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THE GROWTH OF SYCAMORE (ACER PSEUDOPLATANUS L.) SEEDLINGS IN DIFFERENT WOODLAND SOILS

D. R. Helliwell

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Introduction

Sycamore was introduced into Britain more than four hundred years ago and is now widespread. It is possible that it was present before glaciation, as the pollen is not readily preserved in sediments (which could account for the absence of records), but it is generally regarded as an exotic species and, therefore, of little value for nature conservation; and in some places it is regarded as a positive threat to conservation, because of its ability to colonise sites where other tree species would be preferred.

Previous work (Helliwell, 1965), indicated that, although sycamore seeds will germinate under almost any conditions, successful regeneration requires an absence of dense ground vegetation, a relatively high level of available phosphorus, and a soil pH greater than 4. It is likely, therefore, to be less of a nuisance than many people suppose, although it may give cause for concern on the more fertile soils, especially in those parts of the country which lie outside the natural range of beech.

(On the continent of Europe, sycamore is widespread in mountainous areas, but is rarely very numerous. The situation in Britain differs to some extent, in that silver fir is absent as a native species, and beech occurs naturally only in Southern Britain; hence there is rarely any major species present which is more shade-tolerant than sycamore, giving greater opportunity for the latter to regenerate whenever soil and climate are favourable).

The earlier work referred to (Helliwell, 1965) investigated a range of factors, including light intensity, moisture stress, and soil chemistry in a number of different woodland soils, and there were strong indications that the phosphate content of the soil was of critical importance in many cases where the pH value lay between 4.0 and 5.5. Successful regeneration of sycamore has not, to the author's knowledge, been recorded on any soil with a pH value less than 4.0; and on soils with a pH value greater than 5.5 regeneration is usually copious unless the soil is subject to drought. (Some work is being carried out at University College, London, on the growth of sycamore and ash (Fraxinus excelsior) seedlings on soils with relatively high pH values, and the results should be published shortly.)

In order to examine this matter further, the abundance of sycamore, expressed as a percentage of basal area in 6 sample plots, was correlated with chemical data from a bulked soil sample for each of 47 woodlands in the English Lake District*. No significant correlations were obtained with any of the soil variables, which included total phosphate and phosphate extractable in 2.5% acetic acid. Harrison (1971) has found, however, that a much better correlation with the growth of nettles (Urtica dioica) can be obtained by measuring the labile soil phosphate, using a radioactive tracer (P_{32}).

Selection of sample soils

13 woodland soils were selected, including 5 in North Wales which had been studied to some extent in the earlier study and 8 from sites which had been visited during studies in the English Lake District (Harrison, 1971, and Helliwell, 1973). pH values ranged from 3.9 to 5.5 and loss-on-ignition from 10.1% to 44.8%. Sycamore was present at 7 of these sites and absent from the other 6.

* (Data kindly loaned by Dr. R. G. H. Bunce)

Soil from each woodland was brought to Merlewood at the end of March 1972, any stones over 2 cm were removed, and eight 25 cm. diameter black plastic plant-pots were filled with each soil.

Soil analyses

Three samples of each soil were taken soon after collection and the amount of labile phosphate was measured using Harrison's method. Additional samples were also taken on 7th November to check that no major changes had occurred.

Air-dried 2mm. sieved samples were also prepared, and were analysed for total phosphate content, total nitrogen content, and amount of extractable P, K, and Ca, using 2.5% acetic acid as extractant.

The results of these analyses are given in Table 1.

The labile P measurements were fairly consistent within any one soil, though a few samples varied by as much as 50%, but the values obtained in November were not very close to those obtained in March, the coefficient of the correlation between the two sets of values being only 0.45 . The correlation between the labile P per unit weight in November had, however a correlation coefficient of 0.73 with the labile P in March per unit volume. (The conversion from unit weight to unit volume was made by use of Jeffrey's conversion table, based on loss-on-ignition (Jeffery, 1970)). Even this, however, accounts for only 50% of the variation between the two sets of data.

Growth of seedlings

1971 was a very poor year in this part of the country for sycamore seed production, but a tree was located from which about 600 apparently sound seeds were collected. These were stored in the usual way and stratified in moist sand for 8 weeks before sowing at a density of 5 seeds per pot. Germination was fairly even, but, contrary to expectation, was nowhere near 100%, and only about 135 seeds germinated.

