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EFFECTS OF TREES ON SOIL PROPERTIES, A
RESAMPLING OF J D OVINGTON'S PLOTS AT BEDGEBURY

by

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1 INTRODUCTION

Because the United Kingdom imports about 92% of the timber that it uses, a considerable expansion of the afforested area appears to be inevitable (Centre for Agricultural Strategy 1980). A study of the effects of tree species on soils is therefore timely and of practical importance, because it is desirable to be forewarned of changes likely to result from the establishment of trees, so possibly being able to direct those changes by selecting the most suitable tree species for conserving and improving soil fertility, an aspect of particular importance to poor marginal land where most of the expansion is likely to occur.

In 1951, to gain an insight into the effects of trees on soils, J. D. Ovington sampled soils in plots of coniferous and deciduous species on five sites. His papers (Ovington 1953, 1954, 1955, 1956a, 1956b, 1958a, 1958b) did not present a statistical analysis of the data. In 1974, plots at Bedgebury, Abbotswood, and West Tofts which had not been felled and replanted were resampled by ITE and Forestry Commission staff to define changes in soil and litter chemical properties which might have occurred in the intervening period. None of the existing plots had fertilizer applied either on planting or subsequently, and none has had herbicide applications at any stage. However, there is evidence which suggests that parts of the Bedgebury site were marled at some time.

The three sites which were resampled differ in soil parent material and in the species planted. This paper presents the results for species planted at Bedgebury.

2 SITES AND SAMPLING PLOTS

The Bedgebury Forest Plots (Kent) are on the Hastings Beds of Tunbridge Wells Sand (Lower Cretaceous). They occupy the crest of a gentle anticline, the axis of which runs north-east, the land falling gradually, with a slope of about 3 degrees, towards the north-west, from about 91 m to 67 m above sea level. There is a gradation of soil through the plots, soils on the lower ground in the north-west being fairly permeable loams, while to the south-east leaching of the surface horizons and gleying of the subsoils become more noticeable. The soils are deficient in phosphorus and other nutrients (Mitchell & Westall 1972).

In the plots sampled, the soil is a compact silty clay, of average depth 70 cm, which becomes plastic and sticky when wet, but upon drying forms hard lumps that are difficult to break. Drainage is imperfect, so that in winter, or during heavy rainfall at other times, the soil frequently becomes waterlogged. The degree of gleying varies within plots. The upper soil is stone-free but flattened shaly stones increase in frequency with depth. The pH varies from 5 to less than 4 (Ovington 1953). The area had an extensive drainage system, but drains were found only in plots of *Pseudotsuga menziesii* and *Picea omorika*.

Before the Forest Plots were planted, the area carried a crop of chestnut coppice with oak standards and a few Norway spruce, Scots pine, and larch. Except for a shelterbelt to the north-east, the site was clear-felled in 1928, and plots of a quarter acre were planted, each with a single species. The tree species and planting years of the resampled plots are given in Table 1. Full soil profile descriptions are given in Ovington (1953).

Within each plot, five profiles were sampled. Original manuscript tables at Merlewood showed that the depths of two of the soil layers in Ovington's published pH data for Bedgebury (Ovington 1953) were incorrect. His 45-50 cm should read 40-45 cm, and his 65-70 cm should read 55-60 cm. The original tables gave different data for total calcium in L and F/H layers at Bedgebury from those published (Ovington 1958). Consequently, we used the original values. The sampling depths for the soil variables were 0-5, 5-10, 15-20, 25-30, 40-45 cm.

3 METHODS

3.1 Chemical analyses

The analyses which were common to both the 1951 and 1974 samplings were L and F/H layers: loss-on-ignition, total nitrogen, total sodium, potassium, calcium, magnesium, phosphorus. Soil: pH, loss-on-ignition, total nitrogen, extractable sodium, potassium, calcium, magnesium, phosphorus. There were some differences in the chemical methods used in 1951 and 1974, which made it necessary to apply conversion factors to some of the 1974 values to produce a 1951 equivalent (Appendix 1).

3.2 Statistical analyses

Ovington's plots were not part of a designed experiment, this was an opportunistic sampling of plots which had been planted for another purpose. Each species occurred only once at each site.

Analysis of variance: Ovington's papers did not give any indication of the variance within plots. In order to compare plot (ie species) means between years, we need an estimate of the within-plot variance. In the present work, the only course open to us was to assume that the within-plot variances in Ovington's samplings were the same as those in the 1974 samples, although this is not altogether satisfactory.

To obtain a pooled within-plots estimate of the variance, we did a one-way analysis of variance of the 1974 data for each site, soil depth (or L or F/H layer) and chemical element, separately. If there is heterogeneity of variance between plots (Bartlett's test), the pooled within-plots estimate of the variance cannot be used to compare between years. In such cases, transformation may remove heterogeneity. In cases where transformation was not effective, the means of individual plots in 1951 and 1974 were compared using Fisher's randomization test.

Where heterogeneity did not occur or was removed by transformation, comparisons were made between the plot (species) means for the 1951 and 1974 samplings using Tukey's honestly significant difference. That test was also used to look for differences among plot (species) means in 1974, and between plots and shelterbelt in 1951. In the absence of untreated plots which might be used in a similar way to the control plots of a designed experiment, the shelterbelt may be of use as a reference plot because it contains the remains of the original vegetation. For the L and F/H layers, on the 1974 sampling, there were not always 5 replicates per plot, and so Dunnett's (1980) modification for unequal sample sizes was used. Scheffé's (1953) method was used to test for differences between means for broadleaves and conifers in 1974.

Principal component analysis: A principal component analysis was carried out on the correlation matrix of the data for the 7 chemical variables (means of plots) for both years for the L and F/H layers together. A similar analysis was carried out on the 8 chemical variables (means of plots) for both years for all the soil layers common to both samplings. A third set of analyses was carried out on the 1974 data alone, treating each layer separately. Components with eigenvalues greater than unity were accepted as being of practical importance. Eigenvector elements equal to, or greater than, 0.75 times the largest value (absolute) showed the variables which contributed most to the components. In each case the minimum spanning tree of the Pythagorean distances was computed from the components considered to be of practical importance.

4 RESULTS

Two complementary types of figure are used to present the results. One type illustrates the change of each variable with depth and the depths at which differences between years are significant. In the second type, for each soil depth, the mean values of the plots (species) are ordered on a single axis for each year. The second type illustrates more clearly than the first type the magnitudes of the differences between years, the relative values of the species in either year, and the significant differences, or lack of difference, between species in 1974.

4.1 L and F/H layers, analysis of variance

pH: Not measured in 1974 for L and F/H layers.

Loss-on-ignition: *P. menziesii* litter had the lowest loss-on-ignition (greatest ash content) in 1951, but the loss-on-ignition had increased significantly by 1974 (Figure 4). *N. obliqua* showed the reverse effect in the F/H layer. *P. nigra* had the greatest loss-on-ignition (lowest ash content) in both layers in both years.

Nitrogen (total): In both 1951 and 1974, *C. lawsoniana* litter had the smallest, and *Q. petraea* the greatest, total nitrogen content (Figure 6). In 1974 the mean total nitrogen content of the hardwood litters was significantly greater ($p < 0.001$) than that of the coniferous litters. *P. menziessi* showed a significant increase, and *P. abies* a significant decrease, in L layer total nitrogen between years. In the F/H layer, *C. lawsoniana* also had a low total nitrogen content in both years. *Q. petraea*, *L. eurolepis*, *N. obliqua*, *T. heterophylla* and *T. plicata* showed significant decreases in total nitrogen from 1951 to 1974, and most other species showed small decreases. These decreases must be due to some change other than the total nitrogen content of the litter, and may reflect different biochemical activity in the forest floor.

