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Effects of Fire on Nutrient Availability in a North Carolina Coastal Plain Pocosin

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ABSTRACT: Nutrient availability was monitored in recently burned and unburned blocks of a large ombrotrophic shrub-bog in Jones Co., North Carolina, U.S.A. Availability of Mg, K, PO_4-P, NH_4-N and NO_3-N was significantly increased, whereas available Ca was lower in the burned area than the unburned area. Concentrations of several nutrients, particularly PO_4-P and NO_3-N, were considerably more variable spatially in the burned area. Nutrient concentrations in peat from the clipped plots were not different from those of unmanipulated areas. Bioassays using *Pinus serotina* revealed phosphorus deficiency in unburned peat which was ameliorated by burning.

INTRODUCTION

Pocosin or freshwater shrub-bog ecosystems occur on over 4 million ha of the lower Coastal Plain of Virginia and the Carolinas (Richardson *et al.*, 1981). Fires recurring at intervals of 20-40 years have long been recognized as an integral part of the ecology of these wetlands (Wells, 1946; Woodwell, 1956; Kologiski, 1977; Christensen, 1981), but the environmental effects of fire, especially with regard to nutrient mobility and availability, have not been studied.

Pocosins are highmoor, ombrotrophic bogs (Gorham, 1957; Moore and Bellamy, 1974) dominated by a continuous shrub cover 1-4 m high with scattered emergent trees, usually pond pine (*Pinus serotina*). (*See* Wells, 1946; Kologiski, 1977; Snyder, 1980; Christensen *et al.*, 1981, for detailed discussions of the floristic composition of these communities.) Aboveground standing crop varies from 500 to over 4000 $g \cdot m^{-2}$ (Wendel *et al.*, 1962; Christensen *et al.*, 1981). The least productive areas occur in the high centers of bogs which may be several thousand hectares in extent. Productivity is thought to be limited by nutrient availability, especially phosphorus (Woodwell, 1958).

Vegetational responses to fire in pocosins are known primarily from qualitative observations. Wells (1946) suggested that production and species richness increased following fire, but made no measurements to test this suggestion. We have presented data elsewhere (Christensen *et al.*, 1981) suggesting that aboveground production is increased following fire; however, a large portion of this increase may result from allocation of below-ground resources rather than elevated rates of photosynthesis.

Our goal in this study was to determine what impact fire has on nutrient availability and to evaluate the potential importance of fire-caused nutrient changes using a nutrient bioassay experiment.

METHODS AND MATERIALS

Study area.—The study area was located in the Great Lake Pocosin, Croatan National Forest, Jones Co., North Carolina (34°55′N, 77°05′W). Throughout the study area 30-50 cm of hemist peat overlies 100-200 cm of fine-textured muck. Living plant roots are confined to the hemist horizon. Logs and stumps of swamp forest trees, particularly *Chamaecyparis thyoides*, are common at the base of the peat profile. Radiocarbon dates for wood from similar logs collected in the Hofmann Forest (15 km from the study area) vary from 6000-7900 years BP (Daniels *et al.*, 1977). These dates correspond with the timing of a regional episode of bog initiation throughout the Atlantic Coastal Plain (Daniel, 1981). The subpeat surface is a densely packed clay sand.

12-20"

In 1955 a grid of drainage canals ca. 2 m deep was established in this area, creating rectangular blocks of pocosin approximately 2 km long and 0.3 km wide. On March divided equally among these 10 nutrient treatments: (1) distilled water (DW) only; (2) complete nutrient supplement (CNS); (3) CNS minus nitrogen; (4) CNS minus phosphorus; (5) CNS minus sulfur; (6) CNS minus calcium; (7) CNS minus magnesium; (8) CNS minus potassium; (9) CNS minus iron; (10) CNS minus micronutrients. All nutrient solutions were prepared as described by Machlis and Torrey (1956), except that nitrogen was provided both as NO_3-N and NH_4-N as recommended by Woodwell (1958). Iron was provided as Fe-EDTA. Each week 3 ml of appropriate treatment solution was provided to each pot. Plants were otherwise watered as needed with distilled and deionized water. After 60 days, roots and shoots were harvested from each plant, dried 48 hr at 70 C and weighed. Data were analyzed using 2 x 10 factorial analysis of variance (Barr *et al.*, 1979).

RESULTS

Changes in total biomass during the study area are shown in Figure 1. Concentrations are expressed on a per gram as well as volumetric basis (based on mean bulk density of 0.11 for the 0-5 cm peat horizon). At every date following burning, magnesium was significantly more available in the burned area than the control, even after two growing seasons. Calcium concentrations, on the other hand, were either the same or lower in burned peat compared to unburned peat. Potassium concentrations were significantly higher in the burn in the first growing season following burning, and significantly lower in this area during the second growing season. Concentrations of potassium were, in general, an order of magnitude lower than either calcium or magnesium.

