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ABSTRACT — The productivity of natural stands of cattails (*Typha latifolia)* has been correlated with the amounts of nutrients in the soil and water by Boyd and Hess (Ecology, 51: 296, 1970). The direct effects of varying levels of nitrogen (N), phosphorus (P) and potassium (K) on productivity were examined in our study by growing cattails in Hoagland's nutrient solution. Concentrations of ¼, 1/16 , and 1/64 the amount of N present in complete Hoagland's solution (0.01M) resulted in 63 percent, 48 percent and 26 percent of the dry weight of plants grown in complete solution. Rhizomes used to start plants contained considerable amounts of P and K since growth in solutions with no P or no K resulted in dry weights up to 37 percent of that of plants grown in complete solution. Nutrient availability also affected plant morphology. Reduced N increased root growth up to 75 percent greater than that of plants grown in complete solution.

With the recent increased interest in alternative energy sources, the high productivity of marshes has promoted suggestion of cattails *(Typha)* as a source of biomass for conversion to other forms of energy (Fox, 1975; Moss *et al.*, 1977). Past research on cattails has centered around understanding its role in natural habitats and controlling its growth as part of wildlife management. As we turn from controlling cattail growth to investigating management techniques for maximum growth, knowledge of the growth response of cattails to nutrient availability is needed. In addition, methods for assessing the nutrient status of stands under management must be developed. Tissue analysis is widely used as a means of identifying the nutrient status of plants, particularly perennials (Smith, 1962). Generally, as increasing amounts of a nutrient are available, plant growth increases and the concentration of that nutrient in the plant increases. At the "critical level" further increases in nutrient result in increased concentration of the nutrient in the plant but no additional growth. If the concentration of the nutrient in the plant is below the critical level, then the plant's growth is limited by that nutrient. Because the critical level is affected by age of plant, part of plant sampled, and environmental conditions, critical levels are often defined as a range and require extensive research to define. Bould (1963) and Smith (1962) review the development and evidence for this interpretation of plant growth response to nutrient availability. This paper presents preliminary data for establishing critical ranges for phosphorus and potassium in *Typha angustifolia x latifolia* (Smith, 1967), also known as *T. x glauca* Godron.

In addition to affecting total plant growth, varying nutrient levels affect the pattern of growth. By using nutrient solutions to grow the plants, total recovery of below ground organs is possible. Thus the effect of varying nutrient availability on the development of plant organs may be accurately observed.

Methods used to grow cattails

Rhizomes of *Typha angustifolia x latifolia* were removed from paddies at the University of Minnesota (Fox, 1975; Moss *et al.*, 1977) during April 1977 and stored at 4 degrees C. Three weeks prior to the beginning of the experiment the rhizomes were trimmed in length to 10 cm and placed in buckets of water in the greenhouse (usually 21-24 degrees C day, 18-20 degrees C night). On June 12-14, 1977, the rhizomes with shoots (0.76-1.07 m) were suspended with nylon fishing line from one-inch mesh chicken wire frames which fit on the top of 19-liter plastic buckets. One rhizome was placed in each bucket. The exteriors of the buckets were painted black. Black plastic covers with slits for the shoots were fitted over the top of the buckets and wire frames. Sixteen liters of nutrient solution were added to each bucket. The plants were kept in the greenhouse (usually 23-29 degrees day, 18-20 degrees C night). The solutions were replaced after four weeks and thereafter every three weeks, deionized water was added as necessary to maintain 16 liters between solution changes for a total of 13 weeks. Hoagland's solution (Hoagland and Snyder, 1933) was used as the nutrient solution with 0.01 mM ferric ethylenediaminetetraacetic acid (Fe-EDTA) as a replacement for ferric tartrate. Complete solution had concentrations of 10 mM nitrogen, 1 mM phosphorus and 6 mM potassium. Treatments with reduced concentrations of nitrogen or phosphorus were ¼, 1/16, 1/64 and 0 times the nitrogen or phosphorus concentrations of complete solution. Potassium treatments had ½, 1/8, 1/32 and 0 times the potassium concentration of complete Hoagland's solution. The solutions with reduced amounts of N, P, and K were otherwise complete solutions. Thus there were 13 treatments: 0 M, 0.16 mM, 0.6 mM, 2.5 mM nitrogen; O M, 0.016 mM, 0.06 mM, 0.25 mM phosphorus; O M, 0.19 mM, 0.75 mM, 3 mM potassium; and complete Hoagland's solution. There were three replicates for each treatment except the no N, P, and K, which had two replicates each.

