



Diurnal Fluctuation in Moisture Content of Ponderosa Pine and Whiteleaf Manzanita Leaves

FOREST



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ABSTRACT: Leaves of ponderosa pine and whiteleaf manzanita were sampled for moisture content during three 24-hour periods--one in the summer of 1963, and two in the summer of 1964. There was a diurnal fluctuation in the leaf moisture content which was highest at night and at a minimum some time during the day. The diurnal range in moisture content decreased as the summer progressed. Two minimums, one in the morning and one in the afternoon, occurred in both species. Inactivity of wildfires at night may be due in part to increased moisture in living fuel.

Diurnal variations in the moisture content of living fuels may have a pronounced effect on how the fuel burns. Although the moisture in dead fuels has been studied quantitatively, such work in living fuels is noticeable lacking.

Botanists and physiologists have long known that the stomata in leaves open and

close somewhat regularly, usually closing at night, and opening quite rapidly in daytime.¹ Since these small apertures are the main avenues of water loss from mesic plants, it would seem logical that leaf moisture content varies diurnally and that this variation is related to the same factors that control stomatal behavior (i. e. light, moisture availability, and temperature). The moisture content of leaves would be expected to be high at night and at a minimum some time during the day.

Many deviations from "standard day" stomatal cycles are possible. Rate of diffusion through the stomata can reach a maximum in the mid-morning, and another maximum during the afternoon.² This action could possibly result in two minimums in leaf moisture content. As soil moisture becomes limiting, the total time that the stomata are open and amount of opening decrease.³ This may mean that as summer progresses the difference between daily maximum and minimum moisture content in leaves will decrease.

¹Bonner, James, and Galston, Arthur W. Principles of plant physiology. 499 pp., illus., San Francisco: W. H. Freeman. 1959.

²Meyer, Bernard S., and Anderson, Donald B. Plant Physiol. Ed. 2, 784 pp., illus. New York: D. Van Nostrand. 1952.

³Shimshi, D. Effect of chemical closure of stomata on transpiration in varied soil and atmospheric environments. Plant Physiol. 38: 709-712. 1963.

The effects of environment on stomata action have been studied extensively. Few quantitative data have been published, however, on the diurnal change in leaf moisture content, and none on native California plants normally considered major wildland fuels.

For three 24-hour periods, one in the summer of 1963 and two in the summer of 1964, the leaves of ponderosa pine (Pinus ponderosa Laws.) and whiteleaf manzanita (Arctostaphylos viscida Parry) were sampled for moisture content. The aim of this study was to obtain quantitative values of living fuel moisture variation during 24-hour periods and to see if these values change from month-to-month during the fire season. Studies reporting annual moisture trends and their correlation with soil moisture, elevation, and physiological condition of living fuels were reported previously.⁴

METHODS

The study site was in the central Sierra Nevada near Sonora, California, at 4,000 feet elevation. It had a slope of 5 to 10 percent and a southeast aspect. Second-growth ponderosa pine 15 to 20 feet tall and whiteleaf manzanita shrubs averaging 6 feet were used. In each 24-hour period on June 18, July 15, and September 26, nine shrubs and nine trees were sampled.

Samples consisted of about 80 gms. of old growth leaves and needles, randomly taken at mid-crown. Three sample bottles were filled from each species at 1-hour intervals during the day and at 2-hour intervals during the night. The same shrubs and trees were included in each sample period. The six samples were sealed and immediately weighed to the nearest 0.1 gm. at the sample site. After each 24-hour period, the bottles were shipped to the Pacific Southwest Station's forest fire laboratory at Riverside, and moisture content was determined by the solvent distillation method.⁵

Before taking each sample, we recorded the wet and dry bulb temperatures in the sample area by sling psychrometry. Soil moisture at depths of 12, 30, and 48 inches was measured in the immediate vicinity by a neutron probe. It was taken within two days of a leaf sample and was used only to show general summer drying trends. These trends in 1963 and 1964 were quite similar when we compared soil moisture, air temperature, and living fuel moisture for the two summers (June-September). Consequently we were able to use data from two years in this report.

