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The affects of Nitrogen and Phosphorus addition on peatland plant communities

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Introduction

Nutrient limitation is the phenomenon of a plant's production being limited by the inadequate supply of a necessary nutrient. This nutrient may be one the plant needs in large quantities or one that is merely very scarce. Most often, nitrogen and phosphorus are the limiting nutrients for plants and the communities they comprise, nitrogen more often than phosphorus, (Laurie Kellogg, personal communication).

In agricultural systems, nutrient limitation is well known. Soil fertility is an important part of the growth and development of plants, therefore agronomists have invested time and money in research to determine optimal nutrient applications, times of fertilization and many other aspects of fertility (Fellmann and Kahnt 1987 and Sticksel et al. 1999). Plants that do not grow and produce fruit are economically worthless; those that produce to their maximum potential. are most valuable.

Peatlands are also economically important, if in a less obvious way. First, as wetlands, they serve as drainage sites for surrounding areas, because they are by nature lower than these surrounding areas (Cole, 1994). Good drainage is of particular interest to those who live in low-lying areas where flooding is frequent. Related to their capacity as drainage sites, wetlands also often serve as nutrients sinks, trapping nutrients from fertilizer runoff or sewage. This function prevents the eutrophication of nearby lakes and rivers (Dr. Hellenthal, personal communication). However, not as much is known about nutrient limitation in peatlands.

Peatlands are wetlands which accumulate dead organic matter; the conditions in peatlands are not favorable to decomposition because of the cold temperature (peatlands usually occur at relatively extreme latitudes) and the anaerobic situation due to being water-logged (Bridgham, 1996). Due to this slow or nonexistent decomposition, organic matter is seldom broken down into its inorganic constituents, suppressing the nutrient cycling and potentially limiting the plant community's growth. Plants in these areas are forced to find their nutrients elsewhere, either in precipitation, groundwater, or less often, by predation. There are several types of peatlands, and nutrient source (according to hydrology) is actually one of the means by which they are classified.

Peatlands fall into a natural gradient, from ombrotrophic peatland, or bog, to minerotrophic peatland, or rich fen. Bogs characteristically have a low concentration of dissolved cations and a resultantly low pH. Their vegetation is dominated by Sphagnum mosses, conifers, and ericaceous shrubs. Sphagnum mosses absorb cations which reduces the water's buffering capacity and secrete organic acids (Clymo and Hayward, 1982). Both of these phenomena contribute to the low pH in bogs. Intermediate fens have generally a higher pH (4.9-6.0) and concentration of cations. Rich fens have a slightly higher pH. This low pH, at least in intermediate fens and bogs further impedes the decomposition. Bogs are more likely to obtain nutrients from precipitation, a condition referred to as ombrotrophy. Fens generally obtain nutrients from groundwater, which is referred to as minerotrophy. (Bogs are generally older than fens, and the accumulation of peat has brought the ground surface above the water table). Both of these nutrient sources are poor relative to an ecosystem in which nutrients are cycled through decomposition. However, low nutrient availability does not necessarily imply nutrient limitation (Chapin et al., 1985).

In fact, knowledge about the relative amounts and importance of nutrients to communities, populations, and species within peatlands is constrained because there are few experimental studies. Nitrogen and phosphorus have been identified as limiting nutrients in these areas, but contradictory results have been found in both the laboratory and the field. Some studies have found N and P to be limiting nutrients (Aerts et al. 1992), while others have found that they actually inhibit growth in higher concentrations (Lee et al. 1987). How well-adapted peatland communities are adapted to their nutrient poor conditions is yet to be determined; additional manipulative experimentation is needed.

During the growing season of 1999, we examined the effects of the addition of N, P, and N+P in combination on plant diversity. We added the nutrients to three peatland types and monitored their effects on the percent cover of graminoids, forbs, and the number of shrubs and trees. We hypothesized that the plant communities will eventually change according to fertilization type. Across a nutrient availability gradient, high nutrient availability to low, there will generally be different species. There will be those that thrive in fertile and those that thrive in barren sites; each will outcompete the other in the conditions to which it is adapted (Chapin, et al., 1985). Hypothetically, adding nutrients to a site will increase the fertility of the area. This change could give a competitive advantage to species adapted to more fertile conditions. Eventually, those plants limited by P would begin to dominate P-treated areas, those limited by N, the N-treated areas, and so on. The plant community compositions would be altered accordingly.

