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Seasonal and Diurnal Variation in Moisture Content of Six Species of Pocosin Shrubs

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Cover photo: A gallberry plant is collected from the dense mixture of finely branched deciduous and evergreen shrubs growing on an organic, pocosin soil in eastern North Carolina. A fuel complex like this can become highly flammable in the dormant season when the dead fuels become dry and the living fuels are at a low point in their annual cycle of moisture content. This photograph was taken in April 1965, a few weeks prior to the rapid spring buildup in the moisture content of live fuel.

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Seasonal and Diurnal Variation in Moisture Content of Six Species of Pocosin Shrubs

by

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INTRODUCTION

Understory shrubs growing on organic soils in pocosins of the eastern North Carolina coastal plain can become a particularly severe fire hazard during certain dry seasons of the year. These shrubs commonly form dense thickets of highly flammable fuels capable of supporting very intense wildfires. Such fires, once started, often have the potential for widespread destruction because of control difficulties in these relatively unbroken and inaccessible expanses of vegetation.

The peculiar branching habit of these shrubs probably contributes to their high flammability. Their foliage and stems usually form a dense, relatively homogeneous mixture of finely divided fuel particles suspended just above the litter. In addition, the leaves of many species of pocosin shrubs remain on the plant through the winter. Thus, they increase the proportion of easily ignited fine fuel particles distributed throughout the fuel complex during the dormant season.

Practical experience in fire control in the organic soils area has suggested that moisture content of these shrubs may be one of the more important factors influencing fire behavior. The most intense and difficult-to-control fires tend to occur during the spring and fall, two seasons of the year in which moisture content of the shrub undergrowth is relatively low. Other environmental factors, such as precipitation, wind, and relative humidity, are often at a level favoring high flammability at these seasons.

Wendel and Storey[1] showed that a definite pattern of seasonal moisture variation exists for several species of vegetation found on pocosin soils on the Hofmann Forest in eastern North Carolina. In 1959 they observed moisture fluctuations over a 1-year period in four common species: gallberry (Ilex glabra (L.) Gray), swamp cyrilla (Cyrilla racemiflora L.), redbay (Persea borbonia (L.) Spreng.), and switch cane (Arundinaria tecta (Walt.) Muhl.). The general pattern of moisture variation during this time was similar for the four species. All showed a rather rapid increase in moisture content during the period of growth resumption in the spring, followed by a gradual decline in moisture through the summer on into fall and winter. However, moisture content at any given time during the year was apt to vary widely among the four species.

Although Wendel and Storey's data provided valuable insight into general patterns of seasonal moisture variation in pocosin shrubs, additional information was needed to establish trends for other years and to describe other, more specific characteristics of the moisture regime in these fuels. This report explores four questions concerning the moisture regime in pocosin shrubs, namely: (1) How does the pattern of seasonal moisture variation during other annual growth cycles compare with Wendel and Storey's data for 1959? (2) How does moisture content differ among stems, new leaves, and old leaves? (3) How is the timing of new growth initiation in the spring related to the buildup in moisture content of the whole plant? and (4) Does diurnal variation in moisture content occur in pocosin shrubs?

METHODS

Seasonal variation in moisture content was observed in six species of pocosin shrubs over a 10-month period from March through December 1965. The six species included the four that Wendel studied (gallberry, swamp cyrilla, redbay, and switch cane) plus two others, fetterbush (Lyonia lucida (Lam.) K. Koch) and honeycup (Zenobia pulverulenta (Bartr.) Pollard). (Although switch cane is not technically a shrub, for simplicity it will be so termed throughout this paper.)

Samples were collected on six plots located on the Hofmann Forest in eastern North Carolina. Each species was sampled on a different plot. Transects had been laid out on each plot as shown in figure 1. Samples were collected on these transects once each week between noon and 4 p.m. On a given plot, samples were obtained by clipping a suitable plant near each of the five subsample points along a transect; separating each whole plant into stems, current year's foliage, and previous year's foliage; and combining subsamples of each type of tissue into one composite sample for each of the three transects on a plot. Moisture content of the samples was determined by ovendrying for 24 hours at 103° C.