Sodium (total): *T. heterophylla* litter had a very large total sodium content in 1951. Although this had decreased significantly by 1974, it was still greater than for any of the other species (Figure 8). In the F/H layer, *T. heterophylla* again had the greatest sodium content in both years. *P. menziesii*, *P. abies* and *P. nigra* all showed significant increases with time in total sodium in the L layer, while those species plus *N. obliqua*, *Q. rubra* and *T. heterophylla* all showed significant increases in the F/H layer.

Potassium (total): There were very few significant changes in total potassium in either the litter or F/H layer (Figure 10). *T. heterophylla* showed a significant decrease in total potassium in the L layer between years, while *N. obliqua* and *T. plicata* showed significant increases in the F/H layer between years.

Calcium (total): There was a narrowing of the range of total calcium in both the L and F/H layers with time (Figure 12). In the F/H layer, this was due chiefly to a decrease in the larger values. *N. obliqua* had the greatest total calcium content in both layers in both years. In the L layer, *L. eurolepis* showed a significant increase, while *Q. rubra* showed a significant decrease, between 1951 and 1974.

In the F/H layer, *N. obliqua*, *Q. rubra*, *C. lawsoniana*, *T. plicata* and *T. heterophylla* all showed significant decreases in total calcium between 1951 and 1974, and most of the other species showed small decreases. This is similar to the pattern of changes for total nitrogen in the F/H layer, and it does not seem to be due to a corresponding decrease in the total calcium content of the L layer.

Magnesium (total): In 1974 the mean total magnesium in the hardwood litters was significantly greater ($p < 0.001$) than that of the coniferous litters. *Q. rubra*, *N. obliqua*, *T. plicata*, *C. lawsoniana*, *T. heterophylla*, *P. abies* and *P. menziesii* all showed significant decreases from 1951 to 1974 in the L layer (Figure 14). All 10 species showed large decreases in the F/H layer. *P. abies* and *T. heterophylla* had the lowest total magnesium contents for both layers in 1974.

Phosphorus (total): In 1974, the mean total phosphorus content of the hardwood litters was significantly ($p < 0.01$) greater than that of the coniferous litters. In the L layer, *Q. petraea*, *P. menziesii*, *L. eurolepis*, *N. obliqua* and *Q. rubra* showed significant increases in total phosphorus content from 1951 to 1974 (Figure 16). All the remaining species showed small increases. *C. lawsoniana* and *P. nigra* litters had the lowest total phosphorus content in both years. In the F/H layer, only *P. menziesii* showed a significant increase.

4.2 Soils, analysis of variance

pH: The means are plotted against depth in Figure 1. The differences between the mean values of the ten species and that of the shelterbelt in 1951 are summarized in Table 2, which shows that although there are suggestions of trends emerging there is no really consistent effect for any species. Figure 2 shows that in 1951 the species had not assumed any clear order with respect to pH.

It is clear that, over most of the profile, there was a significant ($p < 0.05$) increase in pH under *N. obliqua*, *P. menziesii*, *P. nigra* and especially *Q. petraea*. Figure 2 shows that at all soil depths there is a tendency for the range of pH values to decrease from 1951 to 1974. Also, by 1974, a recognizable order had developed in the surface soils, with the three hardwood species having significantly greater pH values (0-5 cm, $p < 0.01$; 5-10 cm, $p < 0.05$; 15-20 cm, $p < 0.01$). To a depth of 25 cm, *Q. petraea* and *Q. rubra* plots were the least acid in 1974, and *T. heterophylla* and *P. abies* plots were the most acid. Below 40 cm, the *C. lawsoniana* and *L. eurolepis* plots were the most acid. *P. abies*, *C. lawsoniana*, *T. plicata*, *L. eurolepis* and *Q. rubra* showed decreases at some depths but not at others.

LOI: The means are shown plotted against depth in Figure 3. In 1951, there were few statistically significant differences between the 10 species plots and the shelterbelt, and the significant differences occurred only in the 25-30 cm and 40-45 cm layers. They are probably of little or no ecological importance.

There were few statistically significant changes between 1951 and 1974 (Figure 4), and those that did occur were usually only in one layer. However, *P. menziesii* showed significant decreases at both 25-30 cm and 40-45 cm, and small, non-significant, decreases in the other layers. In 1974, the range of loss-on-ignition values between plots had increased in the 0-5 cm layer, *T. heterophylla* still having the greatest loss-on-ignition and *Q. rubra* the smallest. These two plots had the extreme pH values for this layer. Only *L. eurolepis* showed a statistically significant increase in the 0-5 cm layer, but several of the other conifers, eg *T. heterophylla*, showed some increase. Several species, eg *T. heterophylla*, showed a noticeable decrease in loss-on-ignition in the 5 cm to 20 cm depth range. Most plots showed a slight decrease in the lower layers; *Q. rubra* had the smallest loss-on-ignition in all layers, and was lower (but not significantly) in 1974 than in 1951.

N (total): The means are shown plotted against depth in Figure 5. In 1951, 7 of the 10 species showed a significantly lower nitrogen content in the 5-10 cm layer than at the same depth in the shelterbelt. Only *T. heterophylla* showed a difference in a deeper layer (25-30 cm).

At 0-5 cm, the soil under *L. eurolepis* showed a significant increase in total nitrogen between years (Figure 6), whereas in most other plots there was a slight (but not significant) decrease. Seven of the 10 species had significantly lower nitrogen content in the 5-10 cm layer in 1974 than in 1951, and for 6 of those species differences were found in deeper layers.

In 1974, soil under *Q. rubra* had the lowest total nitrogen content in all layers. Under *P. nigra*, soil at 0-5 cm was relatively low in nitrogen, but had the greatest total nitrogen at 5-10 cm, 15-20 cm and 25-30 cm.

Na (extractable): The means are plotted against depth in Figure 7. There were no significant differences between the 10 species and the shelterbelt at any depth in 1951. In 1974, the soils under *Q. petraea* and *Q. rubra* had the smallest extractable sodium values in all horizons. Under the other hardwood, *N. obliqua*, the soils had relatively large values for extractable sodium (Figure 8). However, the mean extractable sodium under the hardwood species was significantly smaller than that under the coniferous species at 0-5 cm ($p < 0.001$), 5-10 cm ($p < 0.01$), 10-15 cm ($p < 0.05$) and 25-30 cm ($p < 0.01$).

Between years, *Q. petraea* and *Q. rubra* showed significant decreases at 0-5 cm and 25-30 cm (Figure 8) and small, but not significant, differences at the other depths. The range of extractable sodium values increased at all depths. Most of the conifers showed increases in extractable sodium in all layers, but these were statistically significant only for *L. eurolepis* and *P. abies* at 0-5 cm, and for *C. lawsoniana* at 15-20 cm. However, under *P. nigra* extractable sodium decreased in all horizons, although the change was not statistically significant. In 1974, *P. nigra* soil had the lowest extractable sodium of all coniferous plots down to 30 cm depth, but had the greatest extractable sodium content of all coniferous plots at 40-45 cm.