Materials and Methods

Sites:

The sites studied were nine peatlands on the property or in the vicinity of the University of Notre Dame Environmental Research Center (UNDERC): three bogs, three rich fens, and three intermediate fens. The bogs had water tables beneath the ground surface, a low pH (3.9-4.3), and their vegetation was dominated by Sphagnum mosses. The rich fens had above ground water tables, higher pH (5.8-6.6), and graminoids were more prevalent among vegetation. The intermediate fens had characteristics that were between the other two types (pH =4.9-5.0;). The vegetation was a mix of graminoids and mosses.

Within each site were four 32 x 32 m treatment areas demarcated by PVC pipes at each corner. To keep track of these plots and their prescribed fertilizers, we marked each of their PVC pipes with a colored tape associated with treatment. Pink designated a nitrogen-treated area, yellow a phosphorus-treated area, and orange an area that was treated with both fertilizers. White designated the control area. We fertilized these areas during the periods between May 29th and June 1st and between July 6th and 7th. Each of these areas contained five 1 m^2 permanent plots within which we did our analyses. Both the treatment areas and the permanent plots were established during the growing season of 1998. They have been fertilized twice a year since, both treatments during the growing season. Each of the four treatment areas received a different fertilization regime. We fertilized one with nitrogen (3g/m^2 of N in the form of urea); one with phosphorus (1g/m^2 of P in the form of phosphate); one with both nitrogen and phosphorus (3g/m^2 and 1g/m^2 respectively); and left one of the areas untreated as a control.

Cover Analysis:

We analyzed the percent cover of moss, graminoids, and forbs, and stem counted shrubs and trees during the period of July ?-?. We used the point-intercept method to analyze the graminoids and forbs (Jonasson, 1988). We used a one meter long wooden frame with holes every ten centimeters. Points are taken by lowering a bicycle spoke through a hole and counting how many times it hits a species. We took forty points in each of the five permanent plots of each treatment area, for a total of two hundred points. We then determined cover percentage to be the total number of hits for a species over the total points, two hundred. For shrubs, we counted the number of stems of each species there were in each permanent plot. To analyze tree cover, we counted the number of trees within two randomly chosen 10x10 m plots.

The cover analysis data was used to produce Shannon-Wiener indexes (H) for graminoids and forbs, according to the equation:

$$H=\Sigma[X_i *\log_2(X_i)],$$

where X_i is the proportion of the ith species, here just cover percentage multiplied by one hundred. The proportions for shrubs and trees were simply total stems/individuals of a species divided by total stems/individuals of shrubs or trees respectively.

Data Analysis:

Treatment effects on each functional group (graminoids and forbs; shrubs; and trees) were examined using one-way analyses of variance (ANOVA's). I compared the effects of the different treatment types (N, P, N+P, C) within peatland type (bog, intermediate fen, rich fen). Second, I compared nutrient addition among peatland types. For those data sets which were found to have significant p-values (a=0.07), I ran the post-Hoc Tukey test to determine which subsets were significantly different from each other.

Results

For the diversity of graminoids and forbs, there was no significant difference among the treatment regimes in the rich fens or in the intermediate fens. There was a significant difference in bogs (p=0.05). Within that set of data, I found that the N treatment (p=0.037) and the P treatment (p=0.052) differed significantly from the C treatment. Likewise, both differed significantly from the N+P treatment (N: p=0.022; P: p=0.03).

Also, peatlands were shown not to be significantly different in diversity of graminoids, forbs, shrubs, or trees. There was no significant difference among bogs, intermediate fens, and rich fens within the N treatment type, within the P treatment type, within the N+P treatment type, or within the C treatment type.

Conclusions

The data here support the possibility that N and P are limiting nutrients in bogs, as the Shannon-Wiener indexes (N: H=2.1; P: H=2.09) were significantly higher in the plots treated with these nutrients respectively than in the control plot (H=1.7).

Two possibilities may account for the inconclusive results. First, nutrients are susceptible to inorganic adsorption in infertile soil, making it unavailable to plants growing there (Chapin et al., 1985). In addition, decomposers in the area may be nutrient limited. Due to a greater surface-to-volume ratio and a more rapid growth response than that of macrophytes, decomposers can outcompete these macrophytes for a large portion of the added nutrients. Both of these phenomena lessen the availability of nutrients to plants in the first place.

Second, it takes time for plants to respond to fertilization. Those plants that are adapted to nutrient poor conditions respond less quickly than those adapted to fertile conditions (Chapin et al., 1985). Those plant communities that populate areas that are old in terms of succession also respond more slowly to nutrient additions than those plant communities characteristic of early succession (Chapin et al., 1985). The plants in bogs fit into both of these categories (Chapin et al., 1985 and Cole, 1994). Also delaying the appearance of a response is the fact that there is a tradeoff in plants between competitive ability and colonization (Pacala, year?). Those plants that have a competitive advantage in a habitat have less of an ability to spread throughout that habitat. The plants that benefit from the fertilization may not immediately colonize the entire habitat simply because they now have a competitive advantage.