[1] Wendel, George W., and Storey, Theodore G. Seasonal moisture fluctuations in four species of pocosin vegetation. U. S. Forest Serv. Southeast. Forest Exp. Sta. Pap. 147, 9 pp., illus. 1962.

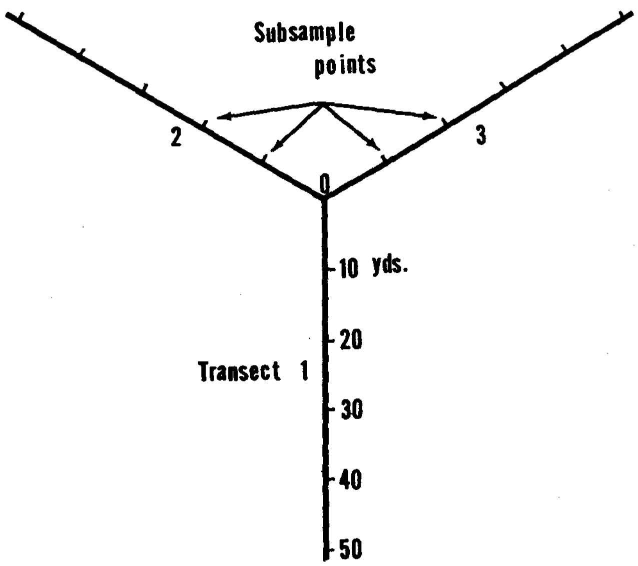

Figure 1.--Layout of transects on each plot from which samples were obtained. (Subsamples were collected at the indicated points along each transect, then combined to make three composite samples, one from each of the three transects on a plot.)

Diurnal variation in moisture content of the current year's foliage was observed in four species: gallberry, swamp cyrilla, honeycup, and fetterbush. Samples were collected every 4 hours throughout a 36-hour period on June 21 and 22, 1965. Samples of a given species were taken from a single clump composed of numerous plants. We collected each sample by clipping four to six terminal shoots to provide approximately 10 grams of fresh leaf tissue, taking all foliage samples from the lower two-thirds of the shoot,[2] blotting with a paper towel to remove surface moisture if present, and combining leaf tissue from each of the terminal shoots into one composite sample. Five composite samples of each species were collected every 4 hours. Moisture content was determined by ovendrying for 18 hours at 103° C.

RESULTS AND DISCUSSION

Seasonal Variation

The patterns of seasonal variation in moisture content of leaves and stems were, in general, similar for nearly all species. However, noticeable differences did occur (figures 2a-2f).

Moisture content of new leaves was very high (200 to 400 percent) when the leaves first appeared in the spring. It declined rapidly during the first 4 to 6 weeks after initiation and then decreased gradually through the rest of the summer on into the winter months. Leaves that had remained on the three evergreen species (gallberry, fetterbush, and redbay) from the 1964 growing season through the winter of 1965 had about the same moisture content in March 1965 that the current year's leaves had attained by December 1965. This relationship suggests that little change in the moisture content of leaves takes place through the winter months, a characteristic which Wendel also noted. The curves for moisture content of previous year's foliage show a slight increase about the time of new foliage initiation.

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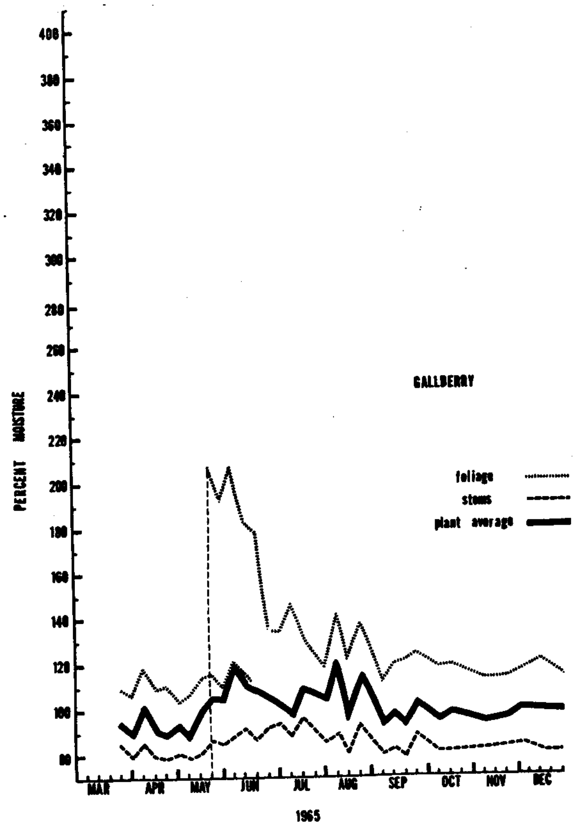
[2] To reduce experimental error resulting from variation in stage of maturity of terminal leaves, only the leaves from the lower two-thirds of the stem were used.


