EFFECT OF GENOTYPE AND NUTRIENT REGIME ON GROWTH AND ELEMENTAL CONCENTRATION OF SYCAMORE (*PLATANUS OCCIDENTALIS* L.) SEEDLINGS

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ABSTRACT

The objective of this study was to investigate the affect of nutrient regime and seed source on the growth and foliar nutrient concentration of sycamore (*Platanus occidentalis* L.) seedlings. Seedlings were grown in Hoagland's solution ranging from 0.125-strength to 2.0-strength for 10 weeks. Nutrient concentration significantly effected the specific leaf area: weight ratio, total and component dry weights, stem height, leaf area and foliar nutrient concentration. Mean growth component values and percentages of foliar N, P, K and ash, averaged over all seed sources, increased as nutrient solution concentration increased to 0.5-strength. Values for growth components and percentage P decreased with further increases in solution concentration. Simple correlations between foliar N, P and K concentrations and stem height, leaf area and total dry weight were significant but foliar P showed the highest relationship.

Seed source significantly affected the growth parameters and a significant seed source -x- nutrient concentration interaction was determined for plant total dry weight, leaf area and stem height.

Leaf senscence increased as the nutrient solution concentration decreased. No cholorosis or death of leaves occurred for plants grown in solutions at 0.5-strength and above. The number of leaves produced was not significantly affected by solution concentration or seed source.

INTRODUCTION

Recent interest in establishing high density hardwood plantations, capable of high fiber yields on short rotations, has stimulated efforts to establish the site conditions necessary to maintain rapid growth rates (Herrick and Brown, 1967). American sycamore is one of the species that has received increasing attention. Sycamore is fast growing and capable of high fiber yields on a variety of sites (Atay, 1965). It is a widely occurring species (Fowells, 1965) which is largely self-sterile (Beland and Jones, 1967), within stand genetic variation is considerable (Schmidt and Wilcox, 1969), and site fertility is known to affect growth (Leaf, 1968 and Stone, 1968).

This study was designed to investigate the effect of genotype and available nutrient levels on seedling growth and elemental concentration. Correlations among foliar elemental concentrations and plant total dry weight and stem height were tested to provide a means of predicting growth from elemental analysis of foliage.

Nutritional experiments usually are designed to test the effects of varying levels of one nutrient when all others are kept constant (Ingestad, 1970), but some experimentors have varied all nutrients in proportion by diluting or concentrating a standard solution (Schomaker, 1969; Steinbeck, 1971). This approach has merit since different species do not respond equally to the same level of available nutrients (Ward and Miller, 1971). In fact, experiments exercising genetic control have demonstrated significant variation in growth and nutrient uptake of clones (Steinbeck, 1971) and seed sources (Kitzmiller, 1972) of the same species.

MATERIALS AND METHODS

Seed were collected in mid April from six mature American sycamore (*Platanus occidentalis* L.): three growing on wet sites along stream sides and three growing on apparently drier sites in mid and upper slope locations. Seed were germinated in perlite. Upon full expansion of the first two true leaves, 120 seedlings (20 seedlings from each seed source) were transplanted into aerated liquid nutrient media. Seedling selection was based on

uniform height and root development. Each seedling was grown in a separate opaque container of 3.8 ℓ capacity.

The five nutrient treatment concentrations were multiples of Hoagland's solution (Hoagland and Arnon, 1938) and consisted of 0.125, 0.25, 0.5, 1 and 2-strength (Table 1). The pH of all solutions was adjusted daily to 6.3 with 0.1N NaOH or HCl solution and solution volumes were maintained by daily additions of deionized water. Fresh nutrient solutions were supplied at 4 day intervals.

Three days after transplanting all seedlings showed height growth. At this time measurements were taken on stem height and leaf number. After 10 weeks of growth, seedlings were harvested because of fixed spacing and harvest was desired before mutual shading occurred. Stem height and individual leaf area were determined. Plant parts were oven dried at 80°C to a constant weight, leaf, stem and root dry weights were measured to the nearest 0.1 mg, ground to pass through a 20 mesh screen and stored in capped bottles for nutrient analysis.