Mean *p*H in both burned and unburned peat was 3.6 for the period of the study. Although significant differences were observed in *p*H from sample date to sample date, the differences were inconsistent and never exceeded 0.3 *p*H units.

Concentrations of phosphate increased dramatically in the burned peat and remained high throughout the first growing season. From October 1979 to June 1980 there were no differences in phosphate concentrations between burned and unburned plots. In addition to higher mean concentrations, the variance in phosphate concentrations was greatly increased by burning. Thus, phosphate is not uniformly available over the area following fire.

Changes in mineral nitrogen were somewhat more complex. Soil ammonium was significantly higher in the burned area on several dates during the first growing season but not consistently so. After July 1979, there was either no difference or ammonium was less concentrated in burn peat (January 1980). Because of sample storage problems, nitrate values were not available for April 1979. Nitrate concentrations were consistently and significantly higher in the burned area during the first growing season, particularly during May and June. Nitrate concentrations were again higher in the burn in March 1980, although the magnitude of the difference was considerably less than in the previous year.

In order to discern whether the observed nutrient changes were a consequence of shrub removal as opposed to ash fall and fire-related mobilization, nutrient concentrations were monitored in the 0-5 cm peat horizon in the clipped plots on several dates during the first growing season. None of these nutrient species was ever present in concentrations significantly different from the unburned control area.

With respect to magnesium and potassium, concentrations are higher in the burn than the control, at least down to 20 cm (Fig. 2). Although phosphate is higher at the surface, it is actually significantly lower in the burn than unburned peat at depths of 5-20 cm. No significant differences were observed in ammonium between areas, but the accumulation of ammonium at depths below 30 cm is striking. In the burn, nitrate was high to a depth of 30 cm.

The results of the nutrient availability bioassay on *Pinus serotina* (Fig. 3) were somewhat more complex than results of similar experiments comparing burned and

unburned soils in other ecosyste
Christensen and Muller, 1975; Cl
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added to the nutrient solution. W
and Fe resulted in seedling gro
Seedling growth in treatments no
tually significantly enhanced rela
(1958) also observed decreased
populations of *P. serotina*.

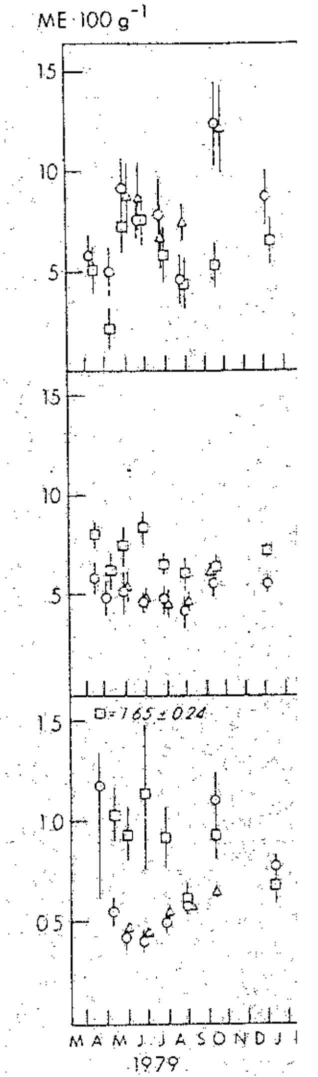

Fig. 1.—Changes in concentrati
following fire in the burned (□), u
mean of 20 samples and lines desig
vided in the text. Concentrations ar
graph and on a peat volume basis (

Growth of pine seedlings in burned peat watered with distilled water only was improved slightly over unburned peat, but this difference was not statistically significant. Growth in the -P treatment was significantly enhanced in the burned peat relative to the same treatment on unburned peat, suggesting that phosphorus was indeed made more available by burning. A comparison of treatments on burned peat reveals that the -N and -P treatments were less productive than the CNS treatment. While the addition of either N or P singly enhanced growth, the addition of both together resulted in even greater production in burned peat.