GALLBERRY
PERCENT MOISTURE
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280
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200
180
160
140
120
100
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foliage
stems
plant average
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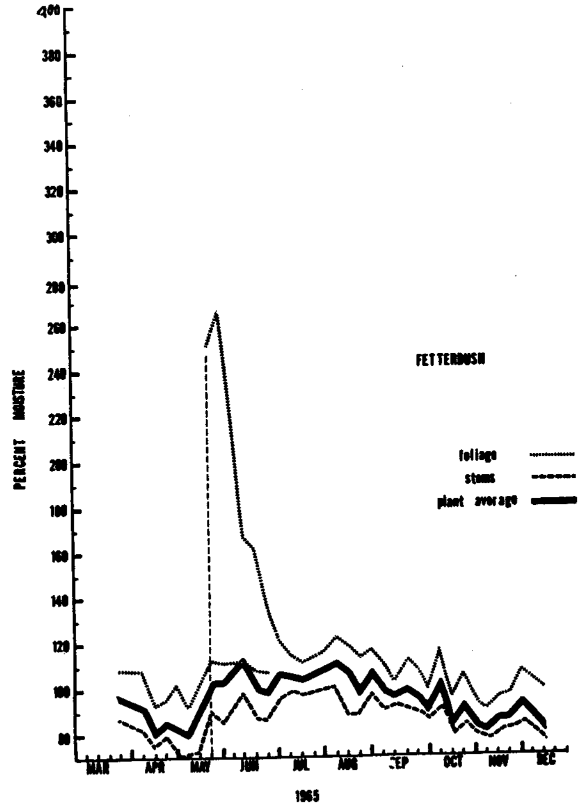
a