Nitrogen was determined by the semi-micro Kjeldhal technique, phosphorus by the ammonium-molybdate vanadate method and potassium using a flame photometer (Wilde and Voigt, 1959).

The experimental design consisted of six seed sources (three wet sites and three dry sites), five nutrient treatments and four replications. Within a replication the seedlings were located in a randomized complete block design. Data were analyzed using analysis of variance. Differences among the mean values for dependent variables were tested using Duncan's Multiple Range Test. Stepwise multiple regression analysis (maximum R improvement) was used to relate foliar nutrient concentration to stem height growth and total dry weight.

RESULTS

Physical Growth Parameters

Total dry weight, total leaf area and stem height varied curvilinearly with increasing nutrient concentration. Plants in the 0.5 Hoagland's solution weighed approximately 1.75 fold

Table 1. Composition of the stock solution and concentration of the elements in 1.0-strength Hoagland's solution.*

Stock Solution		Dilution	1.0 Hoagland's	
Compounds	g/l	(cc/l)	Element	ppm
$NH_4H_2PO_4$	114.9	1	N	210.00
KNO_3	101.1	6	P	31.00
$Ca(NO_3)_2$	164.08	4	K	235.00
$MgSO_4$	120.38	2	Ca	160.00
H_3BO_3	2.86	1	Mg	49.00
$MnCl_2 \cdot 4H_2O$	1.81	1	S	64.00
$ZnSO_4 \cdot 7H_2O$	0.22	1	B	0.50
$CuSO_4 \cdot 5H_2O$	0.08	1	Mn	0.50
$H_2MoO_4 \cdot H_2O$	0.02	1	Zn	0.05
FeEDTA	5.0	1	Cu	0.02
			Mo	0.01
			Fe	5.00

*Note: All nutrient solution concentrations are multiples of this basic 1.0-strength concentration.

Table 2. The effect of seed source on various parameters of growth of sycamore seedlings after 10 weeks of growth in the nutrient media.

Site	Seed Source	Stem Height (cm)	Stem Weight (gm)	Leaf Area (cm^2)	Leaf Weight (gm)	Root Weight (gm)	Total Dry Weight (gm)	A/W Ratio (cm^2/mg)
Wet	1	31a*	1.01a	1036a	1.05a	2.17a	4.23a	0.59a
Dry	2	28ab	0.94a	1050a	0.92a	2.00a	3.87ab	9.84ab
Wet	3	27ab	0.80ab	818ab	0.79ab	1.79ab	3.39ab	10.02b
Dry	4	24bc	0.69b	640b	0.68b	1.52b	2.94b	10.74bc
Wet	5	23bc	0.66b	730b	0.67b	1.60b	2.93b	10.38b
Dry	6	21c	0.48c	588c	0.43c	1.07c	1.92c	12.91c

*Column values not followed by the same letter were significant at the 0.05 level for Duncan's Multiple Range Test.

greater than those at the lowest level, had 1.57 fold greater leaf area and 1.34 fold greater stem height. Leaf area to leaf weight ratio (A/W) was also curvilinearly related to nutrient supply but was at a minimum in the 0.5-strength solution. Thus, the lowest A/W was associated with the solution concentration resulting in the largest plants. Approximately 13 percent of the foliage area on the plants in the lowest nitrogen treatment was dead. The percentage of dead foliage decreased with increasing nutrient concentration and was zero at the three highest levels.

Seed source significantly effected total dry weight, stem, leaf and root weights, stem height, leaf area and area:weight ratio (Table 2). Seed sources 1 and 2 averaged over all nutrient regimes grew consistently better than all other sources for the variables measured. Ranges were determined by sources 1 and 6 which set maximum and minimum values respectively. Consistant with the effect of nutrient concentration on A/W, seed sources 1 and 2 yielded the largest plants and had the lowest A/W ratio (9.59 cm^2/mg and 9.84 cm^2/mg respectively) while source 6 yielded the smallest plants and had the largest A/W ratio (12.91 cm^2/mg). Differences between wet site and dry site sources were not significant.

