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ANNUAL CHANGES IN FOLIAR NITROGEN, PHOSPHORUS, AND POTASSIUM LEVELS OF LOBLOLLY PINE (*PINUS TAEDA* L.) WITH SITE, AND WEATHER FACTORS

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In recent years, the majority of the site classification studies made in the Southern Pine Region have been of the visual soil properties type; that is, the independent site variables investigated, such as thickness of various horizons, depth to an inhibiting layer, and drainage class, were susceptible to field identification. It is obvious that although studies of this nature are quite useful as management tools, the independent variables used are merely indicators of more fundamental relationships between the environment and tree growth. In 1959, a study to investigate the relation between loblolly pine growth and moisture regime was initiated by the Department of Forestry, Mississippi Agricultural Experiment Station. Because moisture regime was thought to be the dominant site factor in this area, the foliar nutrient status was investigated as a supplement to the main work. The purpose of this supplementary study was to determine the period of the year in which foliar samples could be collected from plots throughout the State with a high probability that foliar nutrient levels would remain stable during the sampling period. The study was considered to be essential due to the anticipated variation in levels with time, and the indeterminate growth habit of the species; loblolly pine has been observed to produce two, three, or even four flushes of height growth per year, apparently dependent upon favorable environmental conditions. Although most previous studies have dealt with determinate species, Wells and Metz [10] worked with loblolly pine, and their work is the most comparable to the study reported here; their samples, however, were taken from foliage of increasing age, and it is not possible to make comparisons of results after the first two sampling periods.

METHODS

The effect of site differences on foliar levels of nitrogen, phosphorus, and potassium was determined by selecting two old field sites of widely differing productive potential; both sites supported young plantations of loblolly pine.

The first area, hereafter referred to as the Betheden sample, was located in the Sand-Clay Hills Physiographic Region of east-central Mississippi. The soil in the sample area was mapped as a Ruston series; a well-drained, sandy, upland soil. The plantation was eight years of age at the inception of the study and the site index for loblolly pine, as obtained from older trees in the area, was 80 feet at age 50. The second area, the Noxubee sample, was located approximately eight miles from the Betheden area on the flood plain of the Noxubee River in the Interior Flatwoods Physiographic Region. The soil here was mapped as a Mantachie; a somewhat poorly drained, silty, bottomland soil. The plantation was six years of age at the first sampling, and the site index for loblolly in this area ranges from 100 to 110 feet at age 50. Table 1 indicates marked differences in some of the physical and chemical properties of the two areas.

TABLE 1

Comparison of physical and chemical properties of the sample area soils

Series	Horizon	Thickness	Sand	Clay	% Organic matter	pH	CEC*	Avail. exch. total		
								P	K	N
Ruston .	A_p	5″	59	5	0.7	5.6	1.8	4	56	30
	A_2	9″	71	4	0.4	5.5	1.5	12	72	28
Mantachie	A_p	4″	28	15	1.2	5.3	5.8	5	82	49
	C_1	9″	25	24	0.8	5.2	9.0	10	109	31

* me NH_4 per 100g soil

Each sample area was mapped by auger on a 10-foot square grid to determine soil uniformity, and a composite sample of the upper solum was collected. Sample area boundaries were established to give the greatest uniformity in horizon thicknesses.

Foliage samples were collected from the current flush of growth of the terminal whorl, providing the needles were uncased and more than $1\frac{1}{2}$ inches long, but if the needles of the current growth did not meet the specifications, needles from the previous growth were used. Samples were collected monthly from four dominant trees within the uniform soil area of each plantation, and immediately oven dried for 24 hours at 70°C. The dried needles were ground in a Wiley mill with a one-millimeter mesh screen, redried, and analyzed for total nitrogen, phosphorus, and potassium by the Chemistry Department of the Agricultural Experiment Station using standard A.O.A. C.[1] procedures; soil chemical properties were also determined by these procedures. Foliage samples were first collected and analyzed by individual trees, but it soon became apparent that variation between trees of the same area was not significant; consequently, beginning with the eighth sampling date, samples were composited for each site. At the end of the first sampling period (May 1960), results were examined and because of the large, and seemingly inexplicable, variation in foliar nutrient levels, a second sampling period was initiated in January 1961. A total of 27 monthly samples were collected over a three year period.