Works Cited

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Figure 1 displays the Shannon-Wiener indexes calculated for the different treatment types within rich fens. C= control; N= nitrogen; N+P= nitrogen and phosphorus; and P= phosphorus.

Figure 2 displays the Shannon-Wiener indexes calculated for the different treatment types within bogs. See figure 1 for legend. The letters indicate statistical difference or sameness. The a's are statistically similar to each other but significantly different from the b's, which are statistically similar to each other.

Figure 3 displays the Shannon-Wiener indexes calculated for the different treatment types within intermediate fens. See figure 1 for legend.

Figure 4 displays the total number of shrubs counted in the different treatment types within rich fens. See figure 1 for legend.

Figure 5 displays the total number of shrubs counted in the different treatment types within bogs. See figure 1 for legend.

Figure 6 displays the total number of shrubs counted in the different treatment types within intermediate fens. See figure 1 for legend.

Figure 7 displays the total number of shrubs counted within each peatland type in the control plots. Bog= shrubs in bogs; IF= shrubs in intermediate fens; RF= shrubs in rich fens.

Figure 8 displays the total number of shrubs counted within each peatland type in the nitrogen plots. See Figure 7 for legend.

Figure 9 displays the total number of shrubs counted within each peatland type in the phosphorus plots. See Figure 7 for legend.

Figure 10 displays the total number of shrubs counted within each peatland type in the nitrogen-phosphorus plots. See Figure 7 for legend.

Figure 11 displays the Shannon-Wiener indexes calculated for each peatland type in the nitrogen-phosphorus plots. See Figure 7 for legend.

Figure 12 displays the Shannon-Wiener indexes calculated for each peatland type in the nitrogen plots. See Figure 7 for legend.

Figure 13 displays the Shannon-Wiener indexes calculated for each peatland type in the control plots. See Figure 7 for legend.

Figure 14 displays the Shannon-Wiener indexes calculated for each peatland type in the phosphorus plots. See Figure 7 for legend.

Figure 15 displays the total number of trees counted within the various treatment plots in bogs. See figure 1 for legend.

Figure 16 displays the total number of trees counted within the various treatment plots in intermediate fens. See figure 1 for legend.

Figure 17 displays the total number of trees counted within the various treatment plots in rich fens. See figure 1 for legend.

Figure 18 displays the total number of trees counted within each peatland type in the nitrogen plots. See figure 7 for legend.

Figure 19 displays the total number of trees counted within each peatland type in the phosphorus plots. See figure 7 for legend.

Figure 20 displays the total number of trees counted within each peatland type in the nitrogen-phosphorus plots. See figure 7 for legend.

Figure 21 displays the total number of trees counted within each peatland type in the control plots. See figure 7 for legend.

Shannon-Wiener Index Data for Rich Fens

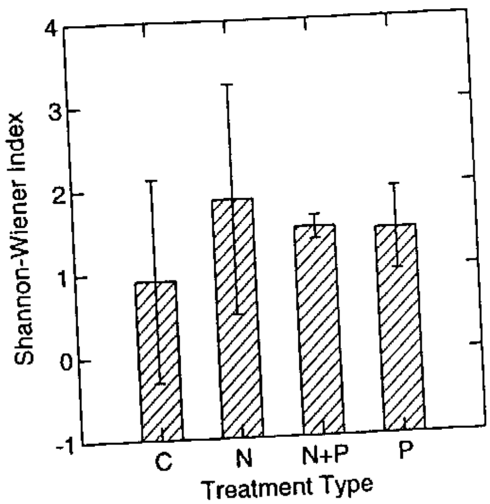


Figure 1.

Shannon-Wiener Index Data for Bogs

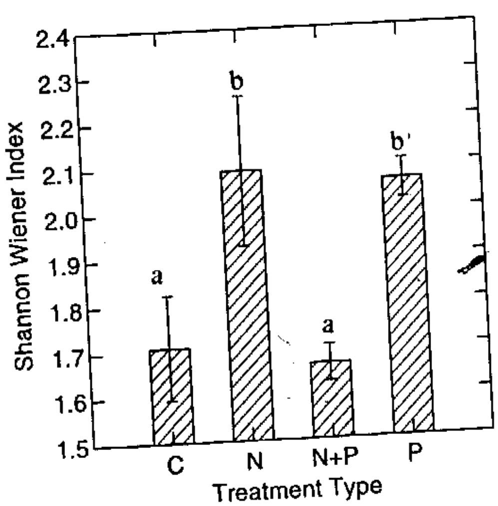


Figure 2.