RESULTS

On June 18, relative humidity at the study sites ranged from 85 percent to 24 percent and the dry bulb temperature from 48° to 73° F. Moisture contents in both pine and manzanita leaves were at their

⁴Philpot, Charles W. The moisture content of ponderosa pine and whiteleaf manzanita foliage in the central Sierra Nevada, U.S. Forest Serv. Res. Note PSW-39, Pacific SW. Forest & Range Expt. Sta., Berkeley, Calif., 6 pp., illus. 1963.

⁵Buck, Charles C. The solvent distillation method for determining the moisture content of forest litter. Jour. Forestry 37: 645-651, illus. 1939.

minimum from noon to 3 p.m. Manzanita had a sample range of 40 MCP (moisture content percent) (fig. 1) and pine 27 MCP--both on dry basis (table 1, figs. 1, 2). Both curves follow the relative humidity

Table 1. *Range in leaf moisture content, by date of sampling and species*

WHITELEAF MANZANITA				
Date	Sample			Mean Range
	Max.	Min.	Range	
	Percent			
June 18	163	123	40	33
July 16	169	121	48	31
Sept. 26	145	119	26	19
PONDEROSA PINE				
June 18	144	117	27	26
July 16	169	121	48	34
Sept. 26	152	118	34	30

curve directly and the dry bulb temperature curve inversely. No mid-morning deficits were detected on this date. Soil moisture was 16, 18, and 22 percent (by volume) at 12, 30, and 42 inches respectively. New leaf growth was just beginning on manzanita; pine appeared to be dormant.

On July 15 the relative humidity ranged from 30 to 50 percent, and dry bulb temperature from 64° to 81° F. The sample points varied greatly with time as compared with June 18. Pine showed minimums at 10 a.m. and 3 p.m. (fig. 3). The sample range was 48 MCP for manzanita, and 48 MCP for pine (figs. 3, 4). Again both curves appeared to be correlated directly with the relative humidity curve and inversely with the dry bulb temperature curve. The initial minimum in both species was the lowest. Soil moisture was 11, 13, and 15 percent at 12, 30, and 48 inches respectively. Judged by the addition of new leaves the plants were then well into their new growth cycle.

On September 26, the relative humidity ranged from 22 to 49 percent and the dry bulb ranged from 64° to 93° F. The sample range of manzanita was only 25 MCP on this date, and the mean range was down to only 19 MCP (fig. 5). The pine, however, had a sample range of 34 MCP and a mean range of 30 MCP (fig. 6). Two minimums appeared to be present in both pine and manzanita. The minimums for manzanita occurred at noon and 3 p.m., and at 1 and 6 p.m. for pine. Soil moisture was at 8, 12, and 12 percent at 12, 30, and 42 inches respectively. New leaf growth had long since ceased.

DISCUSSION

Differences in fire behavior patterns at night and mid-day could be explained in part by the diurnal fluctuations in the moisture content of both ponderosa pine and whiteleaf manzanita leaves. Moisture