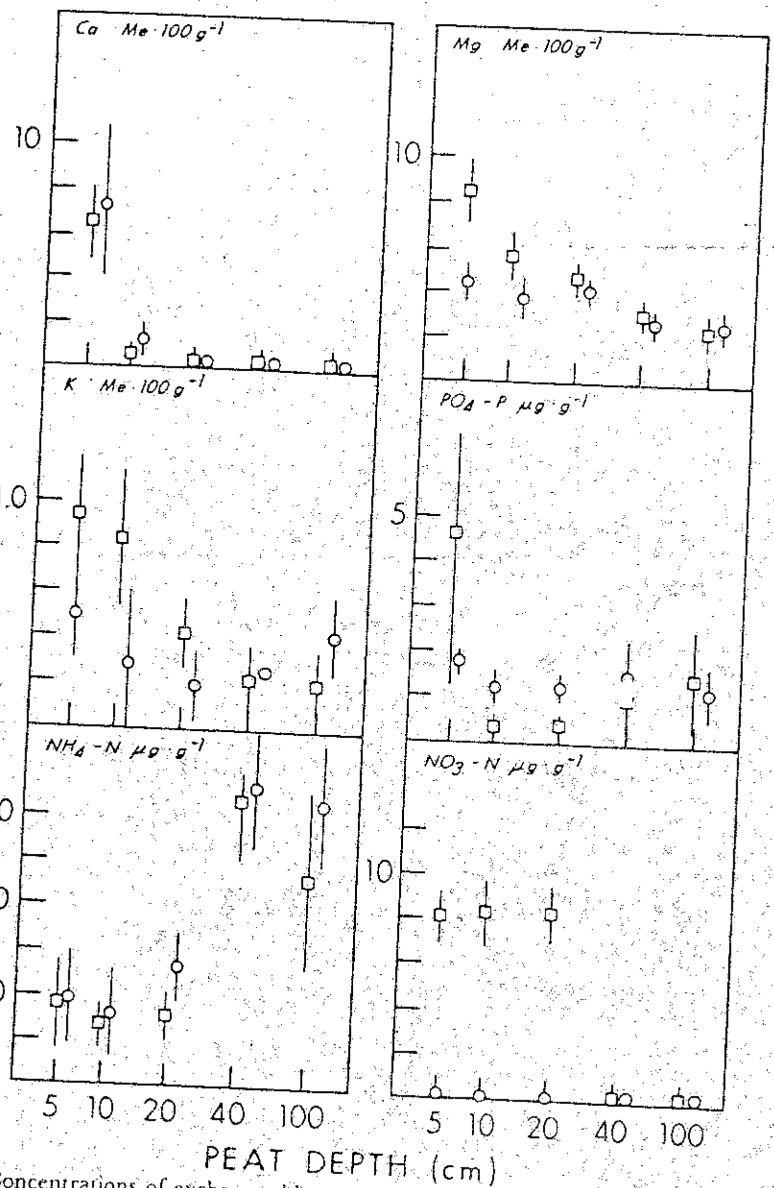

Fig. 2.—Concentrations of exchangeable nutrients at five depths in peat from burned (□) and unburned (△) treatments on 20 June 1979, 84 days following burning. Each point is the mean of five samples and lines designate 95% confidence intervals

amelioration of the prefire phosphorus deficiency. These nutrient changes undoubtedly are responsible in part for increased postfire production. The increased fertility following fire was short-lived, and by the second growing season concentrations of most nutrients were back to prefire levels.

Not only were mean concentrations of particular nutrients elevated following fire, but spatial variation in those concentrations was also increased. This was particularly true for nitrogen and phosphorus. Thus, high and low nutrient patches are created in an area characterized by uniformly low prefire nutrient concentrations. This redistribution of resources might lead to the creation of patches of high and low production within the bog.

The effects of fire on nitrogen transformations and availability have attracted considerable attention, although few generalizations are possible (Raison, 1979). In this study, on those occasions when differences were observed in burned and unburned peat, concentrations of ammonium were higher in the burn. We did not, however, observe a large flush of ammonium such as described by Christensen (1973) in chaparral. Nitrate concentrations were considerably higher in the burned peat. We are uncertain as to whether this increase in nitrate was a consequence of ash addition, reduced plant uptake or changes in rates of nitrification and denitrification. Drying of surface peat, such as occurred in the burned area, has been shown to enhance nitrification relative to denitrification in a variety of organic soils (Gilliam and Skaggs, 1981). The significance of this increased availability of nitrate to postfire plant growth is unknown.

Increased availability of nutrients may result not only from the instantaneous production of ash, but also from postfire environmental changes which favor increased rates of mineralization. Christensen (1973, 1977) found that considerable quantities of nutrients in ash not rendered immediately available by burning in chaparral and pine savannas were nonetheless much more amenable to mineralization by microbes. Furthermore, drying of the upper peat horizons may result in higher rates of peat oxidation (Tate, 1980). This oxidation may be further accelerated by higher peat temperatures owing to increased insolation following burning.

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