Preparing plant material for analysis

When the experiment was terminated, the plant material from each replicate was separated into root, rhizome and shoot portions and dried at 60 degrees C to constant weight. The dry weights of the root, rhizome and shoot samples were added together to give total biomass. Plants similar in height and weight to the starting material were dried and found to have a moisture level of 88 percent. Figures for total biomass were converted to net yields by multiplying the wet weight of the starting material by 0.12 and subtracting it from the total biomass weights. Dried samples were ground in a Wiley mill using a 20 mesh sieve. One gram samples were ashed at 485 degrees C for 9 hours and the ash dissolved in 10 ml of 2N HCl. These solutions were submitted to the Research Analytical Laboratory in the Department of Soil Science at the University of Minnesota for analysis by inductively coupled plasma spectroscopy.

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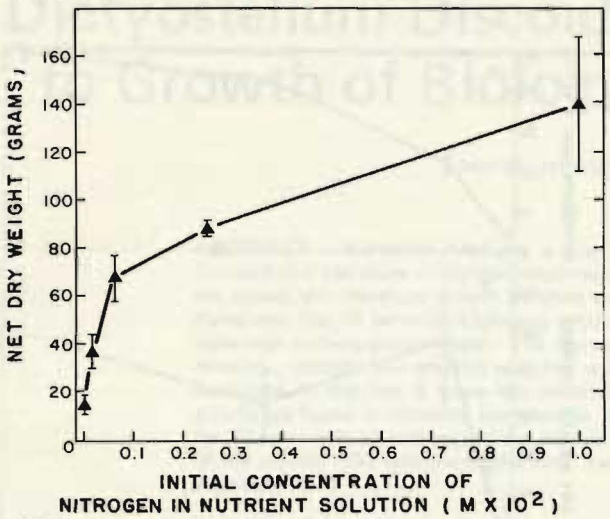
Figure 1. — Effect of nitrogen concentration in nutrient solution on net productivity.



The effects of varying nutrient availability

Nitrogen concentrations of 0, 0.16 mM, 0.6 mM and 2.5 mM resulted in 11 percent, 26 percent, 48 percent and 63 percent of the net dry weight of plants grown in complete solution (10 mM) (see Figure 1). The net dry weights produced by 0 and 0.16 mM nitrogen are significantly different from each other and from the results of all other nitrogen treatments at the 5 percent level (one-tailed t-test). Since productivity was increased by each increment in available nitrogen including complete solution, plants grown in complete solution may still have been nitrogen limited. Results from tissue analyses for nitrogen are not completed and will be reported at a later time.

Phosphorus concentrations of 0 and .016 mM produced plants whose net dry weights averaged 37 percent and 61 percent of plants grown in complete solution (1 mM P) (see Figure 2). Analysis of variance using the revised least significant difference method (LSD) indicated, however, that there were no significant differences at the 5 percent level between treatments. The rhizomes used for starting material had a mean concentration of 4,000 ppm phosphorus. Increasing amounts of phosphorus available to the plants resulted in shoot tissue concentrations increasing up to 13.6 times that of plants given no phosphorus. While the maximum shoot concentration of phosphorus was 4,800 ppm, plants with 920 ppm achieved similar net productivity (Figure 2). Phosphorus tissue concentrations from each phosphorus treatment are significantly different from those of the other phosphorus treatments at the 5 percent level (one tailed t-test).