Interaction of seed source -x- nutrient solution concentration significantly effected seedling dry weight, stem height and total leaf area. The same pattern existed for the three variables, therefore only the dry weight variable is presented (Table 3). Significant growth differences existed among seed sources within a specific nutrient concentration. Source 1 clearly produced the largest seedling at 0.125 strength and 1.0 strength Hoagland's solution with a maximum at 0.5 strength. Source 3 achieved maximum dry weight at 0.5 strength but was generally not greatly affected by increases in nutrient concentration greater than 0.25 strength. Source 6 responded similarly but showed a steady but nonsignificant increase in dry weight with increases in media concentration. Generally, all seed sources increased in dry weight with increases in solution concentration up to 0.50 Hoagland's and then declined with further increases. No differences in dry weight among seed sources was evident at the 2.0 Hoagland's. Seed source 6 showed a lack of response to increases in nutrient solution concentrations, when compared to the other sources, and the response was linear rather than the curvilinear pattern noted

Table 3. The effect of seed source and nutrient solution concentration on the total dry weight (grams) of sycamore seedlings after ten weeks of growth.

Seed Source	Nutrient Solution Concentration (Multiples of Hoagland's Solution)				
	0.125	0.250	0.50	1.0	2.0
	Total Dry Weight (grams)				
1	3.39c*	4.31d	5.08e	4.81de	3.57c
2	2.52bc	5.47e	4.05d	3.74cd	3.58c
3	2.09b	3.42c	3.99d	3.79cd	3.64cd
4	2.16b	3.09c	3.77cd	2.92bc	2.78bc
5	1.86b	2.34bc	3.19c	3.82cd	3.44c
6	1.05a	1.91b	1.95b	2.19b	2.48bc

*Row and column values not followed by the same letter were significantly different at the 0.05 level for Duncan's Multiple Range Test.

Table 4. Simple correlation coefficients between growth variables and the foliar chemical composition for seedlings grown in nutrient media ranging from 0.125x to 2.0x Hoagland's solution.*

Constituent	Growth Variable			
	Total Dry Weight	Stem Height	Total Leaf Area	A/W
N	.731	.764	.814	.772
P	.816	.885	.837	.791
K	.621	.543	.504	.592

*All values significant at the 5% level.

for the other seed sources. The foliar concentrations of N, P and K were highly variable between replicates and are not reported here.

Chemical Composition

Foliar nutrient concentration and percentage ash were a reflection of nutrient solution concentrations (Figure 2). As nutrient solution concentration increased from 0.125 to 2.0-strength Hoagland's, N increased from 2.2 to 2.6%, K increased from 1.3 to 2.2% and ash increased from 10.7 to 12.1%. The percentage of foliar P followed a curvilinear pattern resembling the response of stem height and total dry weight. Foliar P increased from 0.25% to a maximum of 0.36% at 0.5-strength and then declined to 0.31% at 2.0-strength. The total content of N, P, K and ash in the leaves followed a curvilinear response similar to that for total dry weight. This result is attributed to relatively small increases in elemental content with increasing nutrient solution concentration when compared to the correspondingly large decreases in leaf weights.

Significant correlation coefficients between each of the growth variables and foliar concentrations of N, P and K are presented in Table 4. The ranking of correlation coefficients in order of magnitude indicates total dry weight, stem height, total leaf area and area:weight ratio are most closely correlated with foliar P concentration and least correlated with the K.

Multiple regressions relating the growth variables to foliar elemental concentration have been computed for N, P and K. A curvilinear function is used for foliar P and a linear function for foliar N and K. The regression coefficients, constants and multiple correlation coefficients for each of the equations are given in Table 5. The multiple correlation coefficients are between .878 and .932, the various regression equations accounting for 77 to 87 percent of the variation in the independent variable.