In view of the small numbers of seedlings, therefore, only one fertilizer treatment was given, plus a control, in place of the intended three treatments.

In addition to the sycamore seedlings (and numerous weed species, which were removed), a number of birch seedlings grew in some of the pots. The pots containing soil from Bron Eifion produced several hundred such seedlings, and some of these were transplanted a few weeks after germination to each of the other soils, to give a total of 4 plants per pot, (sycamore and/or birch), thus giving some unexpected but useful information on the growth of this species. (The birch in this case was thought to be of the species Betula verrucosa Ehrh.)

The number of sycamore seedlings in each soil varied from 5 to 14, but the number was not significantly correlated with any of the soil variables measured, and the variation appeared to be random.

Treatment

The one treatment which was given involved the addition of 3 gm. of $NaH_2PO_4.2H_2O$ to half the pots, at random, containing each of the 13 soils.

$\frac{1}{2}$ gm. was added on 31st May and a further $2\frac{1}{2}$ gm. on 17th July, as the earlier amount had not reasulted in any obvious increase in growth, although there were, by this time, noticeable differences between the different soils.

Results

The mean height growth of the sycamore seedlings on 30th August was 92.6 mm., without added phosphate, and 128.3 mm. with added phosphate; the birch being 45.1 mm. and 65.5 mm. respectively.

The mean figures for each soil are given in Table 2, together with the dry weights when the seedlings were harvested on 12th September, and the root/shoot ratios.

The correlations between soil variables and weight of seedlings are given in Table 3. The root/shoot ratios were not significantly correlated with any of the soil variables, and the correlations with height growth were similar to those for dry weight. (The correlation coefficient between height growth and dry weight was 0.89 in the case of sycamore and 0.97 in the case of birch.)

Orthogonalized regressions were carried out on these soil variables, in relation to the various plant variables, and significant correlations were obtained with a number of the eigenvalues in the case of mean weight and mean weight increment in both species.

Multiple regression equations were calculated using all of the soil variables and with some omitted, and these are discussed below:-

1. Mean weight of sycamore seedlings (without added P)

Including all 8 soil variables, the regression accounted for 88.2% of the variability in seedling weight.

If pH is omitted from the calculation, 87.9% is accounted for, and the omission of total N similarly makes relatively little difference.

If labile P is also omitted, 73.2% of the variation is accounted, and it is evident from Table 3 that labile P is correlated to some extent with the growth of sycamore seedlings.

The predicted and actual values for the 13 soils are given in Fig. 1, based on all the soil variables except pH, for which the regression equation is

Wt. of seedling = 0.1176 - (total N (per ml.) x 6.841) + (total P x 30.1) + (labile P x 0.0186) - (loss-on-ignition x 0.033) + (extractable P x 0.497) + (ext. Ca x 0.0019) + (ext. K x 0.055)

Fig. 2 shows the predicted and actual values based on 5 soil variables, and it can be seen that, in three cases, the predictability is much poorer, but in the other 10 cases it remains much the same. The regression equation in this case is

Wt. of seedling = -1.7786 + (total P x 28.31) - (loss-on-ignition x 0.026) + (ext. P x 0.0546) + (ext. Ca x 0.00454) + (ext. K x 0.0562)

2. Mean weight of birch seedlings (without added P)

The 8 soil variables accounted for 77.3% of the variability in seedlings weight, and 5 variables (omitting labile P, pH, and total N) accounted for 75.7%, the omission of the labile P measurements making little difference in this case.

The regression equation for the 5 variables is

Wt. of seedling = -0.19195 + (ext. K x 0.01117) x (ext. P x 0.6069)
+ (total P x 1.5257) - (loss-on-ignition x 0.001349)
- (ext. Ca x 0.000845)

Fig. 3 shows the predicted and actual values for the 13 soils.

3. Mean weight increment of sycamore seedlings with added P

The 5 soil variables accounted for 89.0% of the variability in this case, the regression equation being

Wt. increase = 2.043 + (ext. Ca x 0.00375) + (ext. P x 2.294) +
(loss-on-ignition x 0.0315) - (total P x 25.56) - (ext. K x 0.060)

All 8 soil variables accounted for 95.4% of the variability.

