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THE GROWTH OF SYCAMORE (*ACER PSEUDOPLATANUS* L.) AND BIRCH (*BETULA VERRUCOSA* EHRH.) SEEDLINGS IN 50 DIFFERENT SOILS

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Introduction

Previous work (Helliwell 1973b) yielded regression equations which accounted for more than 70% of the variation in the mean dry weight of sycamore and birch seedlings grown in 13 different woodland soils, using data on total soil phosphate, loss-on-ignition, and P, K, and Ca extractable in 2.5% acetic acid.

The present study was undetaken to test the efficiency of these regression equations in predicting the growth of seedlings of these species in other soils.*

Selection of sample soils

A larger number of soils was used than in the previous study, covering a slightly greater range of acidity and organic matter content, but still excluding calcareous soils. Several peaty soils and several agricultural soils were included, in addition to woodland soils; being collected from 50 sites in the eastern half of the Lake District, selected at random from 108 sites visited previously as part of a separate study (Helliwell 1973a), but excluding any with very shallow or stony soil.

Soil analyses

The same analyses were carried out as previously, at the commencement of the growing season, namely:-

> pH, loss-on-ignition, total phosphate, P, K, and Ca extractable in 2.5% acetic acid, and isotopically exchangeable phosphate in aqueous solution.

Total nitrogen was not measured, as it had not been found to contribute any useful information in the earlier study.

Isotopically exchangeable phosphate in a solution of potassium chloride and ammonium citrate was also measured.

* variation in growth <u>within</u> each of these species is to be investigated during 1974-1975.

Isotopically exchangeable phosphate in aqueous solution was also measured in November, as in the previous study, but the soil had just thawed after several days of cold weather and the readings obtained were very high and were not significantly correlated with any of the plant growth variables.

Growth of seedlings

7 sycamore seeds were sown in one 25 cm. diameter pot of each soil and were thinned to 4 plants per pot soon after germination. Only 3 plants died before the end of the experiment.

Birch seeds were also sown in one pot of each soil. Germination was, however, not good, and half the pots produced no seedlings. Only 52 seedlings were obtained altogether, and additional seedlings were obtained from another source and transplanted into the pots to give at least 3 plants per pot. Some of these transplanted seedlings did not grow any larger after transplanting and stayed at about 4 mg. dry weight. Great care was taken in transplanting, however, and some of the seedlings which germinated "in situ" grew little better. The variation in size of seedlings within pots was, accordingly, very great in some cases. This variation could have been due to genetic differences, and this aspect is being examined further.

Results

The seedlings were harvested in September 1973, after 4-5 months' growth and were dried and weighed.

The sycamore seedlings were assessed for phosphate-stress before drying, as described by Harrison and Helliwell (1973), and the results of this and subsequent chemical analysis of the dried plants will be given in a later paper.

The mean plant weights, and other main variables, are summarized in Table 1 and the main correlations between these are given in Table 2.

As in the previous study, the root/shoot ratio of the birch seedlings was not correlated significantly with any of the soil variables; but the root/shoot ratio of the sycamore had a significant correlation with extractable calcium (correlation coefficient of -0.52) in this case.

The isotopically exchangeable phosphate in potassium chloride and ammonium citrate was not significantly correlated with plant growth and added little to the variation in growth accounted for by multiple regression. The isotopically exchangeable phosphate in aqueous solution was significantly correlated with plant growth but the correlation was not very great and the information likewise added little to the variation in growth accounted for by multiple regression.

Regression of plant weight against various combinations of soil variables accounted for the following proportions of the variation in plant weight:-

Soil variables	Mean wt. birch	Mean wt. sycamore
PO_4 extractable in acetic acid (P).	76.0%	49.6%
P + total P.	76.5%	51.0%
P, total P, isotop. exch P in H_2O.	76.6%	51.0%
P, total P, isotop. exch P in H_2O and in KCl	80.2%	53.5%
pH, L o I, K, Ca	13.5%	31.7%
pH, L o I, K, Ca, P	78.5%	59.9%
All 8 soil variables	83.3%	65.0%

Although the number of birch seedlings which germinated was significantly correlated with the phosphate status of the soil, (Table 2), these correlations are only just significant, and only 28.6% of the variation in seedling numbers was accounted for by regression against all 8 soil variables. It is possible, therefore, that successful germination may be influenced by the nutrient status of the soil to some degree. Keith-Lucas (1968) has noted a similar state of affairs with Primula vulgaris Huds.