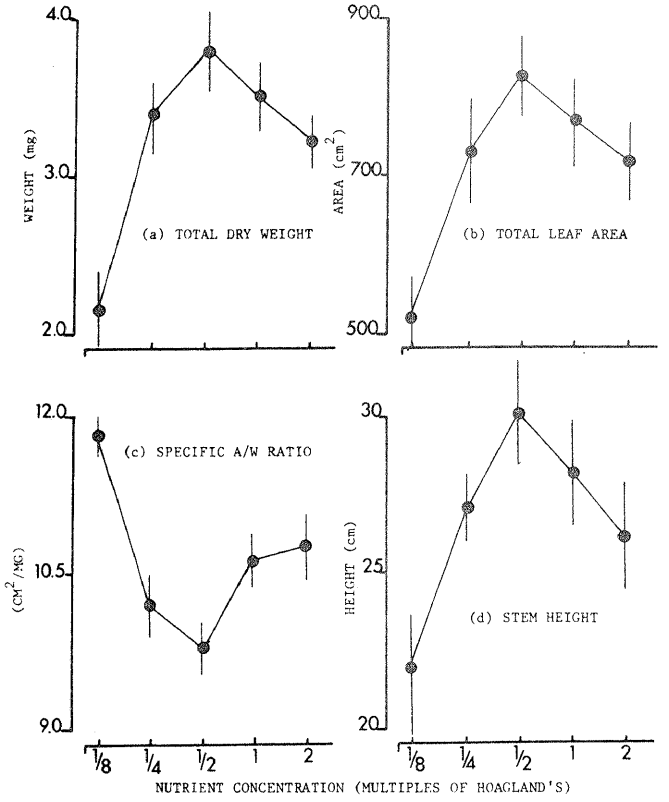

Figure 1. The effect of nutrient solution concentration on the (a) total dry weight, (b) total leaf area, (c) specific leaf area to leaf weight ratio (A/W) and (d) stem height of sycamore seedlings ten weeks after transplanting. (Variables averaged over seed sources and replications.)

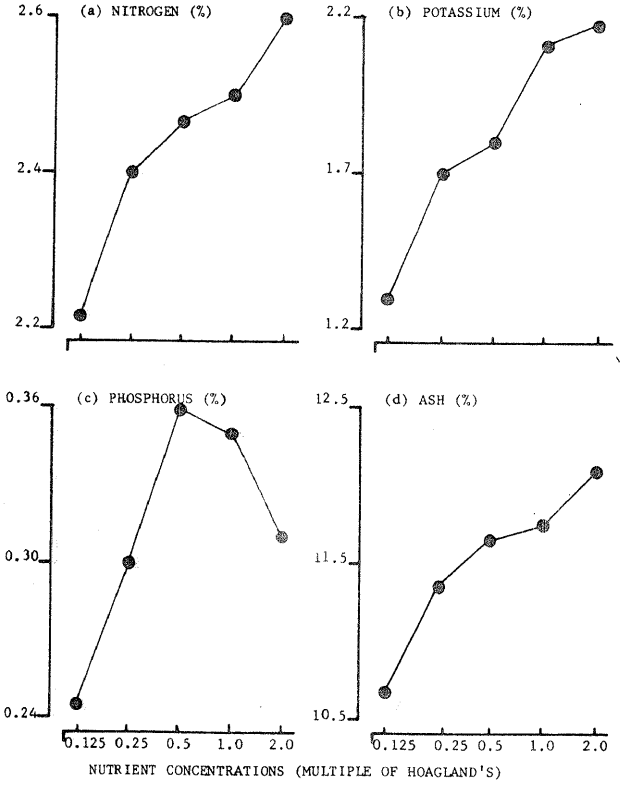

Figure 2. The effect of nutrient solution concentration on the percentages of foliar (a) nitrogen, (b) potassium, (c) phosphorus and (d) ash of sycamore seedlings ten weeks after transplanting. (Percentage values averaged over seed sources and replications.)

Table 5. Regression coefficients, constants and multiple correlation coefficients for estimating seedling dry weight (gms), stem height (cm) and leaf area (cm^2) from foliar composition expressed as percent dry weight.

Regressor Variable	Dependent Variable		
	Total Dry Weight	Stem Height	Total Leaf Area
K	5.94	25.66	862.82
N	1.79	7.45	274.71
P	21.22	104.87	3371.85
Constant	12.54	65.19	1841.74
Multiple Correlation Coefficient	.932	.952	.878

DISCUSSION

Nutritional Response

Nutrient level had a marked effect on the growth and foliar nutrient content of sycamore seedlings after 10 weeks. The total dry weight, leaf area and stem height appeared to reflect the foliar phosphorus concentration. All simple correlations between the growth variables and foliar nutrient concentrations for N, P and K were significant but the highest correlations were recorded for P concentration. Kitzmiller (1972) reported correlation coefficients for sycamore seedlings for foliar concentration of N and P to seedling height and dry weight of .85 and .82, and .31 and .33 respectively. The correlation values for foliar N compare favorably with this study. No simple explanation can be offered for the disparity in the foliar P correlations. For predicting total dry weight, stem height and leaf area N and K contribute significantly to the multiple regression equation indicating that the growth prediction made from P concentration alone can be improved by including N and K concentration as regressor variables.