RESULTS AND DISCUSSION

Variation with time and site

The general trends in foliar content of nitrogen, phosphorus, and potassium with time on both sites found in this study (Figure 1, 2) follow previously reported trends [7 11]; that is, an early season maximum in concentration followed by a gradual decline during the growing season, and an increase to a relatively stable level during the winter. It is noted in Figures 1 and 2, however, that with the exception of phosphorus, there is not found here the stability in winter levels reported by White [11] in red pine (*Pinus resinosa* Ait),

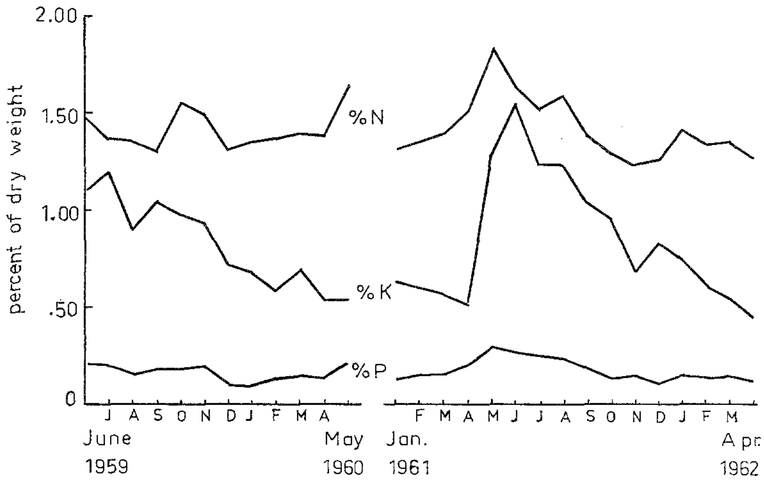

Fig. 1. Change in foliar nitrogen, phosphorus and potassium content with time. Noxubee sample.

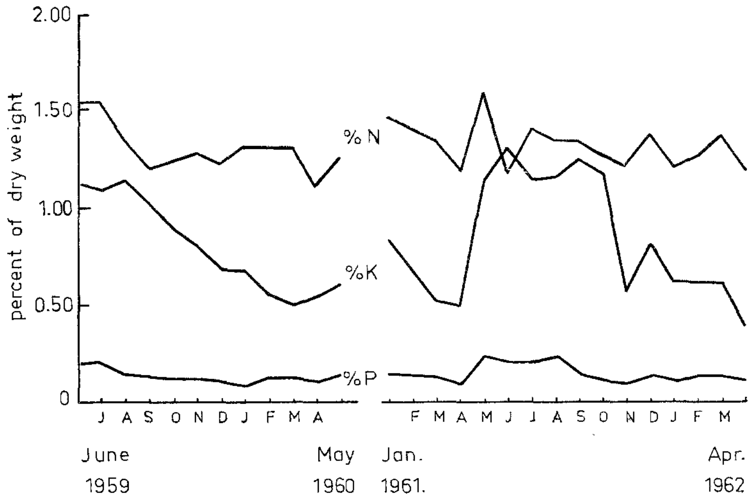

Fig. 2. Change in foliar nitrogen, phosphorus and potassium content with time. Betheden sample.