FETTERBUSH
PERCENT MOISTURE
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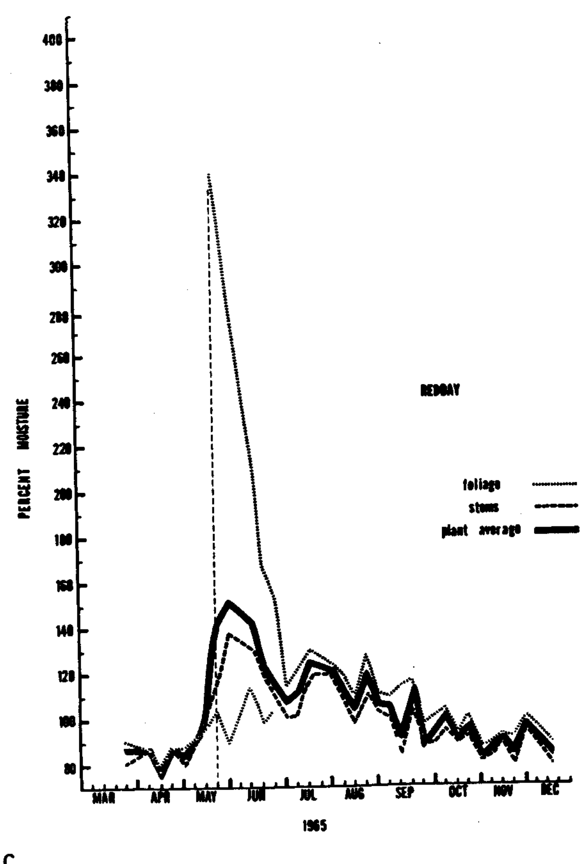
REDBAY
PERCENT MOISTURE
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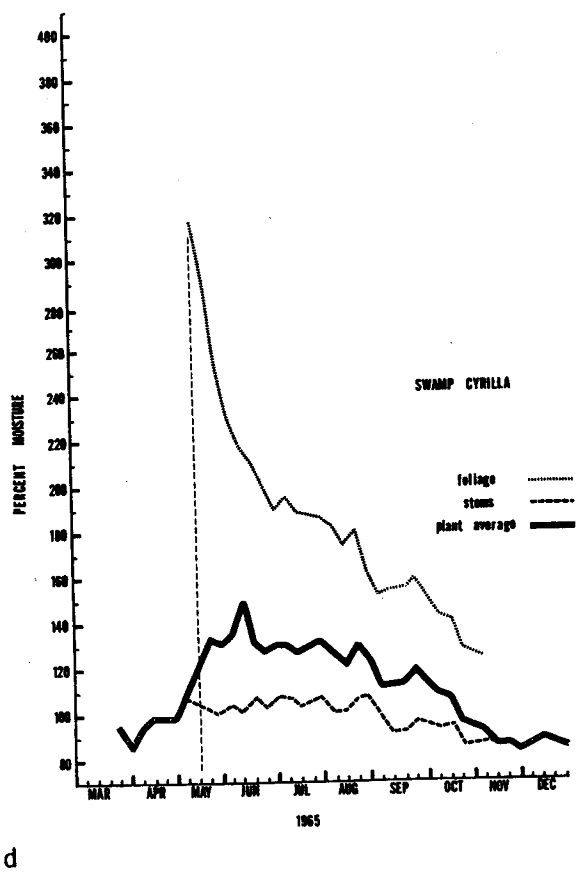
SWAMP CYRILLA
PERCENT MOISTURE
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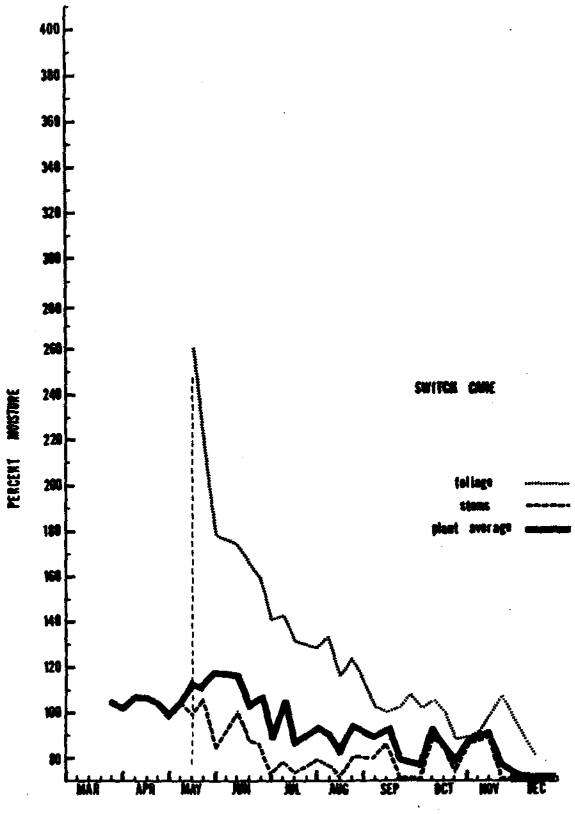

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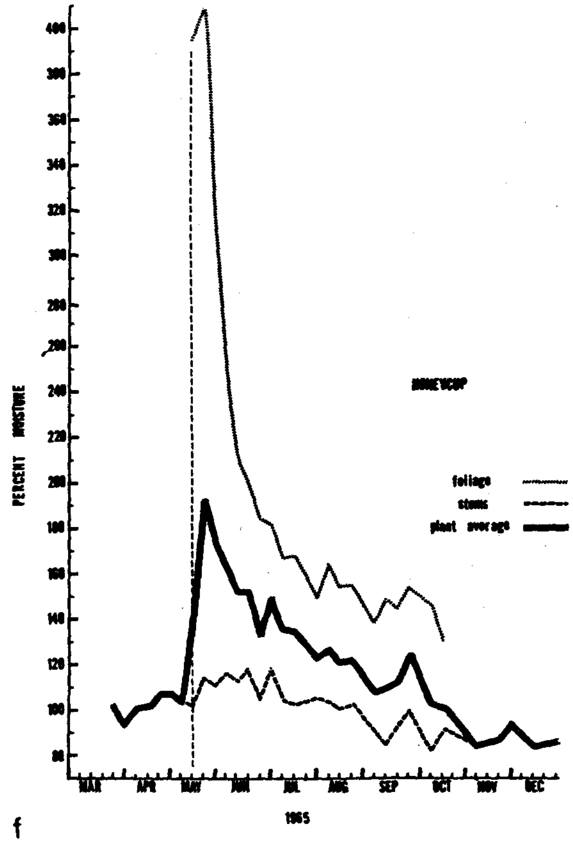