The relationship between foliar P and the growth variables is interesting. The treatment yielding the largest plants had a 50% greater foliar P concentration than the treatment with the smallest plants. Decline in percentage of foliar phosphorus at higher nutrient concentrations may have resulted from interactions between phosphorus and nitrogen or potassium. Such phosphorus, nitrogen interaction has been noted by Ingestad (1957) who concluded that foliar concentration of one of the elements tends to decrease when the other reaches an optimum or when both are in the deficiency range. For this study, the decline in foliar P concentration is associated with an N concentration of 2.45% and in accordance with Ingestad should be near the optimal concentration for N. No published data on the optimum nutrient concentration of sycamore exists for comparison. An antagonistic relationship has also been reported between potassium and phosphorus (Bolle-Jones 1955). Antagonistic response does not exist between nitrogen and potassium and increased supplies of these elements results in luxuary consumption by the plant.

Steinbeck (1971) reported that sycamore clones achieved maximum growth in a 1.0 -x- Hoagland's solution and then declined

with further increases in solution concentration. Madgwick (1971) indicated that maximum growth rates for yellow poplar (Liriodendron tulipifera) occurred in liquid media with nitrogen levels equivalent to the 0.5 -x- Hoagland's used in this study. Madgwick suggested that decreases in unit leaf rate (ULR), and hence the net assimilation rate, associated with further increases in nitrogen levels may have resulted from nitrate toxicity. Such reasoning is a plausible explanation for the response observed in this study.

A/W ratio is indicative of the rate of leaf expansion relative to dry weight accumulation. Madgwick (1971) reported that A/W ratio was highest in the most rapidly growing plants. These results are at variance with our study in which the largest and presumably the fastest growing plants had the lowest A/W ratio. Such a response could be the result of an accumulation of a disproportionate amount of mesophyll in the foliage and could account for an apparently higher rate of carbon fixation. Rate of leaf initiation was not affected by seed source or nutrient level. Faster growing plants, whether classed by seed source or nutrient level, had larger leaves.

Seed Source Response

Differences in growth parameters attributed to seed source averaged over all nutrient concentrations indicate variation in the ability of genotypes of the same species to grow similarly over the same range of available nutrients. Application of this information to the field indicates that site specific selections may be necessary in many situations where the successful regeneration of a particular species is required. These data are in agreement with Kitzmiller (1972) and suggest that genetic selections could be made which would inhance the growth of sycamore over a range of site fertility conditions when compared to nonselected material. This suggestion is further evidenced by the significant seed source -x- nutrient concentration interaction. Some genotypes are more efficient than others in utilizing available nutrients and can achieve maximum growth rates at lower available nutrient levels. Source 1 appeared to be photosynthetically more efficient than the other sources at nutrient levels ranging from 0.125 to 0.5 Hoagland's (exception is taken for source 2 at 0.25 Hoagland's) and had the greatest absolute weights at 1.0 and 2.0

Hoagland's solutions. By contrast, source 6 did not respond significantly to increases in nutrient concentration greater than 0.25 Hoagland's and may have been partly responsible for the highly significant seed source -x- nutrient concentration interaction. If we consider establishing sycamore on sites ranging from nutrient rich to near deficiency, selection of the proper genetic stock is more critical if acceptable growth is to be maintained on poorer sites as compared to the nutrient rich sites.

Only seedlings or saplings can be used in controlled hydroponic nutrient studies, leaving open the possibility that the data so derived may have limited value in assessing the requirements of older trees. There is some evidence that in conifers the high requirements for minerals may continue to an age of 20-30 years or more (Alten and Doehring, 1952). The demands of seedlings, thus may give better indications of continuing needs than usually is believed to be the case (Walker et al., 1965).