K (extractable): The means are shown plotted against depth in Figure 9. There were no significant differences between the 10 species of interest and the shelterbelt at any depth in 1951. Down to 30 cm, soil under *T. heterophylla* had the lowest extractable potassium in both years (Figure 10). Below 15 cm, soil under *P. nigra* had the greatest extractable potassium content in both years, above 15 cm this plot had the greatest extractable potassium content only in 1951. Between 1951 and 1974, soil under *P. menziesii* showed significant increases in extractable potassium in all layers below 15 cm. Soil under *P. nigra*, *C. lawsoniana* and *N. obliqua* showed significant increases between years below 25 cm depth. Under many species, a significant increase was found in at least one layer below 15 cm. Under *P. nigra*, there was a significant decrease in extractable potassium in the 0-5 cm layer.

Ca (extractable): The means are shown plotted against depth in Figure 11. Soil under *P. nigra* had a significantly greater extractable calcium content in the top three layers in 1951 than had the corresponding layers under the shelterbelt. All species showed significant decreases in extractable calcium in some layers between 1951 and 1974, and under *N. obliqua* all layers showed significant decreases (Figure 12).

Below 5 cm depth, soil under *P. nigra* had the greatest content of extractable calcium in both years. At 0-5 cm, it was greatest in 1951 but not in 1974.

Mg (extractable): The means are shown plotted against depth in Figure 13. Of all the plots, the only soil layer which differed from the equivalent depth under the shelterbelt was *P. nigra* 40-45 cm. There were significant decreases in extractable magnesium in most layers under all species between 1951 and 1974 (Figure 14). In all layers below 15 cm depth, soil under *P. nigra* had the greatest extractable magnesium content in 1974. In 1951, soil under *P. nigra* had the greatest extractable magnesium in all layers except 25-30 cm, which had the second greatest value at that depth. Soil at 0-5 cm depth under *P. abies* had the smallest extractable magnesium content in both 1951 and 1974, and was among the lowest in the other layers.

P (extractable): The data are plotted against depth in Figure 15. In 1951, no species differed from the shelterbelt in the extractable phosphorus content of any layer.

Between 1951 and 1974, there was a small increase in extractable phosphorus in the 0-5 cm and 5-10 cm layers under all species, but the difference was significant only under *L. eurolepis*, *Q. petraea* and *T. plicata* at 0-5 cm and under *Q. petraea* at 5-10 cm (Figure 16). In both of these layers, *Q. petraea* had the greatest extractable phosphorus content of all plots in 1974. *P. menziesii* and *Q. rubra* plots showed significant increases at 15-20 cm. Below 25 cm, most plots showed small decreases. Although some of these decreases were statistically significant the absolute change was less than 0.05 mg/100 g OD.

4.3 L and F/H layers, principal component analysis, 1951 and 1974 data combined

Loss-on-ignition (CV 13%) and total phosphorus (CV 18%) showed little variation, while total sodium (CV 46%) showed most variation. Only 7 of the 21 correlation coefficients were significant ($p < 0.05$), the largest coefficients being total potassium negatively correlated with loss-on-

ignition ($r = -0.649$, $p < 0.001$), ie positively correlated with ash content, and total nitrogen and potassium contents being positively correlated with total phosphorus ($r = 0.554$, $p < 0.001$; $r = 0.564$, $p < 0.001$ respectively).

The first four eigenvalues of the correlation matrix may be considered to be of practical importance, together they account for 86% of the total variance. The first component accounts for 33% of the variance, and the corresponding eigenvector shows that it is essentially a contrast between total potassium and phosphorus on the one hand and loss-on-ignition on the other. The second component is essentially a combination of total magnesium, nitrogen and calcium. The third is chiefly a combination of loss-on-ignition and total sodium, while the fourth is dominated by total calcium. The first and second component values are plotted in Figure 17.

4.4 L and F/H layers, principal component analysis, 1974 data only

In the L layers, loss-on-ignition showed very little variation (CV 3%), while total magnesium showed most (CV 34%). Only 7 of the 21 correlation coefficients are significant ($p < 0.05$), the largest being total phosphorus with total nitrogen ($r = 0.948$, $p < 0.001$) and with total potassium ($r = 0.887$, $p < 0.001$).

The first three eigenvalues of the correlation matrix may be considered to be of practical importance, together they account for 95% of the total variance. The first component accounts for 56% of the variance, and the corresponding eigenvector shows that it is essentially a combination of total nitrogen, magnesium, potassium and phosphorus, possibly with total calcium. The second component, accounting for 24% of the total variance, is dominated by total sodium, and the third component, accounting for 15% of the total variance, is dominated by loss-on-ignition. The first and second component values are plotted in Figure 18, with the minimum spanning tree in three dimensions superimposed.

In the F/H layers, total phosphorus shows least variation (CV 10%), and total magnesium the most (CV 45%). Only loss-on-ignition and total potassium are significantly correlated ($r = -0.889$, $p < 0.001$).

The first three eigenvalues of the correlation matrix may be considered to be of practical importance, together they account for 87% of the total variance. The first component accounts for 43% of the variance, and the corresponding eigenvector shows that it is essentially a contrast between loss-on-ignition and total sodium on the one hand and total magnesium, potassium and calcium on the other. The second component, accounting for 27% of the total variance, is dominated by total phosphorus, and the third component, accounting for 16%, is essentially a combination of total calcium and nitrogen. The first and second component values are plotted in Figure 19, with the minimum spanning tree in three dimensions superimposed.

4.5 Soils, principal component analysis

The means, standard deviations and coefficients of variation of the 8 variables for the 1951 and 1974 data combined are given in Table 3. pH shows least variation, with a coefficient of variation of 4%. Extractable phosphorus and calcium are the most variable, with coefficients of variation of 127% and 108% respectively. The correlation half-matrix is shown in Table 4. There are significant positive correlations among all variables except pH, which is significantly negatively correlated with loss-on-ignition, total nitrogen, and extractable sodium and phosphorus.

The first three eigenvalues (Table 5) of the correlation matrix may be considered to be of practical importance, together they account for 88% of the total variance. The eigenvectors of the first three components are given in Table 6. The first component, accounting for 64% of the variance, is a combination of all the variables except pH and extractable magnesium, which dominate components 2 and 3 respectively.

The first and second component values are plotted in Figure 20, 15-20 cm points are omitted for clarity. The order of the soils on the first axis is due chiefly to depth of layer, the deeper layers being at the top of the plot and the 0-5 cm layers at the bottom. However, there are overlaps due to species and years. In particular, at each depth, *Q. rubra* has a noticeably larger first component value in both years than does any other species, and *P. nigra* has a very low first component value for the 40-45 cm layer. Between 1951 and 1974 samplings, there is a general increase in the first component values (ie a decrease in one or more of: loss-on-ignition, total nitrogen, extractable calcium, phosphorus, potassium and sodium) especially for *P. nigra* 0-5 cm. Exceptions to this are *L. eurolepis* 0-5 cm, which shows a large decrease in first component value, and *L. eurolepis* 5-10 cm, *T. plicata* 0-5 cm, and *P. abies* 0-5 cm, which show small decreases.

Q. petraea shows an increase in second component value (ie an increase in pH) at all depths, and is the only species to show an increase in the 0-5 cm layer. In some species, eg *P. nigra* and *T. heterophylla*, there is a decrease in second component value between 1951 and 1974 in the upper soil layers and an increase in the three lower layers. *Q. rubra* shows a decrease in the upper three layers and in the 40-45 cm layer, but an increase at 25-30 cm. At all depths, *T. plicata*, *C. lawsoniana*, *L. eurolepis* and *P. abies* show a decrease in second component value (ie decrease in pH). *T. heterophylla* 0-5 cm had the lowest second component value in 1951, and an even lower value in 1974.

On the third component axis, all the values increased from 1951 to 1974, especially in the upper horizons (ie there was a decrease in extractable magnesium) except for *L. eurolepis* and *Q. rubra* at 40-45 cm.

