fected trees were found among the 142 trees tested in the two adjacent plantings. No varietal effects on test results were observed, but no tests were conducted to measure this factor specifically.

Serological diagnosis of citrus viruses has considerable potential; however, further work is needed, even with CLTV, to develop a test procedure with the best combination of speed, sensitivity, simplicity, and reliability. Serological detection of other citrus viruses will not be possible until the necessary antisera to those viruses are developed, and this will be a difficult task for citrus viruses that have not been transmitted mechanically, or which occur in relatively low concentrations in their hosts.

Serological indexing will not replace indexing procedures based on the use of indicator plants, but where applicable, it will provide an attractive alternative. A highly specific test that can be completed in as little as 12 hours, requires only several drops of leaf tissue extract, several drops of antiserum, and a minimum of equipment or facilities, offers many advantages.

ACKNOWLEDGMENTS

The authors wish to acknowledge the technical assistance of R. Whidden and W. L. Dean, Agricultural Research Technicians, Crops Research Division, Agricultural Research Service, U.S. Department of Agriculture, Orlando, Florida.

LITERATURE CITED

1. Ball, Ellen M. 1961. Serological tests for the identification of plant viruses. Am. Phytopath. Soc., Ithaca, N. Y.
2. Childs, J. F. L. [ed] 1968. Indexing procedures for 15 virus diseases of citrus trees. Agriculture Handbook No. 333, ARS, USDA, Washington, D.C.
3. Desjardins, P. R., and J. M. Wallace. 1962. Serological investigations involving the infectious variegation strain of psorosis virus of citrus. Virology 16: 99-100.
4. Fulton, R. W. 1959. Purification of sour cherry necrotic ringspot and prune dwarf viruses. Virology 9: 522-535.
5. Garnsey, S. M. 1968. A citrus crinkly-leaf-type virus recently discovered in Florida. Proc. Fla. State Hort. Soc. 81: 79-84.
6. Martelli, G. P., G. Majorana, and M. Russo. 1968. Investigations on the purification of citrus variegation virus. p. 267-273. In J. F. L. Childs [ed.], Proc. 4th Conf. Internat. Organization Citrus Virol., Univ. Florida Press, Gainesville.
7. Storm, L. W., and R. B. Streets. 1961. Some possible anatomical and serological techniques in diagnosing stubborn disease in citrus. p. 97-100. In W. C. Price [ed.], Proc. 2nd Conf. Internat. Organization Citrus Virol., Univ. Florida Press, Gainesville.
Storm, L. W., and R. B. Streets. 1962. Identification of two citrus virus diseases by serological agglutination. Phytopathology 52: 754 (abstr.)
9. Wetter, C. 1965. Serology in virus-disease diagnosis. Annu. Rev. Phytopathology 3: 19-42.

FROST CONDITIONS AND DAMAGE TO CITRUS DURING TWO CONSECUTIVE RADIATION FREEZES

G. YELENOSKY, G. HORANIC AND F. GALENA

Horticultural Field Station, USDA
Orlando

ABSTRACT

Damage to citrus was different during two consecutive radiation freezes. The more damaging freeze to citrus was characterized by a more favorable condition for frost formation. The beginning of heavy frost conditions was accompanied by a change in wind direction to the S, greater than 90% relative humidity, and frost points equal to temperature of leaves exposed to sky radiation.

INTRODUCTION

It is difficult to determine whether a radiation freeze will or will not damage citrus when active growth is not visible on the trees (2). In this situation, a major problem is whether to heat or not to heat citrus groves. To heat when it is not necessary, or not to heat when it is necessary, is a costly error in judgment. Most of this judgment is based on the extent of minimum air temperatures.

An example of whether to heat or not to heat citrus groves during a radiation freeze occurred during two consecutive freezes this past December in Florida. The trees, in general, were relatively dormant, as a result of previous cool weather. The first freeze developed during the night of December 15-16, 1968. Citrus growers and others evaluated this first radiation freeze to be relatively non-serious to citrus, in that less than 100,000 boxes of fruit were estimated to be lost. The second radiation freeze developed the following night, December 16-17. This second freeze at the beginning appeared no worse than the first freeze. However, this second freeze was later evaluated by citrus growers and others as relatively serious to citrus in that loss of fruit exceeded 6 million boxes (1).

Some growers lit heaters during the first but not the second night. Other growers did not light any heaters at all. Few growers lit heaters during the second night, which apparently was the more damaging freeze to citrus.

This report describes some of the features of the two consecutive radiation freezes.

Methods and Procedures

An automatic data sampler-recorder, which we used to monitor the two consecutive radiation freezes is described in a previous report (3). The first freeze developed during the night of December 15-16, 1968. The following night, December 16-17, the second radiation freeze occurred, During both of the freezes, we accumulated data on tape every ½ hour on different items in a 7-year-old citrus grove near Leesburg, Florida.

We used Beckman-Whitley total and net radiometers to estimate the loss of heat from the grove. The air temperature and the temperature of the outer leaves of the citrus trees were indicated by copper-constantan thermocouples. The dewpoint of the air was indicated by a lithium chloride, gold-grid dewcell. We converted dewpoints to frost points according to standard conversion tables. The percent relative humidity in the air was charted with a hygrothermograph, and an anemometer and a wind vane indicated wind speed and direction approximately 50 feet above ground level. We used field surveys and reports throughout the State to determine the relative seriousness of the two consecutive freezes to citrus.