or the fall stability reported in the same species by Hoyle and Mader [3]. Mitchell [7], working with various species of hardwoods in the Northeast, also recommended fall sampling for maximum stability. The major cause of the difference between reported trends and the trends established in this study is probably the indeterminate growth habit of loblolly pine; generally two, and sometimes three to four yearly flushes of growth are observed during favorable growing seasons. It could be assumed that within the major yearly cycle of fluctuation in foliar concentration, there would occur minor cyclical movement due to the periodic formation of new juvenile foliage. A further confounding factor is the difference in the number of flushes produced on sites of high and low productivity for loblolly pine; personal observation and the work of Zahner [13] and Switzer [8], indicates that a lesser number of growth flushes will occur on sites where moisture is limiting and, consequently, productivity is usually low. The greatest apparent differences between the two sites occur either in the spring or fall, even though foliar levels are not stable at these times (Figure 3, 4, 5); it is, of course, difficult to state at which period of the year foliar levels are truly reflecting the nutrient status of the plant, and whether one should sample the maxima, the minima, or the stable periods has not yet been

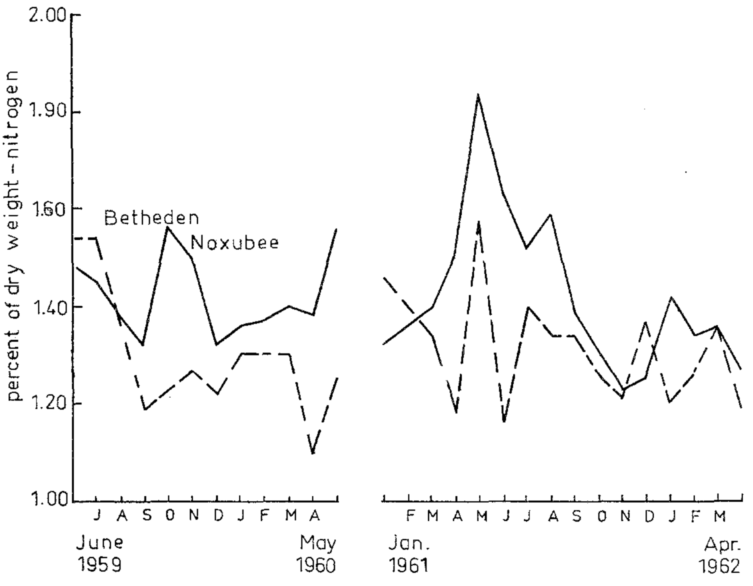

Fig. 3. Comparison of sample-area nitrogen levels with time.

Noxubee ———, Betheden - - - -.

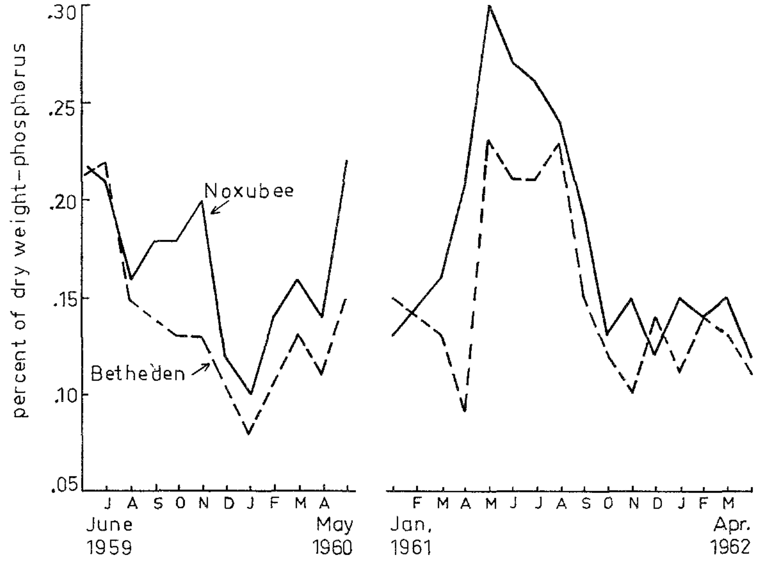

Fig. 4. Comparison of sample-area phosphorus levels with time.