For the 1974 data only, the orders of the species plots on the first components at the different depths are given in Table 7. The variables which make an important contribution to the first axes vary with depth, only total nitrogen and extractable potassium are constantly important at all depths. Loss-on-ignition is important at all depths except 15-20 cm, extractable phosphorus is important only at 0-5 cm, extractable calcium is important at all depths except 5-10 cm and 20-25 cm, and extractable magnesium is important at all depths except 20-25 cm.

The first and second component values of the 1974 0-5 cm soil layer data are plotted in Figure 21 with the minimum spanning tree (3 dimensions) superimposed. The order on the first axis summarizes the differences under the majority of the species, but higher components reveal additional differences such as the low second component values under *T. heterophylla*, *P. abies* and *C. lawsoniana* associated with low pH and large extractable sodium content.

5 DISCUSSION

The pH of surface layers of woodland soils is widely assumed to be strongly influenced by the nature of the leaf litter falling on them. These pH data suggest that in 1951 the trees had not begun to exert their full effect on the soil. That is hardly surprising, as only about 20 years previously the site had been clear-felled and planted with young trees. During at least the first 10 years of their life, the trees would have been too small to have any major effect on soil pH. At the same time, soil changes were almost certainly taking place as a result of the initial clear-felling. This, as well as the lack of within-plot variances in 1951, makes it very difficult to interpret Ovington's data. However, it is evident that by 1974 the trees were having a much clearer effect on the soil. The mean pH of soil under the hardwood species was significantly greater (0.1-0.3 pH units) than that under the coniferous species at 0-5 cm, 5-10 cm and 15-20 cm, and there is some suggestion that trends shown in Ovington's data may have been reversed later.

In 1974 all plots, including those planted with hardwoods, showed an increased acidity of the upper mineral soils, 0-30 cm, when compared with their lower soils. In all plots except *C. lawsoniana*, *L. eurolepis* and *Q. rubra* this acidification of the upper layers relative to their lower layers has become more pronounced than it was in 1951 (Ovington 1953). The *Quercus* species showed the least difference in pH between upper and lower layers (0.02 pH units) and *P. menziesii* the most (0.31 pH units). However, this increased difference between upper and lower layers is often due to greater increases in pH in the lower layers rather than increased acidification of the upper layers (Figure 1). This may be due to small decreases in organic matter in the lower layers and leaching of bases from the surface layers which are deposited at lower depths.

Between 1951 and 1974, there has been a tendency towards a narrowing of the pH range between plots. Between 0 and 25 cm depth, *Q. petraea* and *Q. rubra* had become the least acid plots in 1974, while *T. heterophylla* and *P. abies* had become the most acid. At 0-5 cm, soil under *P. abies* had a pH of 3.99, under *T. heterophylla* it was 3.81. Alban (1969) found that, on 2 of the 3 plots examined, the pH was lower under *T. heterophylla* than under *T. plicata* down to 25 cm. Ovington and Madgwick (1957) found that, on a number of sites including those studied here, soil over the rooting depth under *T. heterophylla* and *P. menziesii* tended to be most acid, while that under *C. lawsoniana* and *T. plicata* tended to be the least acid.

In trying to find an ecological interpretation for these results, it is useful to recognise two groups of variables (a) those concerned directly with the quality and quantity of soil organic matter (LOI, pH, N, P) and with changes in these properties which are brought about by physiological activities of soil organisms, and (b) elements of the soil exchange complex (eg K, Ca, Mg, Na) which can be removed by leaching and can be replaced by weathering of soil minerals or, in the upper soil layers, by tree litterfall. The role of sodium is often difficult to interpret. The main changes between 1951 and 1974 in pH, nitrogen, phosphorus, potassium, calcium, magnesium and sodium are summarized in Table 8.

Under *P. nigra*, the changes in pH are small (0.25 - 0.35 units) and of doubtful ecological importance in themselves, although they may indicate a long-term trend. The losses of nitrogen at 5-10 and 15-20 cm are fairly pronounced, and suggest a change in 'biological activity'. At 0-5 cm, losses of extractable potassium and magnesium are quite large, and the loss of calcium is very large. The loss of calcium is pronounced down to 20 cm and of magnesium to 30 cm. The losses of extractable calcium and magnesium under *P. nigra* were the greatest of all species plots examined. These results suggest considerable leaching in the top half of the soil profile. The marked increase in extractable potassium at 25-30 and 40-45 cm may be due to leaching of potassium from the upper layers, or possibly increased weathering.

At 0-5 cm, soil under *P. menziesii*, *Q. rubra* and *N. obliqua* had the second largest loss of extractable calcium. Under *P. menziesii*, losses of calcium and magnesium were large down to 30 cm. At all depths where there was an increase in pH, the change was less than 0.5 unit. The loss of nitrogen between 5 and 30 cm was fairly marked, suggesting a change in 'biological activity' (cf increase in phosphorus at 15-20 cm). Soil under *N. obliqua* showed similar losses of nitrogen at 5-30 cm. Under this species too, there has been a fairly strong leaching of cations from the upper layers. Under *Q. rubra* there were also large losses of extractable calcium and magnesium at 5-10 cm, and sizeable losses of magnesium down to 45 cm. The decrease in calcium at 25-30 and 40-45 cm, was small, and significant only in relation to the generally small values at that depth. Bornebusch (1939) stated that *Q. rubra* is said to have a great capacity for forming mull in soils where most other trees produce mor, but Petch (1965) stated that *Q. rubra* litter was found to be poor and did not contribute significantly towards a milder humus in mixtures with *Pinus sylvestris* and *P. nigra*.

Soil under *T. heterophylla*, *C. lawsoniana* and *T. plicata* showed a fairly large loss of extractable magnesium at 0-5 cm, and sizeable losses down to 30 cm. Losses of extractable calcium were fairly marked between 5 and 30 cm. These results suggest a slightly less intense leaching under these species than under *P. menziesii*, *Q. rubra* or *N. obliqua*. The fairly sharp drop in total nitrogen at 5-10 cm under *T. heterophylla* and *C. lawsoniana* and the slightly smaller drop at 15-20 cm under *T. plicata* suggest a change in 'biological activity', as does the increase in extractable phosphorus at 0-5 cm under *T. plicata*.

Soils at all depths under *Q. petraea* show increases in pH of 0.21 to 0.38 units. These changes are small, and of doubtful practical significance, but they may be suggestive of a trend. This, together with the decrease in total nitrogen at 5-10 cm and 15-20 cm, and the increase in extractable phosphorus at 0-10 cm, also suggests a change in 'biological activity'. There was no significant loss of extractable calcium under this species at 0-5 cm, but there was a large loss at 5-10 cm and smaller losses occurred down to 45 cm. There were also large losses of extractable magnesium down to 20 cm, and smaller losses down to 45 cm.

Under *L. eurolepis*, the changes are more difficult to interpret. There is an increase in total nitrogen, extractable sodium, potassium and phosphorus at 0-5 cm, and an increase in total calcium and phosphorus in the litter. However, extractable calcium has decreased between 5 and 30 cm, and magnesium has decreased from 5 to 45 cm. At the same time, there was an increase in extractable potassium between 15 and 30 cm.

P. abies showed no loss in extractable calcium at 0-10 cm, moderate losses at 15-20 cm, and a small loss at 25-30 cm. There were sizeable losses of extractable magnesium at all depths. Total nitrogen decreased at 5-10 cm and 25-30 cm.