f

Figure 2.--Annual cycle of variation in moisture content of six pocosin shrub species during 1965. The moisture content of previous year's foliage in a, b, and c is plotted separately from that of new foliage initiated during the 1965 growing season. (Percent of moisture based on ovendry weight of sample.)

Apparently, the leaves of the three evergreen species persist on the plant for only 1 year. During this particular year (1965), previous year's leaves dropped off from 4 to 6 weeks after new foliage initiation.

The moisture content of the stems of most species was lowest during April and the early part of May and during the period from September through December. It increased noticeably during the latter part of May and all of June, then gradually declined through the summer, fall, and winter. Switch cane was an exception in that it exhibited no spring increase in stem moisture. Instead, the moisture content of its stems declined steadily throughout the spring and summer. The spring increase in the moisture content of swamp cyrilla stems began during April, about a month earlier than in the other species.

The curves for the moisture content of stems represent an average of moisture in both new and old stem tissue. If the moisture content of newly formed stem tissue follows a pattern similar to that of newly formed leaves, the spring increase in average moisture content of new and old stems may be largely due to increased concentrations of water in the rapidly expanding new shoots and newly formed cambium tissue. If this is true, then most of the water in the whole plant is concentrated in the smaller fuel particles (leaves and small stems) and in a layer covering the outer surface of all living stems. This rather uneven distribution of moisture within the fuel complex might be an important consideration in evaluating the influence of the moisture content of live fuel on fire behavior.

The difference between the moisture content of leaves and that of stems was not consistent throughout the year. Although leaves, in general, maintained a higher moisture content at all times than did stems, the greatest difference occurred in the spring just after new leaves appeared on the plant. At this time, leaves were from 100 to 200 percent higher in moisture content than were stems. This wide difference lasted for only a few weeks because of the rapid decline in moisture content usually associated with continued development of new tissue. The difference between the moisture content of leaves and stems for the three deciduous species (swamp cyrilla, honeycup, and switch cane) gradually decreased as the leaves continued to develop through the summer until they dropped off in the fall. On the other hand, in the three evergreen species the difference had stabilized by midsummer, about the time the previous year's leaves dropped off. Thereafter, the difference remained about the same (10 to 30 percent) throughout the fall and winter months. The curve of moisture content for previous year's leaves suggests that this 10- to 30-percent difference may continue through the winter until the following summer when the older leaves drop off. Redbay was an exception in that the moisture content of its stems increased above the moisture content of the previous year's leaves just prior to new foliage initiation.

The difference between the moisture content of leaves and stems also varied considerably among species. For example, in redbay the moisture content of leaves ranged within 15 percent of the moisture content of stems over the entire period except during the 6 weeks following new foliage initiation. On the other hand, in honeycup and swamp cyrilla the moisture content leaves ranged well over 40 percent higher than that of stems most of the time. Wendel and Storey (see footnote 1) found similar patterns in swamp cyrilla and redbay during 1959.

The average moisture content of the whole plant was generally lowest during the dormant season (November-April). A marked increase occurred in May with the onset of new growth, gradually tapering off through the summer. In all species except switch cane, this spring increase was a result of increases in the moisture content of both foliage and stems. The moisture content of switch cane stems showed no increase in the spring but continued to decline through spring and summer.

In addition to the broad seasonal trends of variation in moisture content, figures 2a-2f show week-to-week fluctuations in the moisture content of some species which are too large to be explained solely by random variation among repeated samples. The week-to-week fluctuations often greatly exceeded 95-percent confidence limits on the means used to plot curves in figures 2a-2f. (These confidence limits ranged from

$\bar{x} \pm 6\%$ to $\bar{x} \pm 11\%$.[3]) Uneven rates of growth or irregularly occurring diurnal fluctuations in moisture content caused by changing weather conditions may have caused these short-term fluctuations.