Shannon-Wiener Index Data for Intermediate Fens

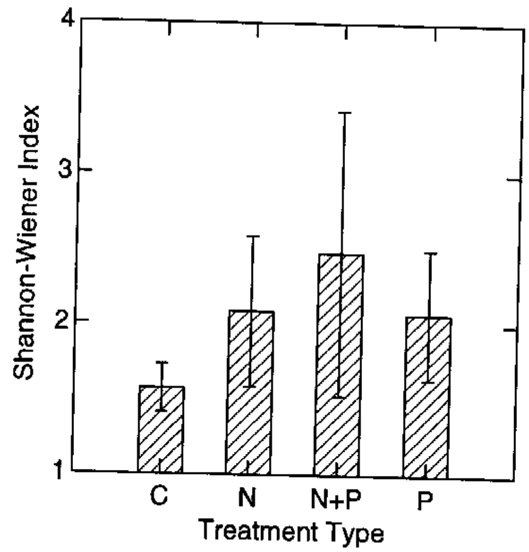


Figure 3.

Shrub Data for Rich Fens

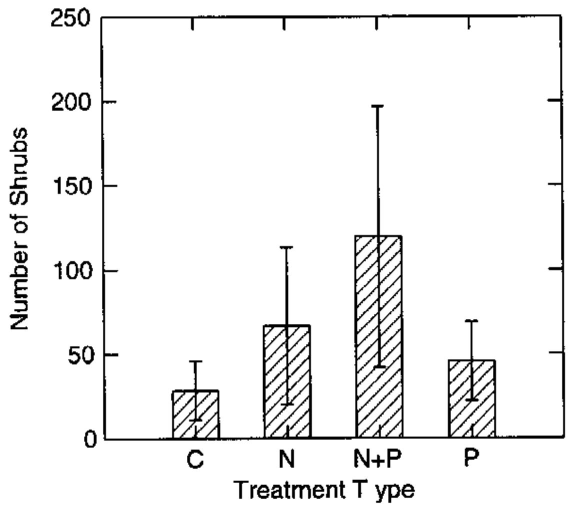


Figure 4

Shrub Data for Bogs

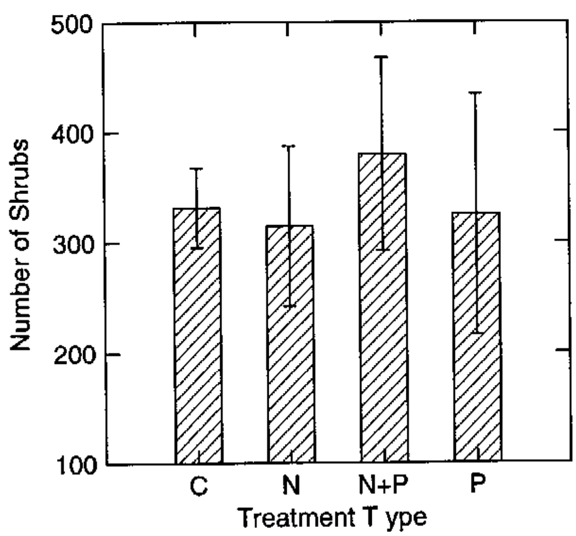


Figure 5.

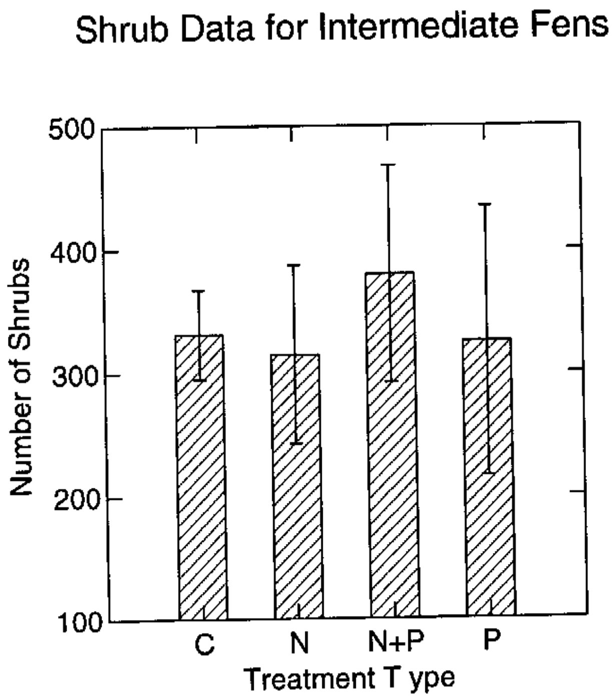

Shrub Data for Intermediate Fens
500
400
300
200
100
Number of Shrubs
C
N
N+P
P
Treatment T ype

Figure 6.