P. abies is generally regarded as a soil-deteriorating species, and it is often found naturally on podzols with raw humus (Bonnie-Svendson & Gjems 1957). However, this is not always the case. Von Miehlich (1971) found little evidence of soil compaction, nitrogen losses, or serious nutrient depletion in the soil of a 25-year-old second generation spruce stand on a loess-pseudogley, which had been under the species for 120 years, compared with the soil of a near-natural oak-beech stand. He concluded that any effects on the nutrition of the spruce were small. The data for Bedgebury show that the smallest loss of nitrogen and mineral elements occurred under *P. abies*.

Interpretation of the changes which took place on the Bedgebury plots between 1951 and 1974 is complicated by the fact that the 1951 results may have included effects caused by the initial clearance of the site, as well as by subsequent growth of the planted trees. Therefore, it is natural to ask if an examination of the 1974 results suggests that a clearer picture had emerged by that time. We might ask if it is possible to draw up a hierarchy of species, based on the 1974 results. In general, it is not as simple as that, as an examination of the results for the different layers shows. There are problems caused by the different soil layers behaving in different ways.

pH was not important in the first component of any soil layer in 1974. This is not really surprising, because pH had the smallest coefficient of variation in each layer. Considering the range of species, the narrow pH range of the surface soils is rather striking. At 0-5 cm, the lowest pH was 3.81 (*T. heterophylla*) and the highest was 4.40 (*Q. rubra*). The pH under *P. nigra* was 4.24, and under *Q. petraea* 4.33.

Generally, the important variables in the first components in 1974 were LOI and total nitrogen (associated with amount and nature of soil organic matter) and extractable potassium, calcium, and magnesium (associated with leaching and with weathering of soil minerals). Extractable phosphorus is important in the first component only at 0-5 cm, which suggests that biological changes were occurring in that layer. As the first component is the axis of maximum variation, it is interesting to examine the order of the species plots on the first component of each layer (Table 7). The directions of the first component axes are influenced by high or low contents of the listed elements, but these are trends only, and not all will be expressed in any one species. The most striking, and unexpected, result is that the *P. nigra* plot has the largest first component value in all layers except 0-5 cm. At the latter depth, the *L. eurolepis* plot has the greatest first component value. *P. nigra* is not a species which one would normally associate with greater soil nutrient content than, say, *Q. petraea*.

It may be that the position of the *P. nigra* plot in the table has little to do with the planted species. Possibly, this plot was initially richer in certain minerals, due to variation in soil parent material. There is also the possibility that parts of the site were marled. Table 7 suggests that at depths below 20 cm there is some similarity in the order of the species plots on the first component. This reinforces our impression that the profile distributions of the measured variables for some species plots are similar, and that this similarity is associated

with position of the site. The similarity of the properties of soils under *P. nigra*, *P. menziesii* and *N. obliqua* is quite striking. These plots are physically adjacent, and are also the plots nearest to the shelterbelt. Examination of the 5 nearest neighbours (calculated from all of the components selected for study) at each depth strengthened this impression. It seems possible, therefore, that spatial variation within the site means that the soil parent material on the plots under the above three species was different from that under the other species. It is not clear how far this affects the surface layers, where differences may have been reduced under the previous vegetation.

Table 7 shows that under no species does the soil behave in the same way at all depths sampled. As any effect of species is likely to be most pronounced at the surface, the order of the species on the first component at 0-5 cm depth can be taken to indicate the relative effects of the species.

6 SUMMARY

- (i) In 1974, the mean total nitrogen, magnesium and phosphorus contents of the hardwood litters were significantly greater than those of the coniferous litters.
- (ii) Because there were no significant differences between years in the total nitrogen contents of the litters of *Q. petraea*, *L. eurolepis*, *N. obliqua*, *T. heterophylla* and *T. plicata*, decreases in total nitrogen content of their F/H layers from 1951 to 1974 may reflect changes in biochemical activities in the forest floor.
- (iii) There was a narrowing of the range of total calcium in both the L and F/H layers from 1951 to 1974. In the F/H layer, this was due chiefly to a decrease in the larger values.
- (iv) From 1951 to 1974, 7 of the 10 species showed significant decreases in total magnesium in the L layer, and all species showed large decreases in the F/H layer.
- (v) In the L layer, 5 of the 10 species showed significant increases in total phosphorus from 1951 to 1974, but in the F/H layer only *P. menziesii* showed a significant increase.
- (vi) The pH data suggest that in 1951 the trees had not begun to exert their full effect on the soil, but by 1974 they were having a clearer effect.
- (vii) In 1974, the mean pH of soil under the hardwoods was significantly greater than that under the conifers at 0-5 cm, 5-10 cm, and 15-20 cm.
- (viii) In 1974, soil under all species showed a greater acidity of the upper mineral soils compared with their lower soils. Under all species except *C. lawsoniana*, *L. eurolepis* and *Q. rubra* this effect was more pronounced than in 1951. *Q. petraea* and *Q. rubra* showed the least difference, and *P. menziesii* showed the greatest difference, between upper and lower layers.

- (ix) At 0-5 cm, soil under *L. eurolepis* showed a significant increase in total nitrogen from 1951 to 1974, whereas under most other species there was a slight decrease. Under most species at depths below 5 cm there were significant decreases in total nitrogen. In 1974, soil under *Q. rubra* had the lowest total nitrogen content and loss-on-ignition at all depths.
- (x) At 25-30 cm, under all species except *Q. rubra*, there were significant increases in extractable potassium, possibly resulting from accelerated mineral weathering.
- (xi) There were significant decreases in extractable calcium, depending on species and depth. Only under *N. obliqua* were the decreases significant at all depths.
- (xii) There were significant decreases in extractable magnesium under all species at most depths.
- (xiii) As any effect of species is likely to be most pronounced at the surface, the order of the species on the first principal component axes at 0-5 cm can be taken to indicate the relative effects of the species.

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Table 1. Ovington's sites resampled in 1974 at Bedgebury, Kent, National Pinetum.

Species	Planted
<i>Pinus nigra</i> var <i>maritima</i> (Ait.) Melv	1934
<i>Picea abies</i> Karst	1932
<i>Chamaecyparis lawsoniana</i> (A. Murr.) Parl.	1931
<i>Tsuga heterophylla</i> (Raf.) Sarg.	1929
<i>Thuja plicata</i> D. Don	1930
<i>Pseudotsuga menziesii</i> (Mirb.) Franco	1931
<i>Larix eurolepis</i> Henry	1929
<i>Quercus petraea</i> (Matt.) Liebl.	1931
<i>Quercus rubra</i> L. sec du Roi	1931
<i>Nothofagus obliqua</i> (Mirb.) Blume	1930

Table 2. Bedgebury pH. Differences between 1951 mean values of the 10 species of interest and the shelterbelt.

	Soil depth cm							
	0-5	5-10	10-15	15-20	20-25	25-30	40-45	55-60
<i>P. nigra</i>				-	-			-
<i>P. abies</i>	-							
<i>C. lawsoniana</i>		+						
<i>T. heterophylla</i>	-							
<i>T. plicata</i>								
<i>P. menziesii</i>			-		-			-
<i>L. eurolepis</i>			+				+	
<i>Q. petraea</i>						-	-	-
<i>Q. rubra</i>		+	+	+				
<i>N. obliqua</i>				-	-		-	-

+ significantly greater }
 - significantly smaller } at p < 0.05

Table 3. Minima, maxima, means, standard deviations and coefficients of variation of the variables for the Bedgebury soils (1951 plus 1974).