Using the regression equations derived from the 13 woodland soils studied previously, the predicted weights of the birch seedlings had a correlation coefficient of 0.80 with the actual weights, which means that 64% of the variation had been predicted correctly; and, in the case of sycamore, the correlation coefficient was 0.56, which means that only 31% of the variation had been predicted correctly. If only those soils which lie within the same range of pH and loss-on-ignition as the 13 soils studied previously are considered (35 soils), the relevant correlation coefficients are 0.91 for birch and 0.55 for sycamore.

Discussion

The isotopically exchangeable phosphate measurements were not very useful in this study, carrying less useful information than the more conventional measurements of total phosphate and phosphate extractable in 2.5% acetic acid. They may, however, be of use in the more detailed study of phosphorus uptake which has yet to be completed.

This study confirms the importance of soil phosphates in determining the rate of growth of sycamore and birch seedlings, when grown under favourable conditions of light, moisture, and temperature and in the absence of competition from other plants. It also confirms the greater importance of calcium and/or pH to sycamore than to birch.

The failure to predict very accurately the growth of birch and, in particular, sycamore seedlings is a little disappointing, but not entirely surprising. Further investigation of mycorrhizas and intra-specific variation in growth may help to improve this predictability.

Table 3 lists the mean dry weights of seedlings in groups corresponding to the association analysis of floristic data from the sample sites. The association analysis was carried out on data from 108 sites (Helliwell 1973a), giving 13 groups at a chi-squared level of 10.0, and the 50 sites sampled in this study came from 9 of these groups. The number of sites sampled in most groups was not very large, making statistical comparisons difficult, but it is evident that soils from sites in Group 8 gave better growth of both tree species; and this is the only group which stands out clearly from the rest. All the sites in this Group were enclosed pasture land. The mean seedling weights for this Group, compared with all the other Groups combined, are given below:-

	Mean wt. (gm) and standard error of		Mean (gm/100g) and standard error of extractable	
	birch	sycamore	P	Ca
7 sites in Group 8	0.941 ± 0.43	3.67 ± 0.77	3.26 ± 1.32	209 ± 20
43 other sites	0.142 ± 0.032	1.42 ± 0.13	0.51 ± 0.057	67.6 ± 17.9

It had been thought that the additional information on the soil and on the growth of tree seedlings might be of use in site assessment, and, to test this, the same multidimensional plotting procedure was used as previously (Helliwell 1973a), using:-

i) the 7 variables used previously:-
soil pH, loss-on-ignition, slope, altitude, soil depth, variation in slope, and variation in aspect.

ii) these 7 variables, plus 5 soil variables:-
extractable P, Ca, K, total P, and labile P.

iii) these 7 variables, plus 2 plant variables:-
dry weight of birch seedlings, and sycamore seedlings.

When the plotted functions for sites which fall within the same groups in the association analysis are compared, it appears that in no case does the inclusion of the 5 additional soil variables give a closer correlation, and, in 5 out of the 9 groups, it gives a poorer correlation. The inclusion of the two plant variables likewise gives no closer correlation, but, on the other hand, it does not give a poorer correlation in any group. It is likely, therefore, that the inclusion of data on plant growth in the process of site assessment is unlikely to give any decrease in the accuracy of the assessment, and may possibly be useful. On the other hand, the inclusion of any large number of soil variables may provide more irrelevant information than useful information, and it would not be wise to include such data unless it could be processed in some way which would give greater weight to the relevant information within it.

Summary

As in previous work on this topic, it was found that a large proportion of the variation in dry weight production of birch and sycamore seedlings could be accounted for in terms of the chemical qualities of the soil. In the case of birch the phosphate content of the soil was of paramount importance in the 50 soils studied, and in the case of sycamore calcium was of some significance in addition to phosphorus.