Shrub data for Control

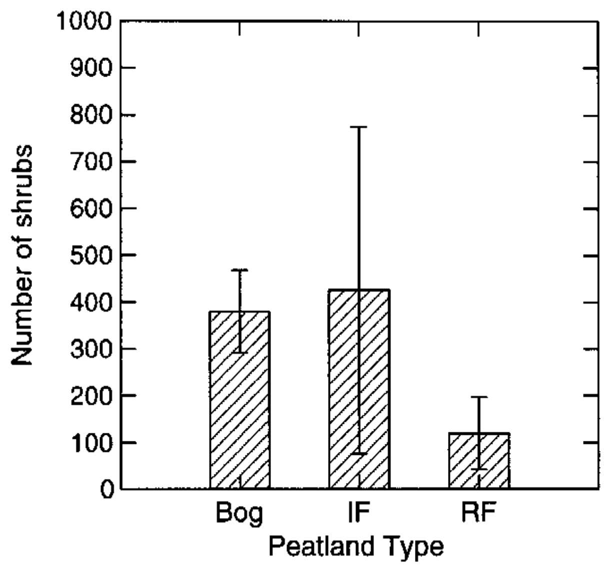


Figure 7.

Shrub data for Nitrogen Treatment

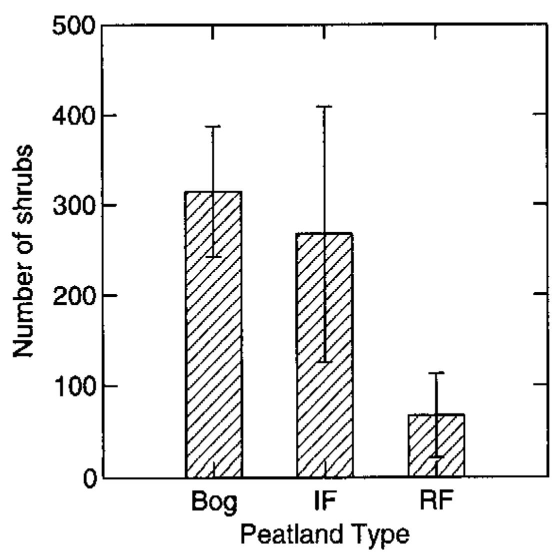


Figure 8.

Shrub data for Phosphorus Treatment

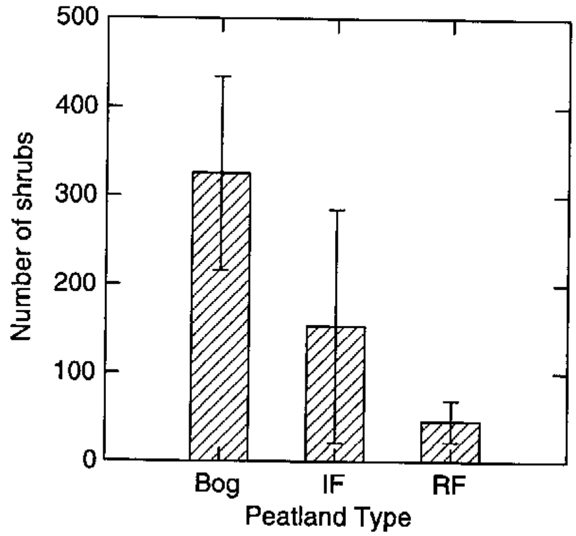


Figure 9.