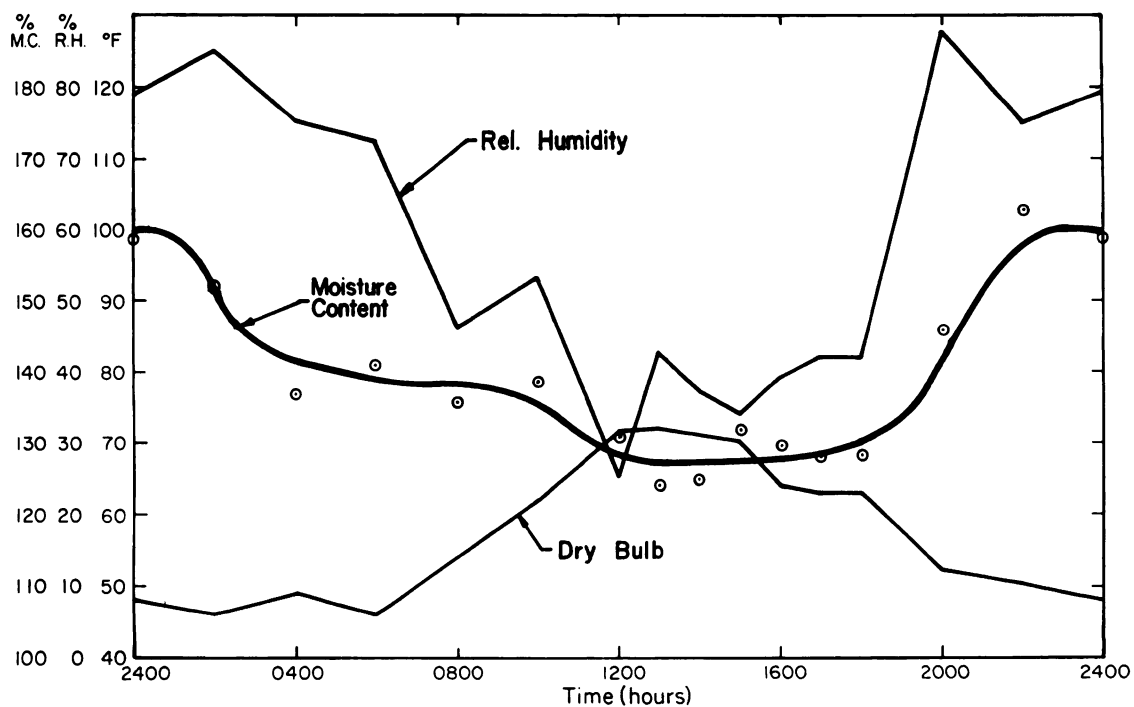


Figure 1.--The diurnal fluctuation in relative humidity, air temperature, and manzanita leaf moisture content, June 18, 1964.

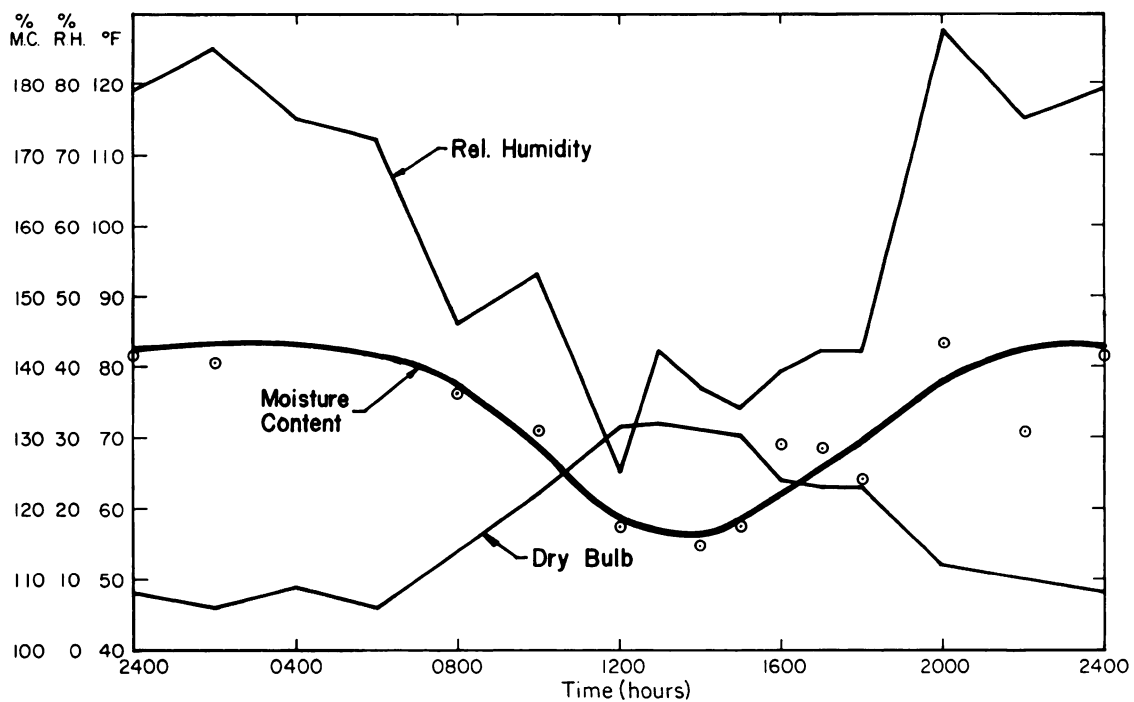


Figure 2.--The diurnal fluctuation in relative humidity, air temperature, and ponderosa pine leaf moisture content, June 18, 1964.