Potassium concentrations of 0 and 0.19 mM resulted in 25 percent and 45 percent of the net dry weight of plants grown in complete solution (6 mM) (see Figure 3). The differences between treatments were shown not to be significantly different at the 5 percent level by analysis of variance using the revised LSD method. The initial concentration of potassium in rhizomes used as starting material was 24,000 ppm. The concentration of potassium in shoot tissue varied among treatment from 4,300 to 48,000 ppm while 21,000 ppm was sufficient for maximum net productivity. Potassium tissue concentration for each treatment is significantly different from all other treatments at the 5 percent level (one-tailed t-test).

Reduced availability of nitrogen and phosphorus appears to increase root tissue above that of plants grown in complete solution (Table 1), although the differences lacked statistical significance at the 5 percent level. However, the ratio of root dry weight to total biomass is significantly different from that of the complete solution at the 2.5 percent level for the 0.16 mM nitrogen treatment, at the 0.1 percent level for the 0.6 mM nitrogen treatment, and the 5 percent level for the 0.016 mM phosphorus treatment (Table 1).

Comparisons with other reports

Controlled experiments examining the relationship between available nutrients and their concentration in plant tissue have not been reported for *Typha* spp. However, there has been considerable research examining nutrient parameters in natural populations. Boyd and Hess (1970) sampled 28 populations of *Typha latifolia* in the southeastern United States. They found phosphorus concentrations in shoots ranging from 0.05 percent to 0.4 percent of the dry weight with a mean of 0.21 percent. Potassium concentrations ranged from 0.5 percent-4.5 percent with a mean of 2.38 percent. The values obtained in this study are thus similar to those found in nature for one of the two species forming the hybrid studied here. The critical value for potassium suggested by this study (21,000 ppm) is near the mean value Boyd and Hess found for their stands. The critical value found here (900 ppm) for phosphorus is less than half Boyd and Hess's mean value and near the minimum they found.

Smith (1962) in reviewing mineral analysis of plant tissues emphasizes that tissue concentrations vary with sampling and analysis methods, species, age of plant, portion of plant sampled, the concentration of other minerals and environmental factors. The low critical value found for phosphorus may be related to the sampling occurring late in the season. Boyd (1970, 1971) finds shoot concentrations of phosphorus and potassium in *Typha latifolia* falling throughout the season although net accumulation per area increases. In one of his studies (1970) phosphorus shoot concentration decreases from 0.31 percent to 0.09 percent and potassium from 3.46 percent to 1.6 percent during the three month growing season. Kvet (1975) also finds decreasing shoot concentrations in *T. latifolia* (P, 0.18-0.09; K, 3-1 percent). Mason and Bryant (1975) report similar results for *Typha*

Table 1.
Effects of different solution concentrations on root dry weight and ratio of root dry weight to total biomass.

Treatment	Root dry weight[1]	Root/Total biomass[1]	p[3]
complete solution			
10 mM N, 1 mM P, 6mM K.	7.2 ± 1.4 g.	0.049 ± .007	
Nitrogen			
2.5 mM	6.9 ± 0.9	0.072 ± .008	>.05
0.6 mM	12.6 ± 2.3	0.155 ± .013	<.025
0.16 mM	12.3 ± 2.5	0.260 ± .004	<.001
0	3.9 ± 0.6[2]	0.161 ± .024[2]	>.05
Phosphorus			
0.25 mM	4.5 ± 1.3	0.042 ± .014	>.05
0.06 mM	19.0 ± 7.9	0.115 ± .027	>.05
0.016 mM	13.7 ± 2.0	0.145 ± .017	<.05
0)	9.3 ± 2.8[2]	0.257 ± .093[2]	>.05
Potassium			
3 mM	8.7 ± 0.7		
0.75 mM	10.6 ± 3.0		
0.19 mM	4.5 ± 0.3		
0	2.4 ± 1.2[2]		

1. Each value is the mean of three samples, ± the standard error of the mean.
2. Two samples.
3. Probability of no difference from complete solution treatment.

Figure 2. – Effect of phosphorus concentration in nutrient solution on phosphorus concentration in the shoot (A) and on net productivity (B).