Fig. 5. Comparison of sample-area potassium levels with time.

established. Although apparent differences seem quite large, the differences in foliar levels between the two sites are not large enough to be statististically significant except for the phosphorus levels during September, October, November, 1959, which are significantly different only at the 5 per cent level of probability.

Variation with weather

Also of interest is the variation in levels between the same months in different years. One of the major reasons for continuation of sampling beyond the initial length of one year was the tentative conclusion that discrepancies in levels between years could be at least partially explained by differences in weather conditions. Boynton and Compton [2] also assumed that significant differences found in their work might be due to yearly climatic variation, and Wehrmann [9] recommended measurements over several years to allow for annual fluctuations. Accordingly, weather data from a station between the two sample areas was plotted against the foliar levels found during 1959–1960, and the trends were sufficiently strong to justify additional sampling. At the end of the second sampling period, foliar levels were plotted against 17 independent variables which represented measures of precipitation, average maximum and minimum temperature, and the average mean temperature for periods preceeding the sampling date of one, two, three, and four weeks. One additional variable was used in an attempt to evaluate both the quantity and the intensity of precipitation; this variable, also an indirect measure of soil moisture content, is the number of days from a precipitation of one-half inch or greater to the sample date. The prediction equations in Table 2 are based upon the two most significant independent variables.

TABLE 2

Prediction equations and regression significance for foliar nutrient levels and weather factors

Dependent variable	Prediction equation	r^2
% N, Noxubee . .	$1.29 + 0.00002(X_4) + 0.00582(X_6)$	0.42**
% N, Betheden. .	no significant correlation	
% P, Noxubee . .	$0.70 - 0.00005(X_1)^2 - 15.31548(1/X_2)$	0.56**
% P, Betheden. .	$0.13 - 0.00002(X_3)^2 + 0.00005(X_4)^2$	0.59**
% K, Noxubee. .	$0.40 - 0.00013(X_5)^2 + 0.01241(X_6)$	0.72**
% K. Betheden .	$0.54 - 0.00007(X_3)^2 + 0.00026(X_4)^2$	0.71**

** significance at the 1% level

X_1: average maximum temperature, °F, four weeks prior to sampling
X_2: average minimum temperature, °F, four weeks prior to sampling
X_3: average maximum temperature, °F, two week prior to sampling
X_4: average temperature, °F, two weeks prior to sampling
X_5: average minimum temperature, °F, three weeks prior to sampling
X_6: number of days from a precipitation of one-half inch, or greater, to sampling

The results in Table 2 strongly indicate the inadvisability of using foliar analysis for site differentiation of loblolly pine. The variation in nutrient levels explained by weather factors is generally quite high, demonstrating that yearly fluctuations are to be expected. The lack of agreement between the variables correlated on each site would also act as a confounding factor; apparently, the foliar levels do not react to the same stimuli on sites as different as the two sample areas. It is noted that although no significant correlation was obtained for the Betheden nitrogen level, both potassium and phosphorus were correlated with the same independent variables – negatively with the average maximum temperature for two weeks prior to sampling, and positively with the average temperature for the same period. The Noxubee levels are correlated not only with different independent variables, but also with a greater variety of weather variables – average temperature, average maximum and minimum temperatures, and number of days since precipitation.

These differences are perhaps due to the variation in the respective microclimates and soil moisture regimes of the two areas; the Betheden area is characterized by a dry, warm microclimate with no problem of excessive soil moisture to inhibit nutrient uptake, whereas the Noxubee sample area has a cooler, more moist climate, and moisture may be limiting at times due to the topographic position and poor internal drainage of the soil.

Although the variables listed in the prediction equations given in Table 2 yielded the greatest explained variation of any two independent variables, other combinations of variables were also significant at the 1% level. In order to compare the trends between sample areas, prediction equations were developed which included the same independent variables for each site (Fig. 6, 7).