	Min.	Max.	Mean	SD	CV %
pH	3.81	4.63	4.24	0.17	4
LOI % OD	1.00	13.20	5.17	2.86	55
Total N % OD	0.02	0.31	0.11	0.07	64
Extractable Na	0.30	5.10	1.71	0.82	48
" K	1.00	12.70	4.38	2.60	59
" Ca	1.10	53.40	7.58	8.17	108
" Mg	0.40	9.70	3.34	2.27	68
" P	0.01	0.67	0.12	0.15	127

Extractables are given as mg/100 g OD soil

Table 4. Correlation half-matrix for Bedgebury soils (1951 + 1974)

	pH	LOI	N	Na	K	Ca	Mg	P
pH	1							
LOI	-.394***	1						
Total N	-.349***	.942***	1					
Extractable Na	-.460***	.762***	.628***	1				
Extractable K	-.054	.779***	.754***	.557***	1			
Extractable Ca	-.150	.757***	.789***	.517***	.744***	1		
Extractable Mg	-.177	.547***	.621***	.359***	.405***	.724***	1	
Extractable P	-.253*	.862***	.776***	.619***	.714***	.616***	.244*	1

* p < 0.05

*** p < 0.001

Table 5. Eigenvalues of the correlation matrix of the Bedgebury soil data (1951 plus 1974).

Component	Eigenvalue	Percentage of variability	
		Component	Cumulative
1	5.11	63.8	63.8
2	1.10	13.8	77.6
3	0.87	10.9	88.5
4	0.37	4.7	93.2

Table 6. Eigenvectors of the first three components of the correlation matrix of the Bedgebury soil data (1951 plus 1974).

Variable	Eigenvector for component		
	1	2	3
pH	0.17	0.79*	0.32
LOI % OD	-0.43*	-0.07	0.10
Total N % OD	-0.42*	0.03	-0.03
Extractable Na	-0.34*	-0.34	0.09
" K	-0.37*	0.26	0.30
" Ca	-0.38*	0.31	-0.21
" Mg	-0.28	0.28	-0.73*
" P	-0.37*	-0.06	0.46

* Absolute value greater than 0.75 times the largest absolute value

Table 7. The order of the Bedgebury species plots on the first components at the different depths, 1974.

0-5 cm High N, Ca, P, LOI, Mg, K	5-10 cm High N, LOI, Mg, K	10-15 cm High N, LOI, K, Ca, Mg	15-20 cm High N, Mg, Ca, K	20-25 cm High K, LOI, N	25-30 cm High K, N, Mg, LOI, Ca	40-45 cm High LOI, Mg, K, Na, Ca, N	65-70 cm High Na, Mg, LOI, K, Ca, N
L. eurolepis	P. nigra	P. nigra	P. nigra	P. nigra P. menziesii	P. nigra	P. nigra	P. nigra
Q. petraea	T. plicata L. eurolepis P. menziesii	L. eurolepis	P. menziesii	L. eurolepis	P. menziesii	P. menziesii	P. menziesii
T. plicata		N. obliqua P. menziesii	N. obliqua	N. obliqua		N. obliqua	
T. heterophylla	Q. petraea N. obliqua	Q. petraea	L. eurolepis Q. petraea		N. obliqua L. eurolepis		N. obliqua
N. obliqua				T. plicata		C. lawsoniana	
P. menziesii	P. abies		Q. rubra	T. heterophylla P. abies	T. plicata Q. petraea	L. eurolepis	C. lawsoniana P. abies
P. nigra			T. heterophylla	C. lawsoniana	C. lawsoniana		T. heterophylla
P. abies	C. lawsoniana	T. plicata	T. plicata			T. heterophylla	
C. lawsoniana	T. heterophylla	P. abies Q. rubra T. heterophylla	P. abies	Q. petraea	T. heterophylla P. abies	P. abies T. plicata Q. petraea	L. eurolepis Q. rubra Q. petraea
Q. rubra	Q. rubra	C. lawsoniana	C. lawsoniana	Q. rubra	Q. rubra	Q. rubra	T. plicata
Low N, Ca, P, LOI, Mg, K	Low N, LOI, Mg, K	Low N, LOI, K, Ca, Mg	Low N, Mg, Ca, K	Low K, LOI, N	Low K, N, Mg, LOI, Ca	Low LOI, Mg, K, Na, Ca, N	Low Na, Mg, LOI, K, Ca, N

Table 8 The main changes in the Bedgebury plots, 1951 to 1974

	<u>Pinus nigra</u>	<u>Q. rubra</u>	<u>P. menziesii</u>	<u>N. obliqua</u>	<u>T. heterophylla</u>	<u>C. lawsoniana</u>	<u>T. plicata</u>	<u>Q. petraea</u>	<u>Larix eurolepis</u>	<u>Picea abies</u>
L	+Na	+P	+Na P N	+P				+P	+Ca P	+Na
		+Ca Mg	+Mg	+Mg	+Na K Mg	+Mg	+Mg			+N Mg
F/H	+Na	+Na	+Na P	+Na K	+Na		+K			+Na
	+Mg	+Ca Mg	+Mg	+N Ca Mg	+N Ca Mg	+Ca Mg	+N Ca Mg	+N Mg	+N Mg	+Mg
0-5							+P	+pH P	+N Na K P	+Na
	+K Ca Mg	+Na Ca Mg	+Ca Mg	+Ca Mg	+Mg	+Mg	+Mg	+Na Mg		+Mg
5-10			+pH	+pH				+pH P		
	+N Ca Mg	+N Mg Ca	+N Ca Mg	+N Ca Mg	+N Ca Mg	+pH N Ca Mg	+pH Ca Mg	+N Ca Mg	+pH Ca Mg	+N Mg
15-20	+pH	+P	+pH K P	+pH	+pH	+Na	+K	+pH	+K	
	+N Ca Mg	+Mg	+N Ca Mg	+N Ca Mg	+Ca Mg	+N Ca Mg	+N Ca Mg	+N Ca Mg	+Ca Mg	+pH Ca Mg
25-30	+pH K		+pH K	+pH K	+pH K	+K	+K	+pH K	+K	+K
	+N Mg	+N Na Ca Mg	+N Ca Mg	+N Ca Mg	+Ca Mg	+N Ca Mg	+N Ca Mg	+Na Ca Mg	+Ca P	+N Ca Mg
40-45	+pH K		+pH K	+pH K	+pH	+K		+pH		
	+N P	+pH N Ca Mg P	+N P	+Ca P	+Ca Mg P	+pH Mg P	+N Mg P	+Ca Mg P	+pH N Mg P	+Mg P