4. Mean weight increment of birch seedlings with added P

In this case, the 5 soil variables accounted for only 28.0% of the variability, although all 8 accounted for 59.1%. Even the higher of these figures is too low to be of very much practical use, although the orthogonalized regression shows a significant correlation with the 5th eigenvalue, which is strongly related to total P and labile P.

Discussion

The value of the labile P measurements was less than had been expected, although it did help to explain to some extent the variation in the growth of sycamore seedlings in the different soils and in explaining the response of birch seedlings to added phosphate. Harrison's (1971) work with nettles was carried out on soils covering a wider range of pH values (up to 7.8), and it may be that the method is of more use in studies of a wide range of soil types than in a study such as this which was deliberately restricted to a limited pH range.

It is obvious that, as had been expected, soil phosphate, in one form or another, is very important in the growth of seedlings of both species. The response of sycamore to added phosphate is correlated closely with the calcium level (and, therefore, the pH value) of the soil and to the "extractability" of phosphate. The response of birch to added phosphate is more obscure, and may, possibly, have been influenced by interference from sycamore seedlings growing in the same plant-pot.

The amount of variability explained by the regressions for the growth of sycamore and birch seedlings appears to be sufficient to predict with some degree of accuracy the likely rate of growth of these species, given adequate light, moisture, and freedom from root competition. Further verification, using a larger number of soils, would be desirable, however, before too much reliance is placed on these regressions.

Such information might help to indicate the likely competitive status of these species. It would appear, from field observation at the 13 woodland sites from which the soils were taken, that sites which produced seedlings of less than 1 gm. mean dry weight are unlikely to contain many sycamore trees, whereas birch will grow on almost any soil if the area is suitably managed.

The sites at Gorswen and Bron Eifion make an interesting comparison. Both appear to be just capable of growing sycamore seedlings adequately, and both give increased growth if there is a localized increase in phosphatic material, but Bron Eifion appears to be an excellent site for the growth of birch whereas Gorswen is one of the poorest sites for this species. Bron Eifion wood is, in fact, almost pure birch; and the Nature Conservancy have been busy removing sycamore at Coed Gorswen to prevent it taking the place of oak and other tree species, as it has been colonizing this wood very rapidly.

The fact that the regression equations given above draw on a number of soil variables, but give a single answer, could mean that they would form a useful means of expressing these soil variables in a form which could be more easily used in site assessment. For example, it may be easier to carry out an analysis on this list of data:-

1. potential of site for growth of sycamore
2. potential of site for growth of birch
3. altitude
4. slope
5. depth of soil

than on this list:-

1. loss on ignition of soil
2. Total P content
3. Extractable K
4. Extractable Ca
5. Extractable P
6. pH
7. soil depth
8. altitude
9. slope

and the results may be easier to interpret. It is intended to investigate this aspect further.

(It is possible that seedlings of sycamore and/or birch do not behave in the same way as mature trees with regard to soil nutrients. A quick examination of sample roots showed that fungal hyphae were present in both species in all soils, but these were not definitely known to be mycorrhizal. The probability is, however, that they were mycorrhizal and were likely to behave in a similar manner to mature tree roots.)

Summary

By using standard analytical techniques for loss-on-ignition, total phosphate, and extractable P, Ca and K it was possible to obtain regression equations which accounted for 73.2% of the variability in the growth of sycamore seedlings in soils taken from 13 different woodland sites, and 75.7% of the variability in the growth of birch seedlings.

The use of a method of assessing labile soil phosphate increased the amount of variability explained in the case of sycamore by a further 10%, but by less than2% in the case of birch, and the method contributed less information than had been expected, over the range of soils used in this study. It may be more useful, however, in soils covering a wider range of pH values and other properties.

It is suggested that the regression equations for the growth of sycamore and birch seedlings, based on 5 soil variables, may give a pair of parameters which would be more useful in the assessment of the qualities of a site for supporting vegetative growth than would the original analytical data.