The use of soil chemical data additional to pH and loss-on-ignition did not appear to be of any direct use in improving the assessment of sites in terms of their vegetative cover. The use of selected variables (e.g. extractable phosphate and calcium) or data on plant growth may be of some use, but this was not demonstrated in this study. This conclusion is in accordance with that arrived at previously (Helliwell 1973a) that the inclusion of variables which are of minor importance can confuse matters.

It does not appear to be possible to predict the growth rate of seedlings with any great degree of acurracy on the basis of the work carried out so far, and further work (e.g. on mycorrhizas) appears to be warranted.

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References

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Table 1. Mean values and standard deviations of soil and plant variables

	Minimum	Mean	Maximum	Standard deviation
pH	3.5	4.6	6.5	0.691
Loss-on-ignition (%)	8.3	22.9	91.1	18.71
Extractable K (mg./100g.)	4	15.0	68	11.73
Extractable Ca (mg./100g.)	4	87.3	540	120.8
Extractable P (mg./100g.)	0.2	0.897	11	1.593
Total P (%)	0.06	0.119	0.34	0.0464
Isotop. exch. P, in H_2O*	2.9	15.02	84	18.32
Isotop. exch. P, in KCl and Amm. Cit.*	4.8	69.52	849	151.14
Mean dry weight of birch	.004	0.254	3.44	0.523
Mean root/shoot ratio of birch	0.21	0.501	1.29	0.266
Mean dry weight of sycamore	0.191	1.736	7.16	1.328
Mean root/shoot ratio of sycamore	0.57	1.074	1.77	0.272
Uptake of P^{32} by sycamore**	27	300	737	135.6
No. of birch seedlings germinating	0	1.04	6	1.38

* micrograms per gm.

** counts per minute per mg. fresh wt. root

Table 2. <u>Correlations between seedling growth and soil variables</u>

		1	2	3	4	5	6	7	8	9	10	11
1	pH	1	-.22	-.26	.68**	.32*	.26	.06	.24	.49**	-.14	-.01
2	Loss-on-ignition		1	.65**	.22	.00	.15	.46**	-.11	-.13	-.06	.01
3	Extractable K			1	-.04	.08	.30*	.39**	-.09	.03	-.19	.05
4	Extractable Ca				1	.38**	.34*	.18	.28	.39**	-.35*	.14
5	Extractable P					1	.80**	.50**	.83**	.70**	-.44**	.31*
6	Total P						1	.42**	.59**	.49**	-.48**	.33*
7	Isotop. exch. P, in H_2O							1	.43*	.36*	-.31*	.34*
8	Mean wt. birch								1	.57**	-.34*	.42**
9	Mean wt. sycamore									1	-.40**	.32*
10	P^{32} uptake by sycamore										1	-.40**
11	No. of birch seedlings germinating											1

* significant at 0.05 probability level

** significant at 0.01 probability level

Table 3. Growth of sycamore and birch seedlings in relation to an association analysis of vegetation at the sample site

Association analysis group	Divisive species	No. of sites sampled	Mean weight of Birch (gm.)	Mean weight of Sycamore (gm.)	Mean value of extractable P & Ca in soil (mgm./100 gm.) P	Ca
1	+ Nardus stricta + Prunella vulgaris + Calluna vulgaris	3	0.510	0.94	1.21	214
2	" " - Calluna vulgaris	9	0.104	1.43	0.39	111
3	" - Prunella vulgaris - Dryopteris filix-mas + Juncus artic.	5	0.135	1.47	0.61	37
5	" " " - Juncus artic + Vaccinium myrt.	6	0.076	1.04	0.91	24
6	" " " " - Vaccinium myrt.	3	0.205	0.77	0.39	10
8	- Nardus stricta + Plantago lanceolata - Oxalis acetosella	7	0.941	3.67	3.26	209
9	" - Plantago lanceolata + Crepis paludosa	8	0.214	1.38	0.45	95

Association Analysis group	Divisive species	No. of sites sampled	Mean weight of Birch (gm.)	Mean weight of Sycamore (gm.)	Mean value of extractable P & Ca in soil (mgm./100 gm.) P	Ca
12	" " - Ilex aquifolium - Veronica cham. + Agrostis can.	3	0.076	1.40	0.35	11
13	" " " " - Agrostis can.	6	0.314	1.39	0.45	18