Shrub data for Nitrogen-Phosphorus Treatment

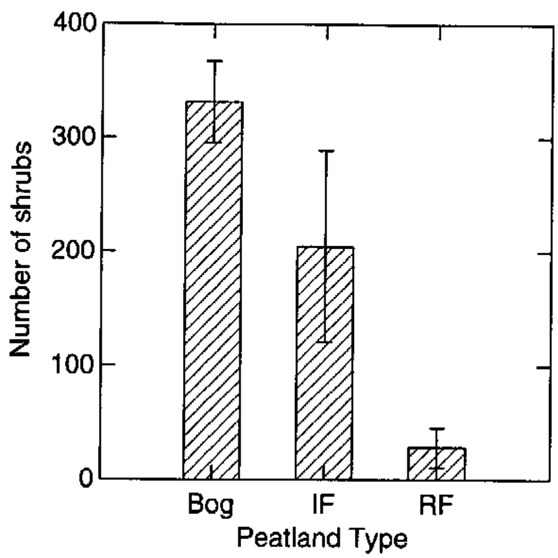


Figure 10.

annon-Wiener Index Data for Nitrogen-Phosphorus Treatment

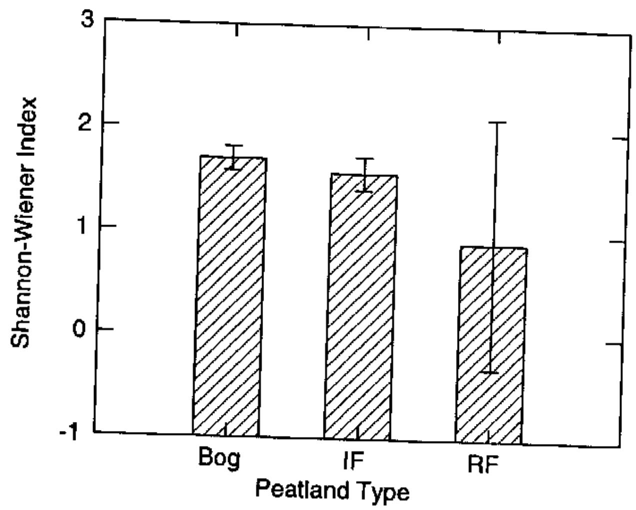


Figure 11.

Shannon-Wiener Index Data for Nitrogen Treatment

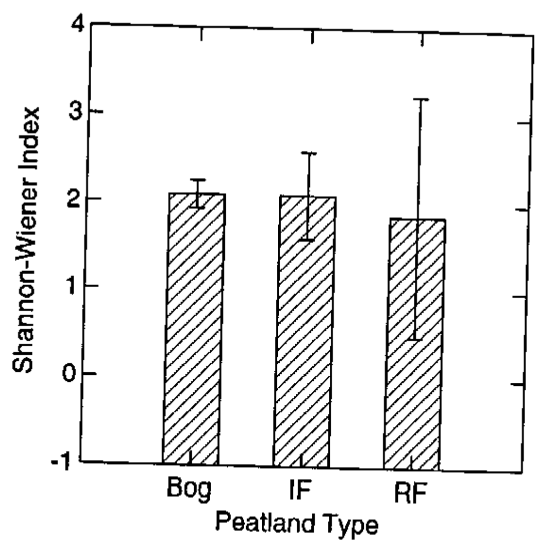


Figure 12.

Shannon-Wiener Index Data for Control

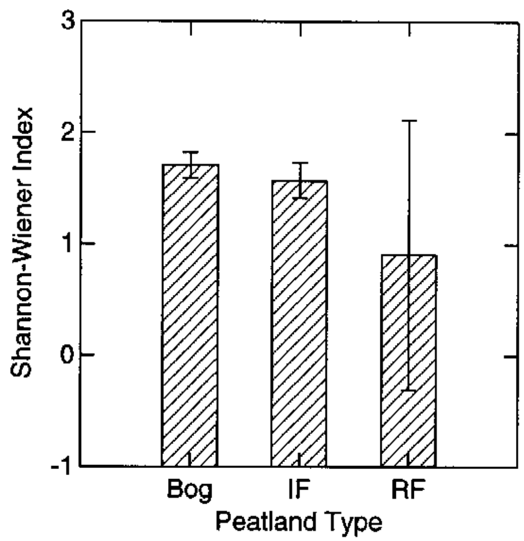
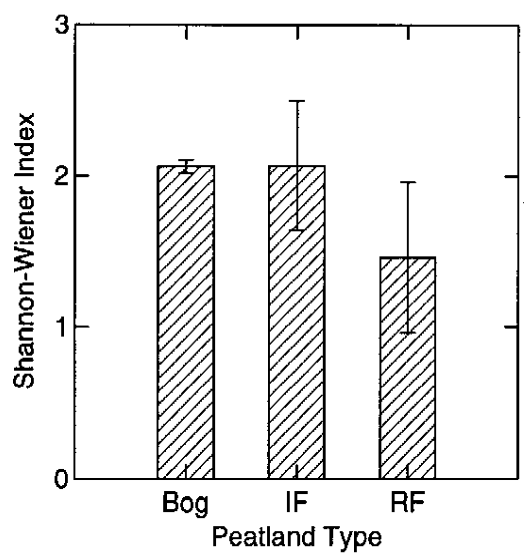


Figure 13.