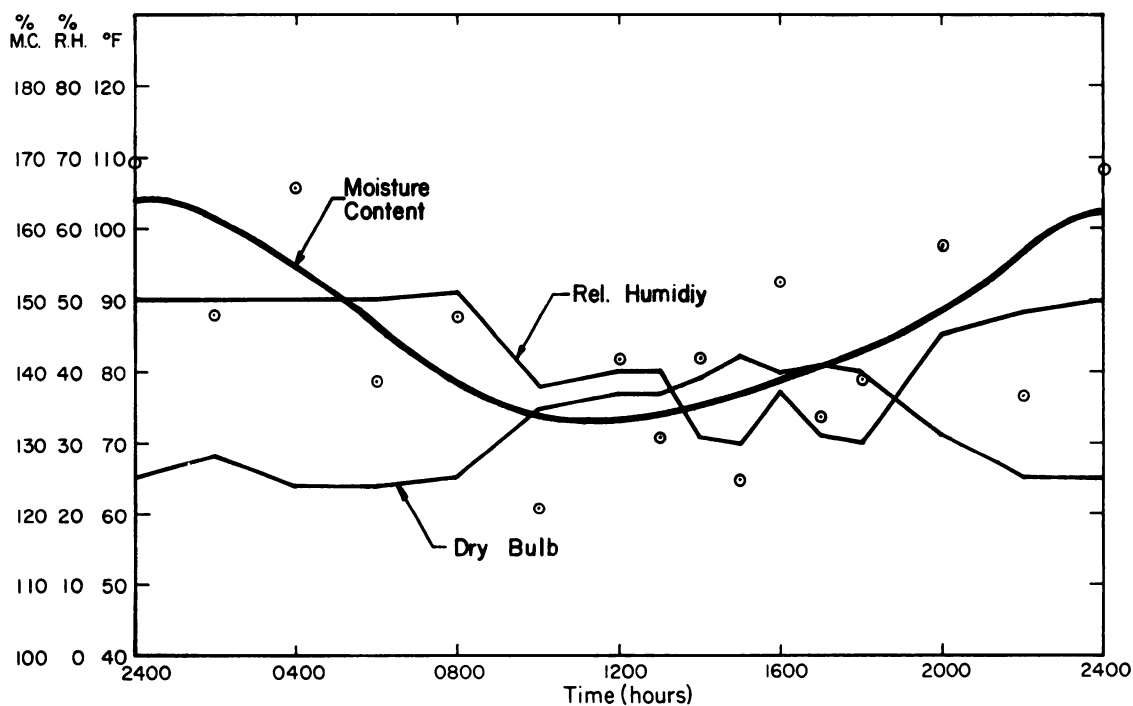


Figure 3.--The diurnal fluctuation in relative humidity, air temperature, and manzanita leaf moisture content, July 16, 1964.