The ever increasing demand for wood and wood products has prompted studies in the selection of genetically improved plant materials and in the investigation of nutrient regimes which are most favorable for growth. With the projection that forest trees will be grown intensively on short rotations and on uniform sites, information acquired from greenhouse studies having genetic and nutritional control will be helpful in selection of growing stock and in estimating nutritional requirements.

LITERATURE CITED

Alten, F., and W. Doehring. 1952. DIE DUNGLING IN DER FORSTVIRTSCHAFT (FERTILIZERS IN FOREST MANAGEMENT). Z. Pflanzenernah. Dung. U. Bodenk. 59: 145-157.

Atay, J. 1965. STUDIES OF STABILIZATION AND AFFORESTATION OF COASTAL SAND DUNES IN TURKEY. Istanbul Univ. Am. Fak. Derg. 1965 15(1): 47-110. In: F. A. 28, No. 3797.

Beland, J. W., and L. Jones. 1967. SELF INCOMPATIBILITY OF SYCAMORE. Proc. 9th S. Conf. For. Tree Impr., Knoxville, Tenn. pp. 56-58.

Bolle-Jones, E. W. 1955. THE INTERRELATIONSHIPS OF IRON AND POTASSIUM IN THE POTATO PLANT. Plant and Soil 6: 129-137.

Fowells, H. A. 1965. SILVICS OF THE FOREST TREES OF THE UNITED STATES. USDA Handbook No. 271, 762pp.

Hoagland, D. R., and D. I. Arnon. 1938. THE WATER CULTURE METHOD FOR GROWING PLANTS WITHOUT SOIL. Univ. Calif. Agr. Exp. Sta. Circ. 347. Berkeley.

Ingestad, T. 1957. STUDIES ON THE NUTRITION OF FOREST TREE SEEDLINGS. I. MINERAL NUTRITION OF BIRCH. Physiol. Plant. 10: 418-439.

Ingestad, T. 1970. A DEFINITION OF OPTIMUM NUTRIENT REQUIREMENTS FOR BIRCH SEEDLINGS. I. Physiol. Plant. 23: 1127-1138.

Kitzmiller, J. H., Jr. 1972. RESPONSE OF SYCAMORE (PLATANUS OCCIDENTALIS L.) FAMILIES TO NITROGEN FERTILIZATION. Ph.D. Thesis, N. C. State Univ., Raleigh. 120pp.

Leaf, A. L. 1968. K, MG AND S DEFICIENCIES IN FOREST TREES. In: Forest Fertilization: Theory and Practice. TVA, Muscle Shoals. pp. 88-122.

Madgwick, H. A. I. 1971. GROWTH OF LIRIODENDRON TULIPIFERA SEEDLINGS WITH DIFFERENT LEVELS OF NITROGEN SUPPLY. For. Sci. 17: 287-292.

Schmidt, D., and J. R. Wilcox. 1969. SYCAMORE VARIATION IN THE LOWER MISSISSIPPI VALLEY. USFS Res. Note SO-91.

Schomaker, C. E. 1969. GROWTH AND FOLIAR NUTRITION OF WHITE PINE SEEDLINGS AS INFLUENCED BY SIMULTANEOUS CHANGES IN MOISTURE AND NUTRIENT SUPPLY. Soil Sci. Soc. Amer. Proc. 33: 614-618.

Steinbeck, K. 1971. EFFECT OF NUTRIENT LEVELS ON THE GROWTH OF SYCAMORE. Canad. Jour. Bot. 17: 353-358.

Stone, E. L. 1968. MICRO-ELEMENT NUTRITION OF FOREST TREES: A REVIEW. In: Forest Fertilization: Theory and Practice. TVA, Muscle Shoals. pp. 132-179.

Walker, R. B., S. P. Gessel, and P. G. Haddock. 1965. GREENHOUSE STUDIES OF MINERAL REQUIREMENTS OF CONIFERS: WESTERN RED CEDAR. For. Sci. 1: 51-66.

Ward, G. M., and M. J. Miller. 1971. THE INFLUENCE OF FERTILIZATION WITH KNO_3 AND NH_4NO_3 ON SOME NITROGEN FRACTIONS IN TOMATO SEEDLING TISSUES. Canad. J. Bot. 49: 1643-1646.