Shannon-Wiener Index Data for PhosphorusTreatment



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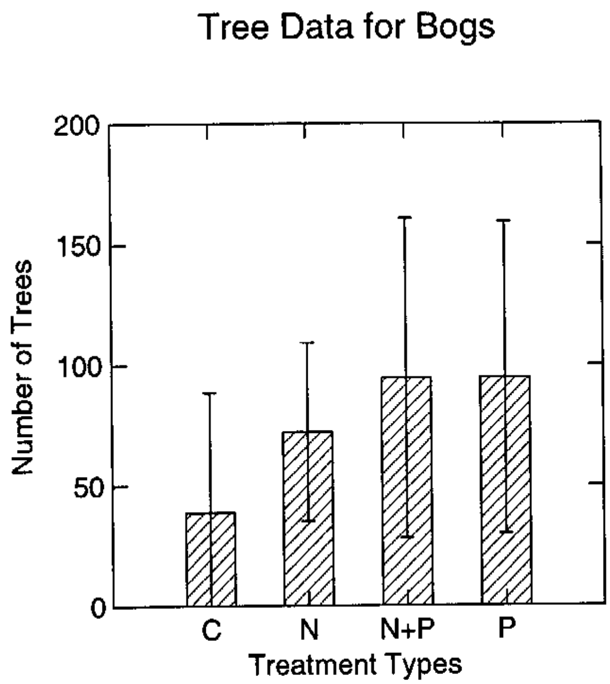

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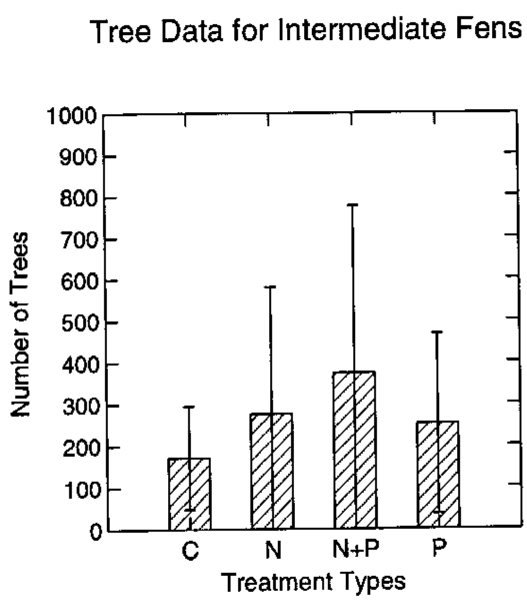

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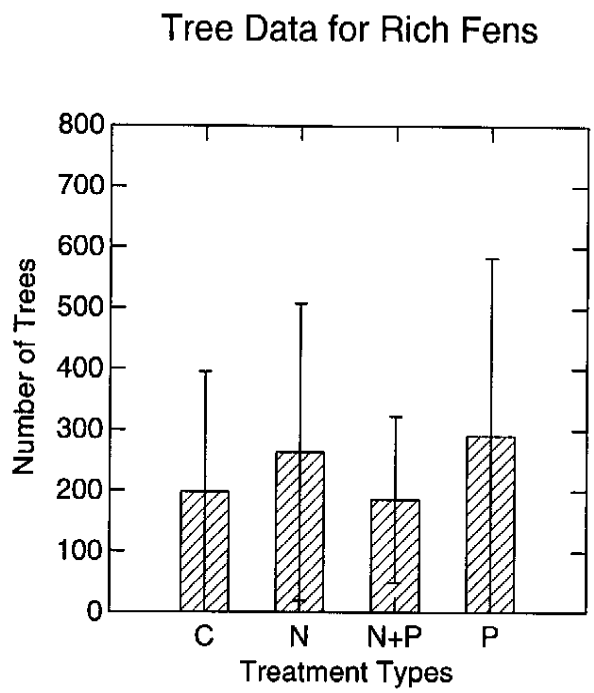
Tree Data for Rich Fens
800
700
600
500
400
300
200
100
0
Number of Trees
C
N
N+P
P
Treatment Types

Figure 17.