The relative proportions of foliage and stem tissue of the evergreen species fluctuated throughout the year. The proportion of foliage tissue was lowest during April and May and during September and October. During these periods the proportion of foliage decreased to around one-third of the total dry weight of the plant. The proportion of foliage increased to as high as one-half in August but was, with a few exceptions, never more than this.

The rapid increase in moisture content of the whole plant in the spring seems to be correlated with new foliage initiation. This increase in moisture content began about 1 to 2 weeks before collection of the first new foliage samples (figures 2a-2f). As bud break had also occurred about 1 to 2 weeks prior to this collection, it appears that bud break and the beginning of the rapid increase in moisture content of the whole plant occurred in each species at about the same time. The moisture content of the whole plant seemed to reach a maximum about 1 to 2 weeks after the first samples of new foliage were collected. It is noteworthy that the first samples of new foliage were collected for all six species at about the middle of the period of rapid increase in the moisture content of the whole plant. If this relationship is typical of most years, observations of the time of bud break and initiation of rapid leaf expansion in the spring might be useful in detecting the onset of the rapid spring increase in moisture content of these pocosin fuels.

The time of bud break and initiation of new foliage differed among the six species. The separation of one week between dates of the first samples of new foliage shown in figures 2a-2f reflects this difference. Numerous observations made while collecting samples also showed, however, that the date of bud break and initiation of new foliage differed among individual plants of the same species growing on different sites.

These data and Wendel and Storey's earlier study confirm the existence of marked seasonal fluctuation in moisture content of pocosin shrubs. Minima occur at a time of year when fire occurrence and difficulty of control are usually highest in the pocosin area, the spring and fall months. However, the important question of just how influential the moisture content factor is in affecting fire behavior remains unanswered. Further study of the relationship between actual flammability and moisture content of pocosin plants in various stages of the annual growth cycle is needed to make these and other studies of variation in moisture content more useful in predicting fire behavior.

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[3] These confidence limits do not apply to that portion of the new foliage curves exhibiting the rapid decrease in moisture content during the first 4 to 6 weeks of development.

Diurnal Variation

Previous research has already shown that local environmental conditions characterized by clear, hot days or inadequate soil moisture can cause reduced moisture content in the leaves of some plants during the afternoon hours. On the other hand, on cool, cloudy, or rainy days when there is adequate soil moisture, little or no reduction may take place.[4]

We took samples of foliage from four species (gallberry, swamp cyrilla, honeycup, and fetterbush) over a 36-hour period during June 1965 to see if we could detect a diurnal fluctuation in moisture content. We purposely chose to sample current year's foliage tissue at a time just after the leaves were fully expanded but while moisture content was still relatively high (150 to 200 percent). If diurnal variation did occur at all, we reasoned that it would be more pronounced in foliage tissue at this time of year. We chose a sampling period when the days were relatively hot and clear and the soil was well supplied with moisture. Figure 3 reflects diurnal air temperature, relative humidity, and solar radiation cycles for the period.