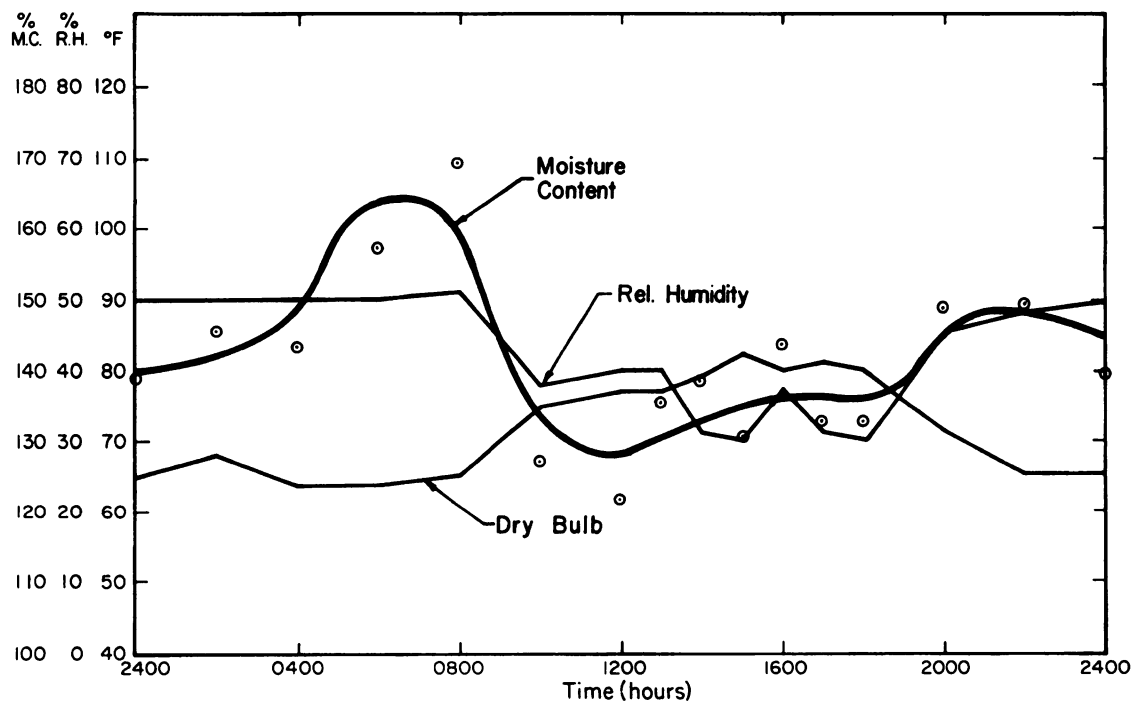


Figure 4.--The diurnal fluctuation in relative humidity, air temperature, and ponderosa pine leaf moisture content, July 16, 1964.

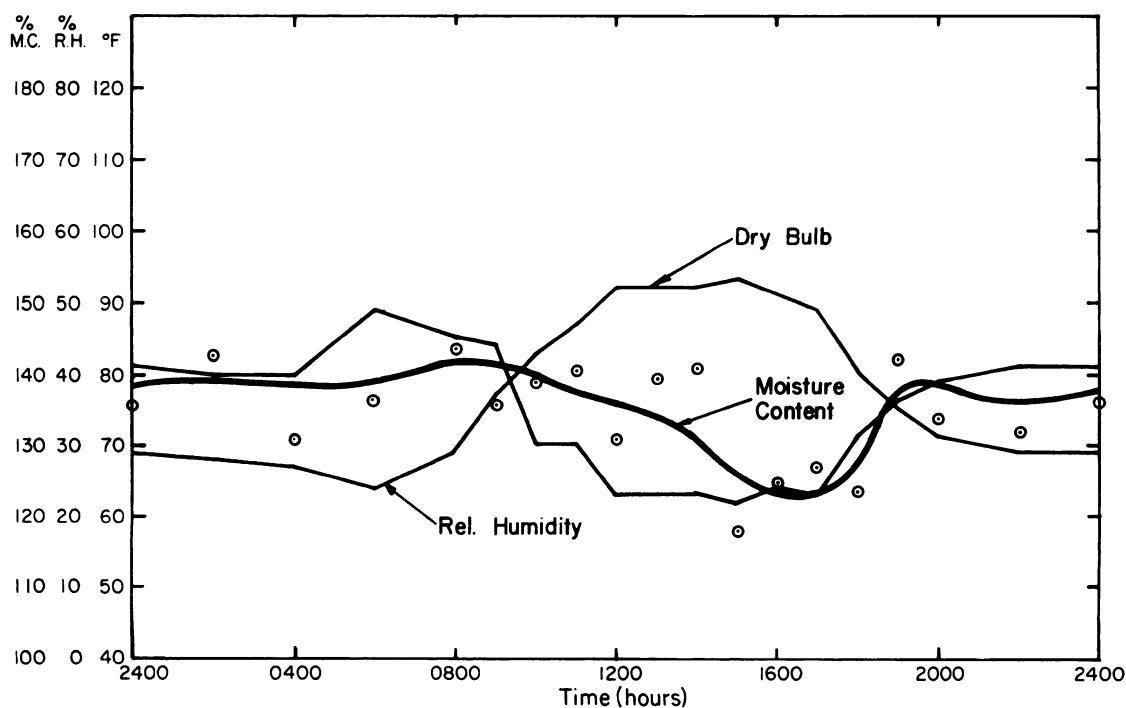


Figure 5.--The diurnal fluctuation in relative humidity, air temperature, and manzanita leaf moisture content, September 26, 1963.

