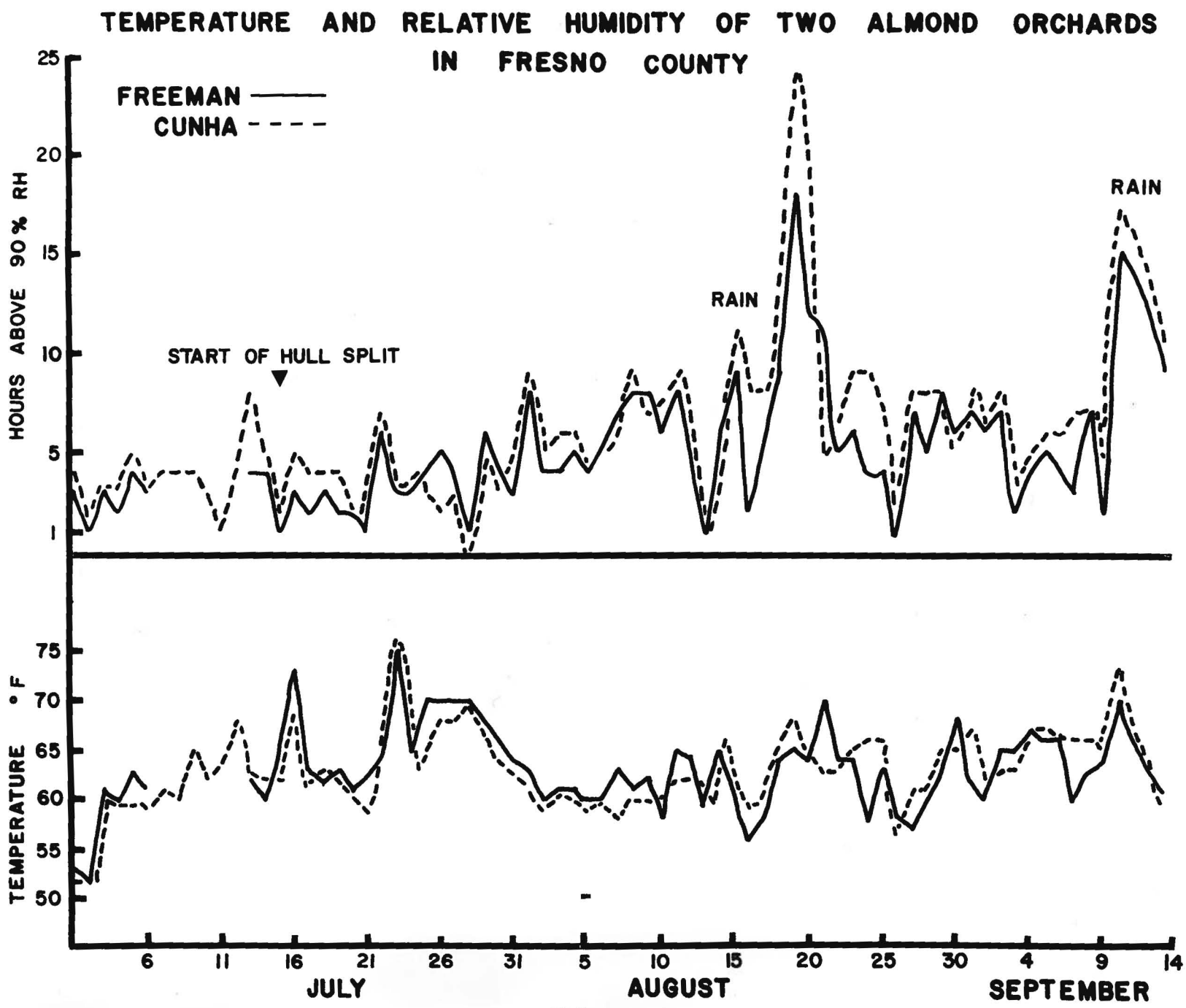

TEMPERATURE AND RELATIVE HUMIDITY OF TWO ALMOND ORCHARDS IN FRESNO COUNTY
FREEMAN
CUNHA
HOURS ABOVE 90% RH
25
20
15
10
5
1
START OF HULL SPLIT
RAIN
RAIN
TEMPERATURE °F
75
70
65
60
55
50
6
11
16
21
26
31
5
10
15
20
25
30
4
9
14
JULY
AUGUST
SEPTEMBER

FIG 3