Acknowledgements

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Table 1

Soil analyses

Soil	loss on ignition	pH	% Total P	% Total N	mg/100g Extractable K	mg/100g Extractable Ca	mg/100g Extractable P	Labile P March	Labile P Nov.
GAN	15.5	4.9	.073	.50	14	57	.16	22.5	25.5
HOWE	17.3	4.2	.096	.66	18	14.0	.51	25.0	18.4
B. BROW	17.7	4.4	.120	.51	18	22	.32	28.9	24.9
LOUGH	13.5	4.5	.085	.62	10	6.5	.13	69.9	24.6
SWAP	44.8	5.4	.100	1.11	11	518	1.36	112.8	60.2
LO[illegible]FELL	31.9	3.9	.088	.93	16	36	.19	42.6	18.8
WINT. PK.	17.3	4.2	.060	.56	11	7.9	.13	57.0	32.4
LMON. E.	37.2	4.3	.120	1.04	17	20	.98	32.2	22.5
V. S. SPRUCE	14.5	5.4	.067	.50	14	299	.47	23.8	14.6
LYULPH'S T.	11.0	5.2	.088	.44	10	79	.60	15.5	24.4
SPRING	17.3	4.4	.081	.62	15	13	.37	36.5	46.3
V. S. PINE	10.1	5.3	.061	.42	32	113	.31	45.9	23.9
GORSWEN	10.6	5.5	.070	.41	11	61	.10	26.3	14.5

"Labile P" = micrograms isotopically exchangeable phosphate per gm. (oven dry weight)

Table 2 Height growth and weights of seedlings

Soil	Mean height (mm)		Mean ht. + P		Mean weight (gm)		Mean weight increase. with added P		Mean root/ shoot ratio		Mean change in r/s ratio with added P	
	Syc.	Birch	Syc.	Birch	Syc.	Birch	Syc.	Birch	Syc.	Birch	Syc.	Birch
GAN.	93	33	147	77	1.43	0.16	1.19	0.32	0.76	0.67	-.08	-.34
HOWE	130	83	85	71	1.66	0.73	-.50	-.13	0.45	0.52	+.29	-.13
B. BROW	127	53	128	53	2.51	0.31	-.63	0.03	0.84	0.32	-.22	-.06
LOUGH	74	25	78	37	0.93	0.09	.05	.07	1.07	0.43	-.13	+.01
SHAP	133	69	285	51	3.50	0.43	5.61	-.06	0.77	0.26	-.02	+.02
LOW FELL	55	28	56	72	0.44	0.09	-.06	.38	1.35	0.31	-.53	+.15
WINT. PK.	55	29	80	39	0.37	0.11	0.64	.15	1.32	0.34	-.17	+.10
BRON. E.	87	107	148	169	1.34	0.69	1.70	.40	0.90	0.38	-.21	+.09
V. S. SPRUCE	65	26	150	51	0.82	0.10	1.20	.24	0.60	0.38	-.12	+.01
LYULPH'S T.	81	34	152	53	1.19	0.18	1.31	.09	1.08	0.39	-.44	-.05
SPRING	80	29	87	43	1.05	0.16	.05	.01	1.03	0.19	-.22	+.13
V. S. PINE	144	45	149	79	2.21	0.28	.37	.15	0.62	0.29	-.03	-.02
GOLDWEN	80	25	123	56	1.09	0.09	1.10	.18	0.95	0.47	-.15	-.18

Table 3

Correlations between soil variables and seedling growth

	1	2	3	4	5	6	7	8	9	10	11	12
1. Loss on ignition	1	.57*	.97**	-.13	.47	.75**	.58*	-.22	.38	.63*	.46	.13
2. Total P		1	.57*	-.06	-.02	.54	.06	-.36	.43	.10	.64*	-.12
3. Total N			1	-.14	.36	.70**	.57*	-.33	.27	.53	.49	.11
4. Extractable K				1	-.12	-.06	-.16	-.01	.29	-.31	.30	.06
5. " Ca					1	.67*	.59*	.63*	.58*	.85**	.05	-.19
6. " P						1	.45	.23	.63*	.78**	.63*	-.21
7. Labile P (March)							1	.08	.46	.64*	.03	-.32
8. pH								1	.26	.68*	.38	.54
9. Mean weight of sycamore									1	.54	.43	-.49
10. Mean weight increment of sycamore + P										1	.16	-.06
11. Mean weight of birch											1	-.25
12. Mean weight increment of birch + P												1

* significant at 0.05 probability level

** " " 0.01 " "

FIG. 1. MEAN WEIGHT OF SYCAMORE SEEDLINGS, PREDICTED FROM REGRESSION ON 7 SOIL VARIABLES.