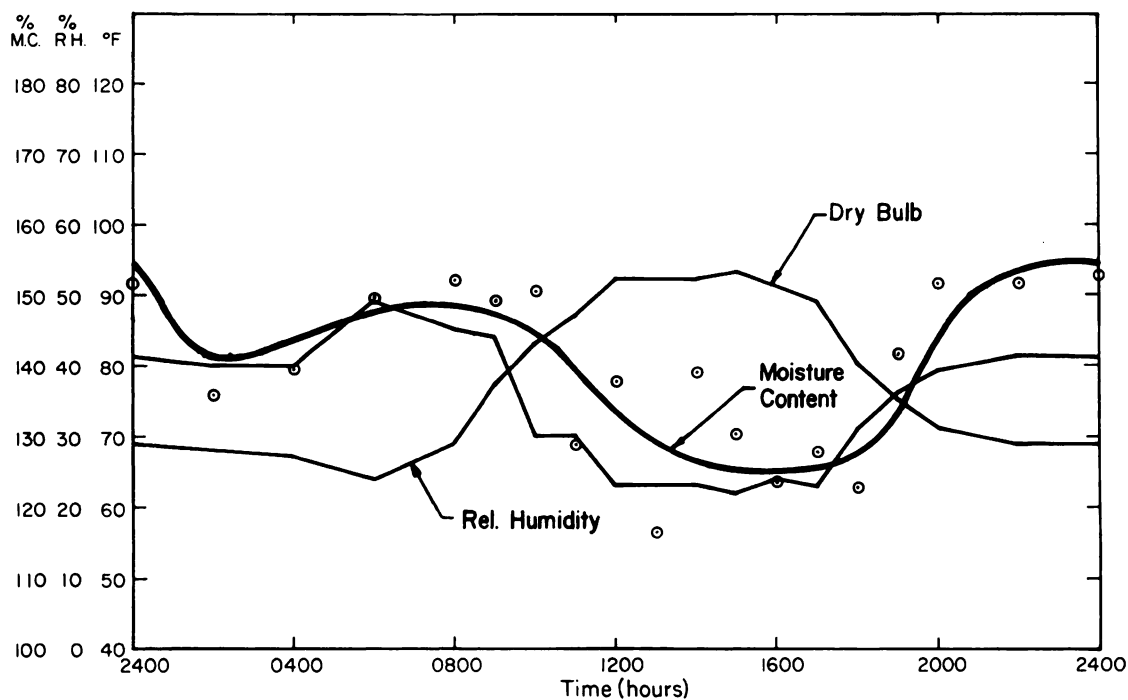


Figure 6.--The diurnal fluctuation in relative humidity, air temperature, and ponderosa pine leaf moisture content, September 26, 1964.

content was highest at night and at a minimum some time during the day. The 30 MCP range between maximum and minimum moisture content during the period of new growth dropped to less than 20 MCP by late September for manzanita. It would be worthwhile to investigate whether the range for this species dips even lower toward the end of summer. Such a decline seems probable from this study, and is especially likely in the drier wildland areas.

The two minimums in moisture content in the two species are probably the result of high mid-morning transpiration rates that cause incipient wilting and start stomata closure during the daytime. After leaf moisture builds up around noon the stomata reopen. The moisture content then begins to drop to a second or afternoon minimum.

The established practice of sampling vegetation foliage from noon to 4 p. m. in an effort to minimize the error due to possible diurnal fluctuation is warranted because the daily minimum occurs at this time.

Further studies in vegetation moisture relationships should be aimed at determining quantitatively the effect of moisture in living fuel on fire behavior. These investigations should be coupled with exploration into means of controlling vegetation moisture content. If, for instance, the optimum moisture content was found to be somewhere between the diurnal maximum and minimum, chemical control of stomata might become an effective aid to fire control.

The Author. . .

CHARLES W. PHILPOT is studying fuel moisture and related variables as part of the Station's research on the factors that influence forest fire behavior. Now headquartered at Riverside, California, he has been with the Station since 1960. He received bachelor's and master's degrees in forestry from the University of California in 1961 and 1962.