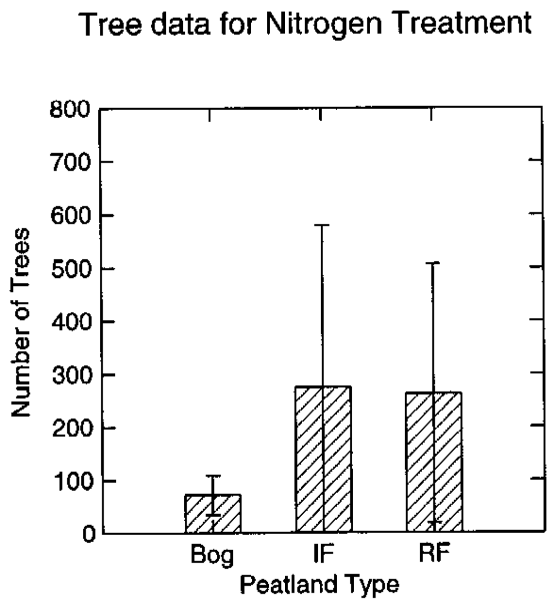

Figure 18.

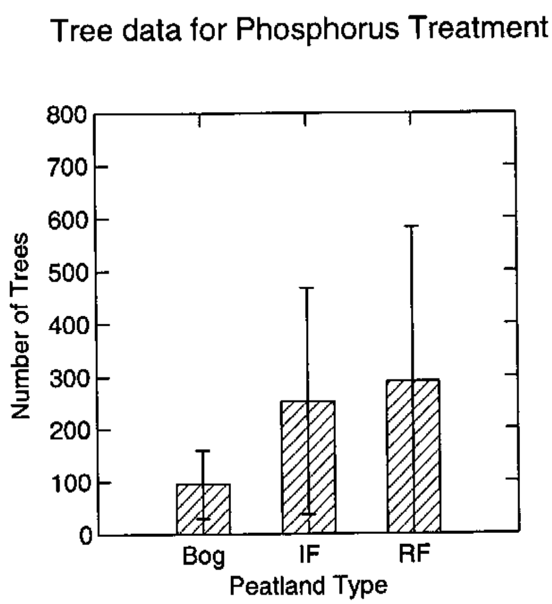

Figure 19.

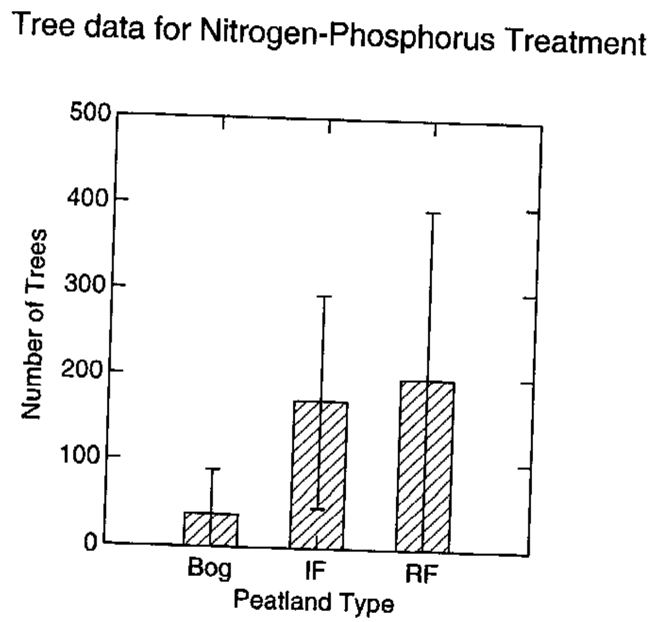

Figure 20.

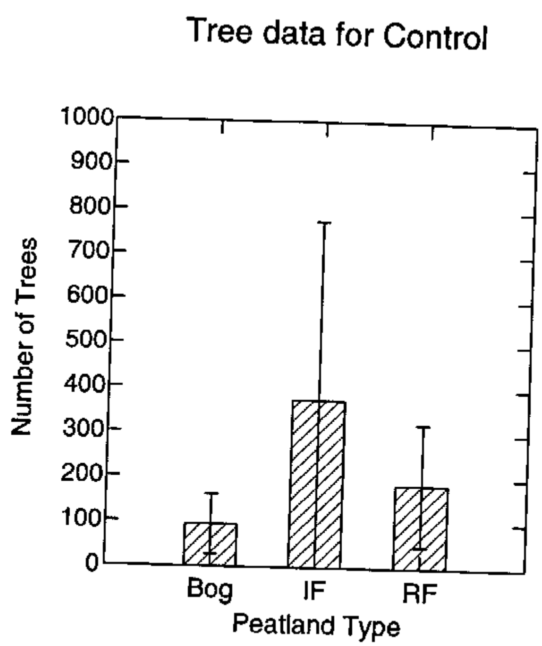

Figure 21.