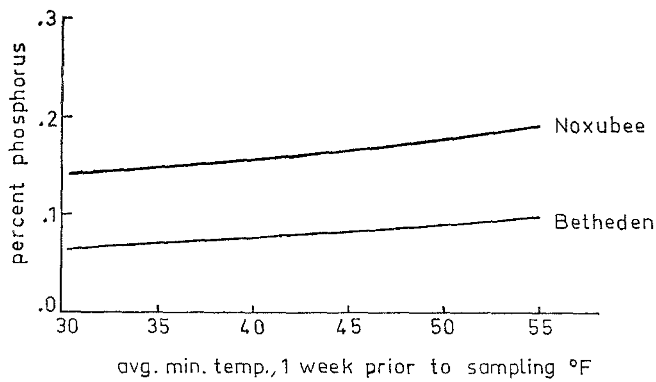

Fig. 6. Foliar phosphorus content for 50°F average minimum temperature four weeks prior to sampling, and variable average minimum temperature one week prior to sampling.

Again there is the indication that phosphorus levels are more variable between sites than nitrogen or potassium; that is, there is a more consistent difference in phosphorus levels, and this nutrient is the only one in this study that could conceivably be used as a reflection of site differences. This view does not appear to be generally acceptable in light of the work of Kessell and Stoate [4] who found that only the foliar sodium content reflected site differences, and the work of Young [12] which indicates that whenever soil phosphorus levels are above a critical content, the foliar phosphorus levels remain fairly constant. Leyton [5 6], and Hoyle and Mader [3], however, advocate the use of foliar analysis to distinguish

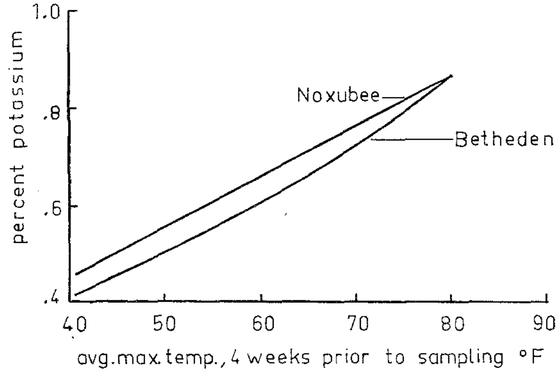

Fig. 7. Foliar potassium content for seven days from precipitations of one-half inch, or greater, to sample date, and variable average maximum temperature four weeks prior to sampling.

between sites; both found significant correlations between foliar nitrogen, phosphorus, and potassium and the height growth increment of Japanese larch (*Larix leptolepis* Murr) and red pine, respectively.

CONCLUSIONS

General seasonal trends in foliar nitrogen, potassium, and phosphorus levels on both sites follow previously reported trends; however, stability of fall and winter levels was not found in this study to the extent reported in other work. The indeterminate nature of loblolly pine growth is a confounding factor which might account for the variability – if weather conditions are favourable, late and early season growth flushes can occur.

Although large apparent differences in foliar levels between sites occurred during the spring and fall, levels were not stable during these periods and the differences were generally not statistically significant. In view of these findings, it would not be feasible to use foliar analysis as a means of site differentiation.

The strong statistical correlation of foliar levels with weather factors would indicate that seasonal fluctuations are to be expected, and this relationship would make it difficult to establish foliar trends that would reflect optimum levels for a species.

ABSTRACT

The study investigated the fluctuation in foliar nutrient levels (over a period of approximately three years) on two sites of widely differing productivity for loblolly pine. Preliminary analysis at the end of the first year indicated large variations in foliar levels with time which were attributed to weather factors, and further sampling was initiated to evaluate the influence of weather. A lack of a stable period during any portion of the year was attributed to the indeterminate growth habit of loblolly pine, and this aspect, together with a strong statistical correlation of weather factors with foliar levels, suggests that if foliar nutrient levels are obtained by the method used in this study, results could not be recommended for use in site differentiation of this species. The weather factors most commonly correlated with foliar levels were average maximum and average minimum temperatures for certain periods preceeding the sampling date.

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