FIG. 2. MEAN WEIGHT OF SYCAMORE SEEDLINGS, PREDICTED FROM REGRESSION ON 5 SOIL VARIABLES.

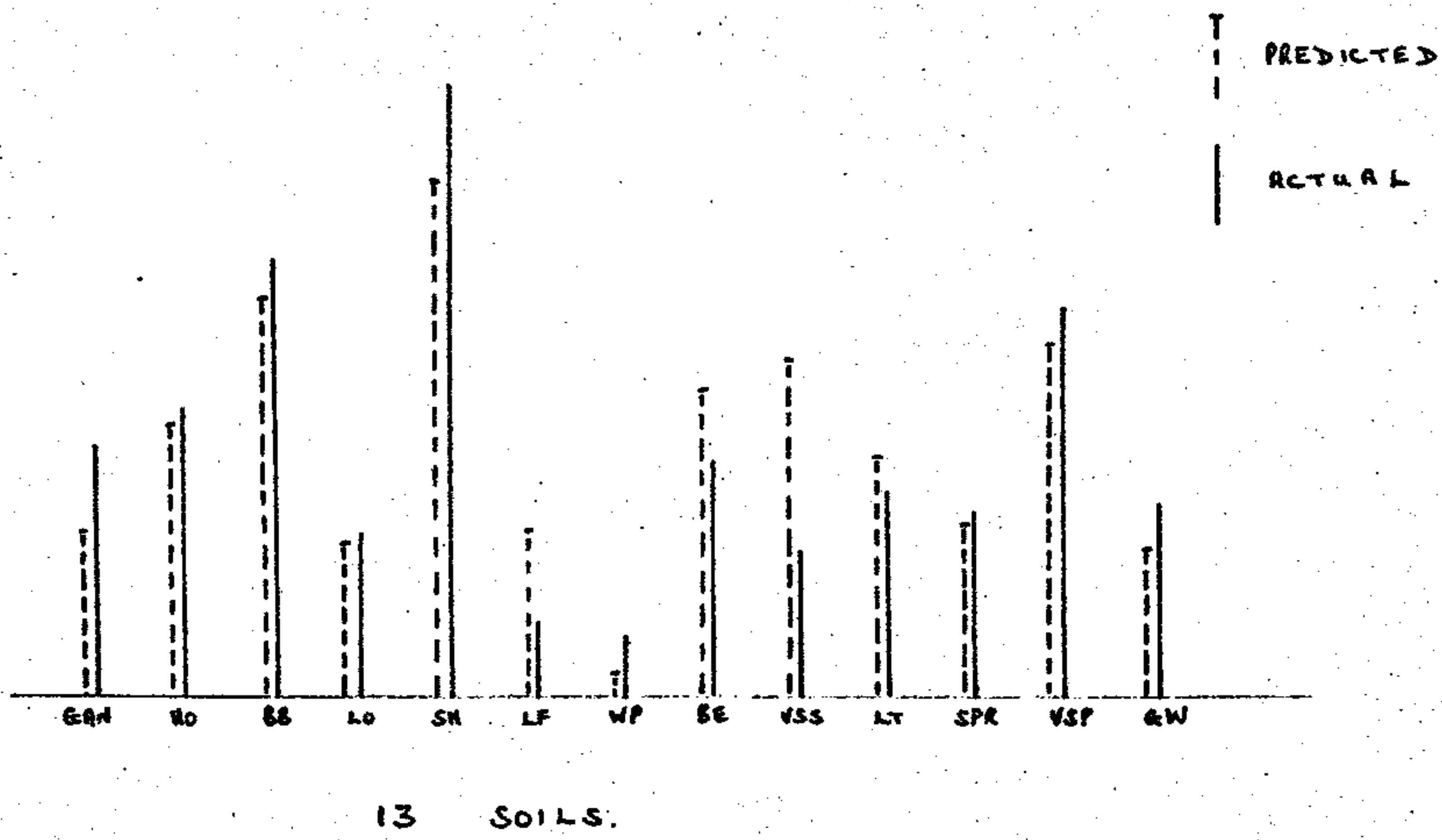

FIG. 3. MEAN WEIGHT OF BIRCH SEEDLINGS, PREDICTED FROM REGRESSION ON 5 SOIL VARIABLES.