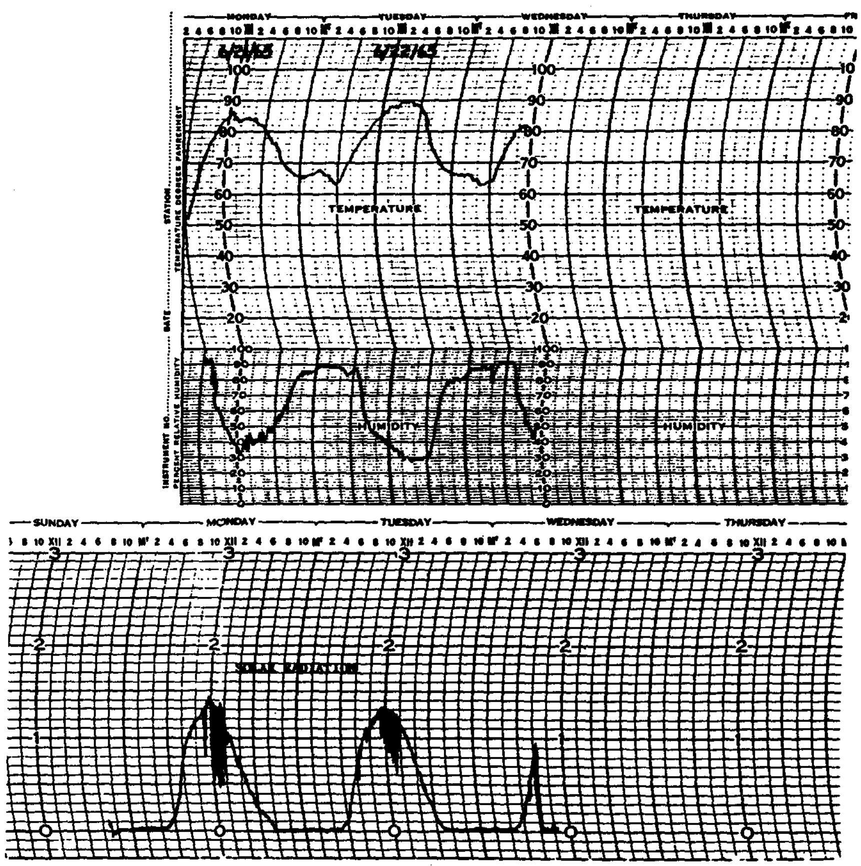

Figure 3.--Variation in air temperature, relative humidity, and solar radiation intensity during the 36-hour period when diurnal variation in moisture content of foliage was measured.

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[4]Meyer, B. S., Anderson, D. B., and Bohning, R. H. Introduction to plant physiology. 541 pp., illus. New Jersey: D. Van Nostrand Company, Inc. 1960.

Our results indicate that diurnal fluctuation in moisture content can occur in the four species studied, at least under the weather conditions prevailing at the time of this study. According to figure 4, maximum moisture contents occurred between 2 and 6 a.m. Minima occurred about 2 p.m. During the 36-hour sample period, gallberry fluctuated from about 143 to 180 percent; cyrilla from about 152 to 178 percent; honeycup from about 162 to 205 percent; and fetterbush from about 165 to 204 percent.