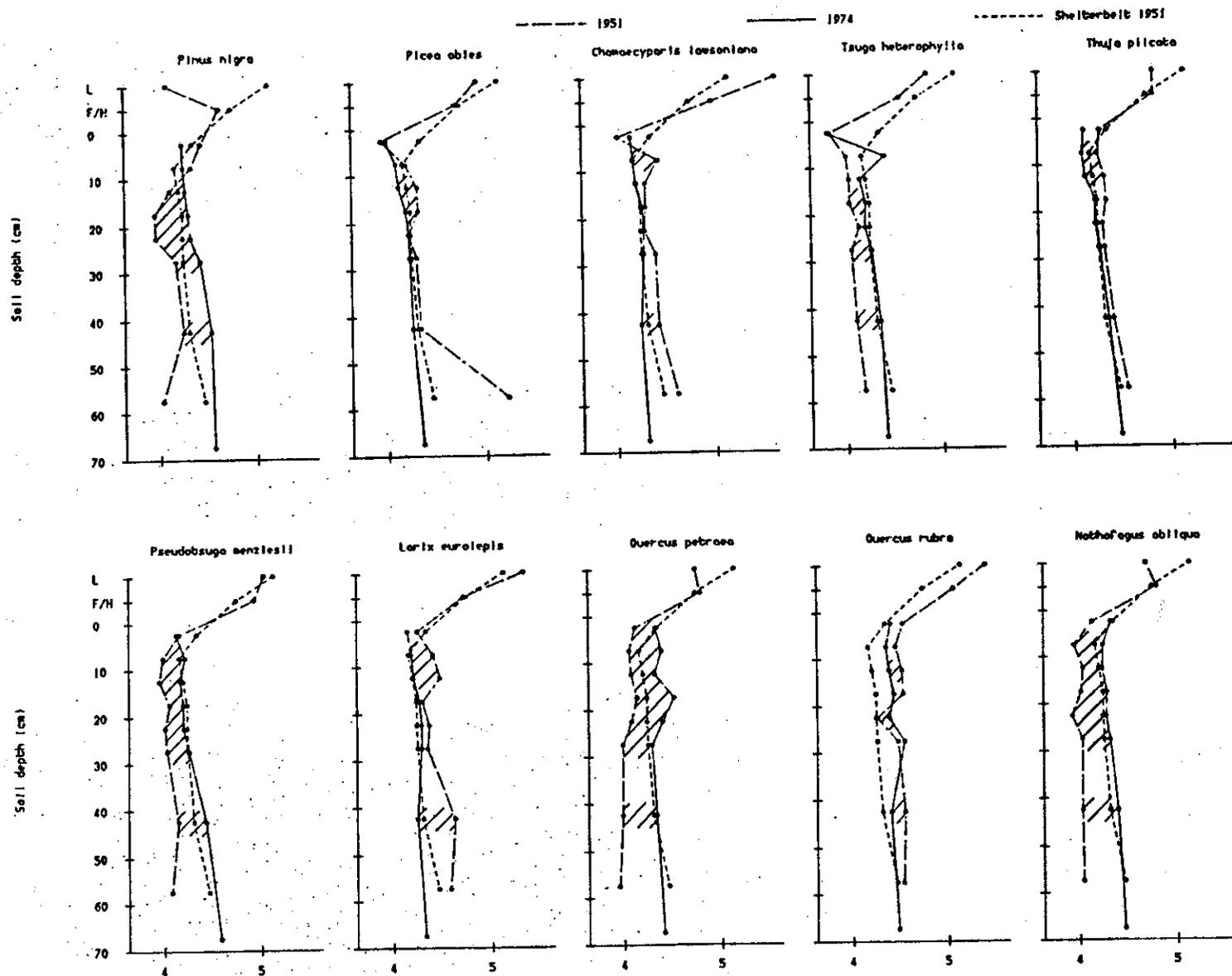


Figure 1. pH at different depths under different species in 1951 and 1974. Differences significant at $p < 0.05$ are hatched.

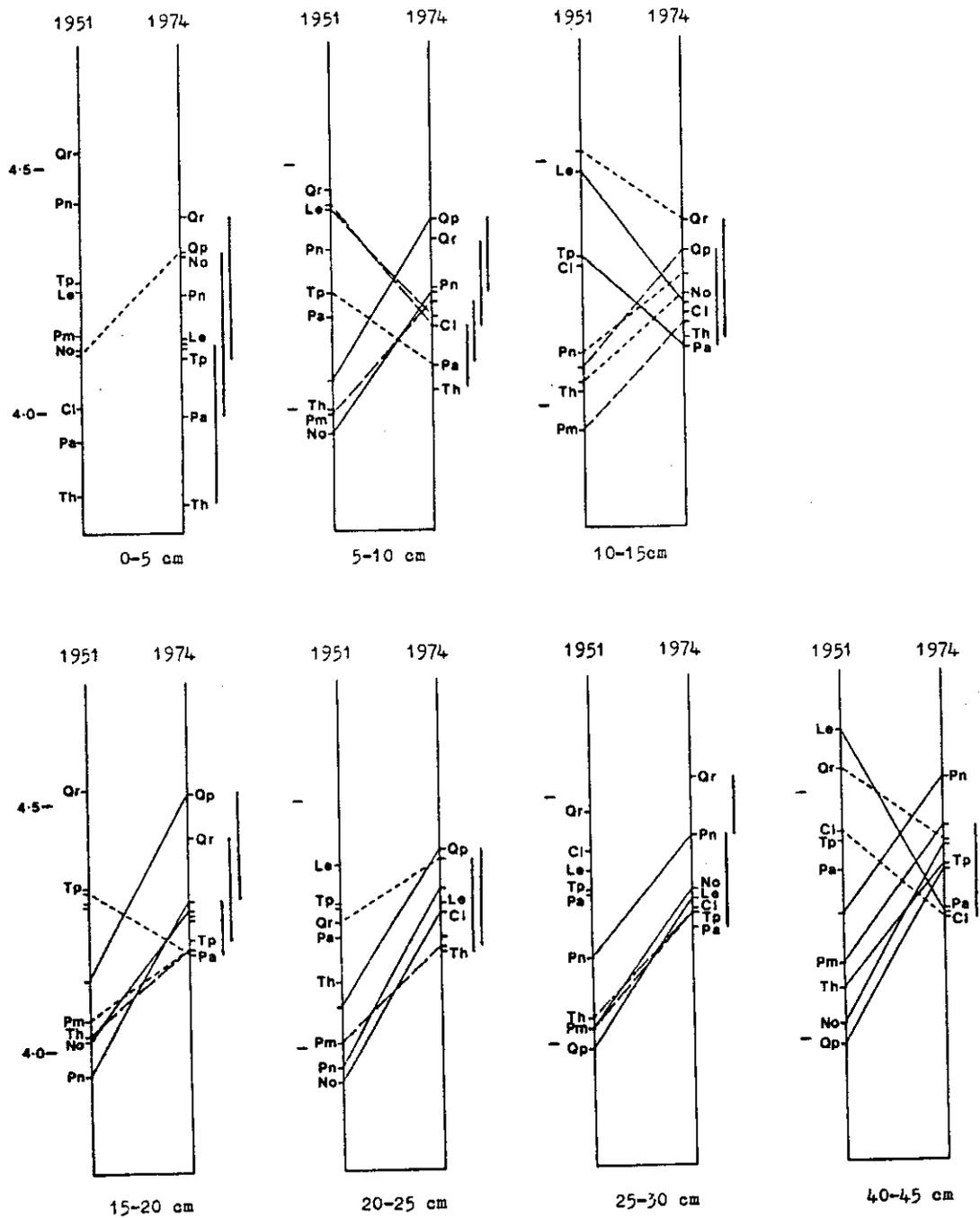


Figure 2. Changes in pH between 1951 and 1974 under different species (names abbreviated) at different depths, significant at $p < 0.05$ - - - -, $P < 0.01$ — —, $p < 0.001$ ———. The vertical lines link species not significantly different in 1974 (Tukey's HSD $p < 0.05$).