Results and Discussion

In the analyses of data, we found the extent of conditions favorable for formation of frost to be the major difference between the two consecutive radiation freezes. The most favorable conditions for frost formation developed during the second freeze, which was the more damaging of the two freezes to citrus. The difference in damage is attributed mostly to the difference in formation of frost. A strong, persistent frost condition, in contrast to a weak intermittent frost condition, will increase the formation of ice in citrus fruit, and will result in greater tissue damage and dehydration of fruit (4).

The beginning of serious frost conditions became apparent at approximately 11:00 PM dur-

Table 1. Wind direction and relative humidity during two consecutive radiation freezes

	December 15-16, 1968 1/		December 16-17, 1968 2/	
Time	Wind	RH (%)	Wind	RH (%)
5 PM	SW	43	SW	34
6	W	48	SW	45
7	SW	66	W	50
8	W	72	SW	64
9	W	80	SW	74
10	W	65	SW	90
11	W	66	S	99
Midnight	W	67	S	99
1 AM	W	72	S	98
2	W	74	S	94
3	W	76	S	98
4	SW	75	W	95
5	W	75	NW	96
6	SW	74	N	99
7	W	74	N	97
8	W	75	N	99

1/ Less damaging than 2/ to citrus.
2/ More damaging than 1/ to citrus.

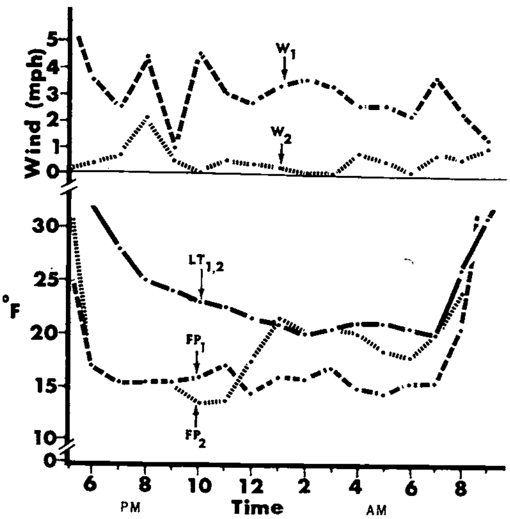

Figure. 1. Wind (W) and frost points (FP) of two consecutive radiation freezes, December 15-16 and 16-17, 1968. The first freeze (W , FP) was less damaging than the second freeze (W_2, PF_2) to citrus. Citrus leaves fully exposed to sky radiation were practically the same temperature during both freezes ($LT_{1,2}$).

Table 2. Features of two consecutive radiation freezes

Item (6 AM to 8 PM)	Dec. 15-16, 1968 1/		Dec. 16-17, 1968 2/	
	Average	Range	Average	Range
Net Heat Loss (BTU hr^{-1} ft^{-2})	71.7	63.7-78.9	66.7	63.7-72.8
Air temperature (°F inside standard weather shelter)	30.0	27.6-35.4	30.8	28.4-37.8
Duration of 28° or lower inside standard weather shelter (hr)	-	2-3	-	0-1
Air temperature (50 ft above ground level)	35.0	33.0-39.4	40.0	35.0-49.8
Temperature of tree (inside the canopy)	29.8	27.0-35.4	30.1	27.2-37.8
Temperature of tree root (3 inches below ground level)	47.4	45.4-50.0	48.4	45.8-52.8

1/ Less damaging than 2/ to citrus.
2/ More damaging than 1/ to citrus.

ing the night of December 16-17. Wind direction changed from the SW to the S, and relative humidity increased to a high of 99% (Table 1). High humidity persisted throughout the night and wind speed remained low, 0 to ½ mph. Favorable frost conditions persisted from 11:00 PM to 8:00 AM the next day. In contrast, favorable frost conditions during the first freeze, the previous night, persisted for less than 1 hour. Wind speeds of 3 mph or more plus relatively dry air (RH 75% or less) helped to lessen frost conditions during the first radiation freeze.

Frost points were lower than the temperature of leaves during the first freeze. During the following night, frost points equaled temperature of leaves at about 11:00 PM, which coincides with the change in wind direction and abrupt increase in relative humidity. Leaves exposed to open sky were essentially the same in temperature during both freezes (Fig. 1).

Minimum air temperatures and net heat loss, plus other features, did not indicate the seriousness of the second freeze, in contrast to the freeze the previous night (Table 2). On the basis of these features only, the first night would be the more serious of the two freezes, whereas, the opposite was true. Under such circumstance, if one did not light heaters during the first night, there was no apparent need to light heaters the second night. Minimum air temperatures alone were misleading. A frost indicator will help to warn of impending damage to citrus during a radiation freeze.

LITERATURE CITED

1. Citrus Summary. 1969. Citrus and Veg. Mag., Vol. 32, No. 6: 18.
2. Cooper, W. C., R. H. Young, and F. M. Turrell. 1964. Microclimate and physiology of citrus: Their relation to cold protection. Agri. Sci. Rev. USDA: 1-15.
3. Horanic, G. E., G. Yelenosky, and W. C. Cooper. 1966. Automatic monitoring and recording of climate factors in cirtus groves. Proc. Fla. State Hort. Soc. 79: 62-65.
4. Levitt, J. 1966. Winter hardiness in plants. In Cryobiology; edited by H. T. Meryman, Academic Press, N. Y.; pp. 495-563.