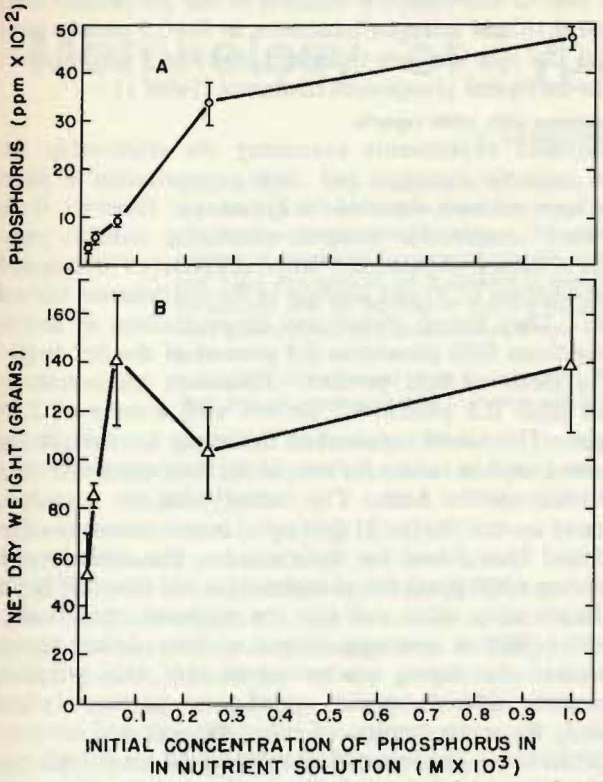
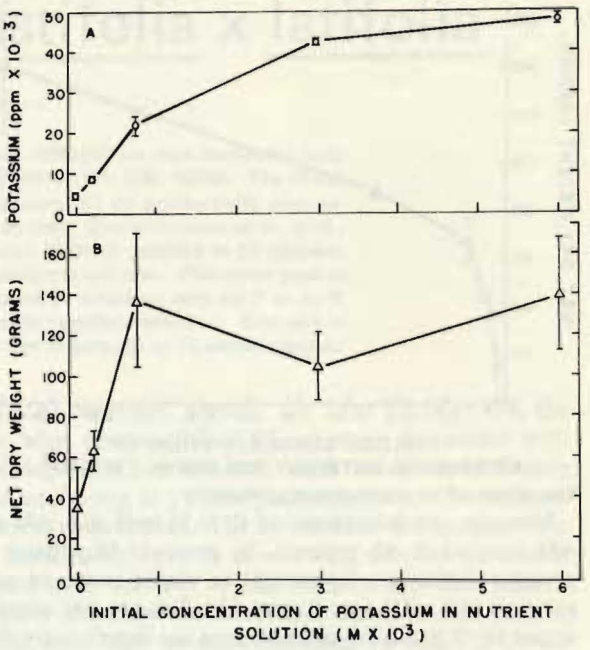


Figure 3. Effect of potassium concentration in nutrient solution on potassium concentration in the shoot (A) and on net productivity (B).



angustifolia (P, .23.1 percent; K, 3.8-1.8 percent). Bayly and O'Neill's study (1972) on *Typha glauca* agrees with reports based on separate species (P, 0.35-0.7 percent; K, 2.0-1.0 percent).

Because *Typha* spp. have rhizomes which store carbohydrates during the winter, their below-ground biomass is significant. Those studies which have included below-ground biomass indicate it ranges from 40 percent (Gustafson, 1976) to 59 percent (Dykjova, 1971) of the total. The bulk of the underground material is presumably rhizomes, since only Gustafson indicates the amount contributed by roots. He found 6 percent of the below ground biomass or 2.3 percent of the total biomass incorporated in the roots. Roots are easily lost when digging up and cleaning rhizomes and hence perhaps not accurately reported from field studies. Assuming that root growth is not altered by solution culture from that in natural substrates, our study shows roots may in fact be a significant portion of the biomass under nitrogen and phosphorus limiting conditions.

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