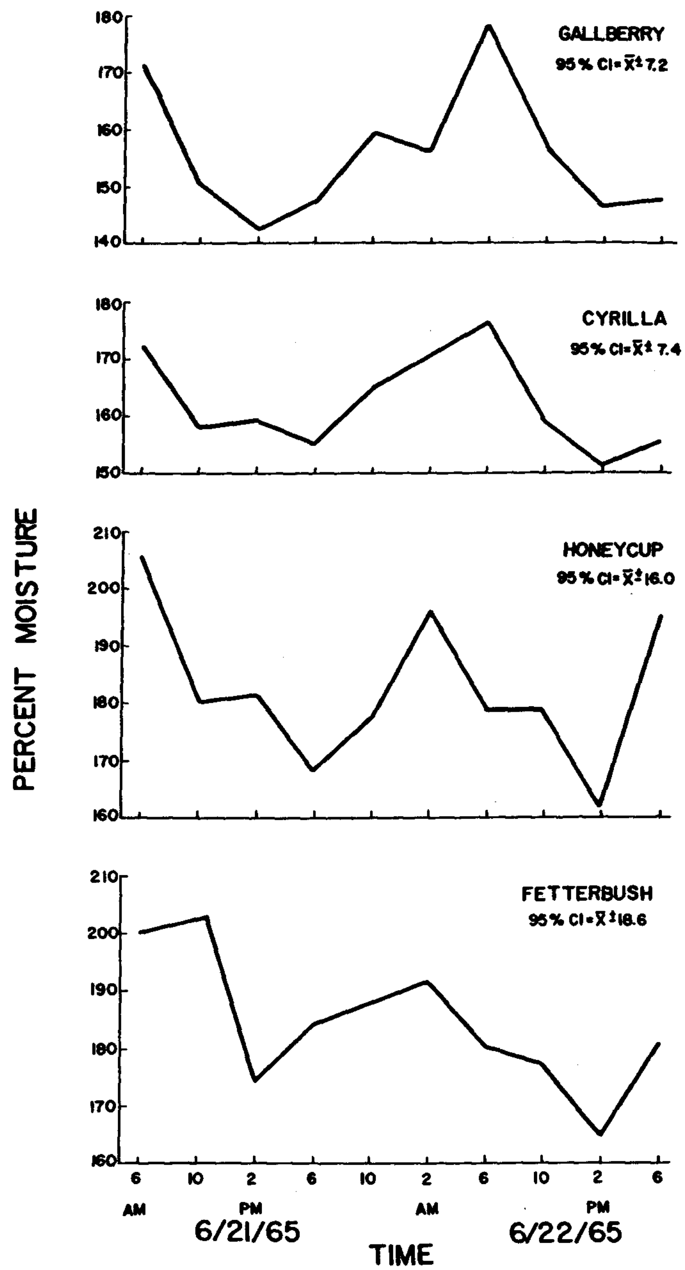

Figure 4.--Diurnal variation in foliage moisture content of four pocosin shrub species. (Percent moisture based on ovendry weight of sample.)

If this much diurnal fluctuation can occur in foliage tissue at this stage of maturity, then it seems that measurable but perhaps smaller fluctuations might also occur at other times of the year. Buck,[5] reporting from California, detected some diurnal variation in manzanita (Arctostaphylos spp.) and snowbrush (Ceanothus velutinus) at various times throughout the entire growing season. Further study of diurnal changes in moisture content of stems as well as foliage at other times of the year could help establish the frequency and degree of occurrence of this phenomenon in pocosin fuels. Such studies should explore the relationship of important environmental conditions such as air temperature, solar radiation, and soil moisture to diurnal moisture cycles. Further, they should attempt to establish the significance of this phenomenon to fire behavior.

SUMMARY

Seasonal variation in moisture content of six pocosin shrub species (gallberry, swamp cyrilla, redbay, switch cane, fetterbush, and honeycup) found on the Hofmann Forest in eastern North Carolina was observed over a 10-month period from March through December 1965. The moisture content of foliage and that of stems was measured separately and compared with the average moisture content for the whole plant.

Diurnal variation in moisture content was observed in foliage tissue of four pocosin shrub species (gallberry, swamp cyrilla, honeycup, and fetterbush) over a 36-hour period during June 21 and 22, 1965.

Minimum moisture contents occurred in the spring and fall in most species. A marked increase in moisture content occurred during May and June with the highest moisture content for the whole plant occurring some time during the first 2 weeks of June.

At any given time of year, leaves almost always had a higher moisture content than stems, but the difference between leaf and stem moisture varied considerably among species and according to the time of year. The difference between the moisture content of leaves and stems tended to be greater in the deciduous species than in the evergreen species.

Leaves on the evergreen species remained on the plant for 13 to 14 months or about 4 to 6 weeks beyond the time that new foliage was initiated the following spring.

The degree of influence that leaves or stems had on the average moisture content of the whole plant varied considerably according to the time of year and stage of plant development within the annual growth cycle. In some species the marked increase in the average moisture

[5]Buck, Charles C. Progress report on variations in the moisture content of green brush foliage on the Shasta Experimental Forest during 1937. Calif. Forest and Range Exp. Sta., 10 pp. 1939. (Unpub. misc. rep.)

content of the whole plant in the spring was mainly a reflection of the rapid initial development of new foliage. However, because leaf tissue constituted a small proportion of the whole plant (based on dry weight), the average moisture content of the whole plant was usually nearer the level of the moisture content of stems than that of leaves. During late summer and fall, leaves had about as much influence as stems on the average moisture content of the whole plant because of the increased proportion of leaf tissue.

The initiation of new foliage in the spring seemed to be correlated with the rapid buildup in moisture content of the whole plant. Both began at about the same time.

The seasonal patterns of variation in moisture content observed in gallberry, swamp cyrilla, redbay, and switch cane generally agree with Wendel and Storey's earlier study in 1959.

Apparently, substantial diurnal variation in moisture can occur in the foliage tissue of gallberry, swamp cyrilla, fetterbush, and honeycup, at least under the weather conditions existing at the time of observation.