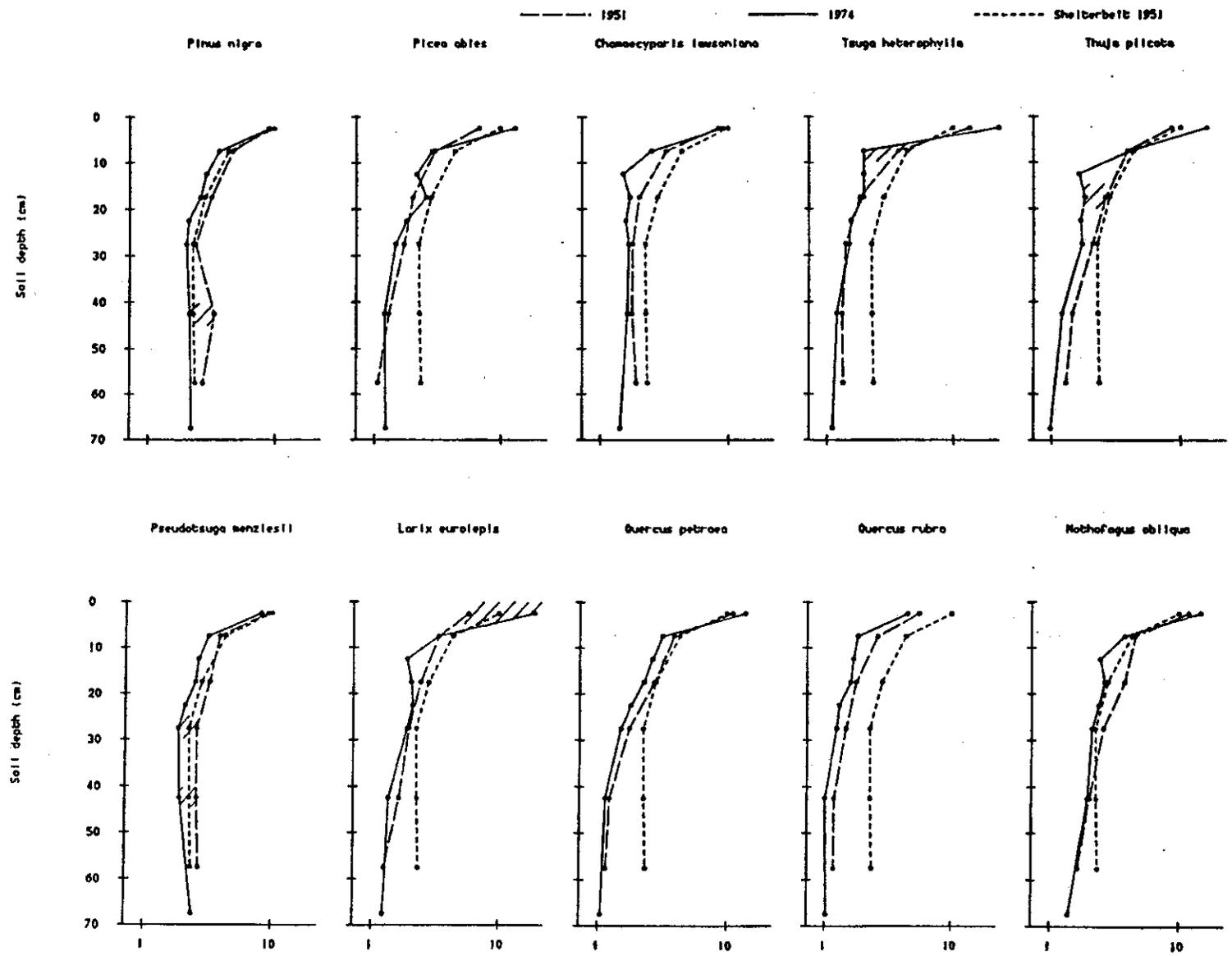


Figure 3. Loss-on-ignition at different depths under different species in 1951 and 1974. Differences significant at $p < 0.05$ are hatched.

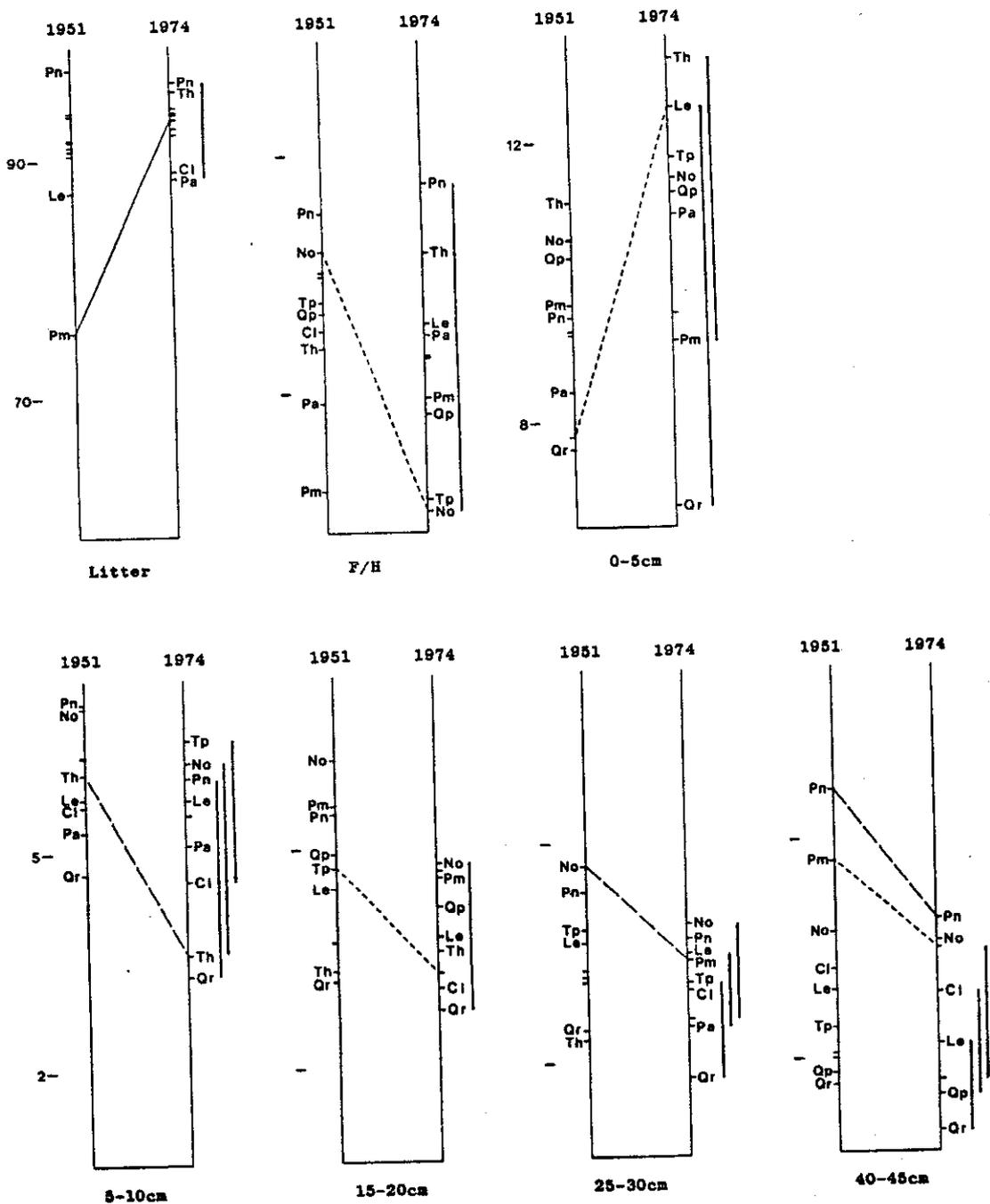


Figure 4. Changes in loss-on-ignition between 1951 and 1974 under different species (names abbreviated) at different depths, significant at $p < 0.05$ — — —, $p < 0.01$ — — —, $p < 0.001$ — — —. The vertical lines link species not significantly different in 1974 (Tukey's HSD $p < 0.05$).

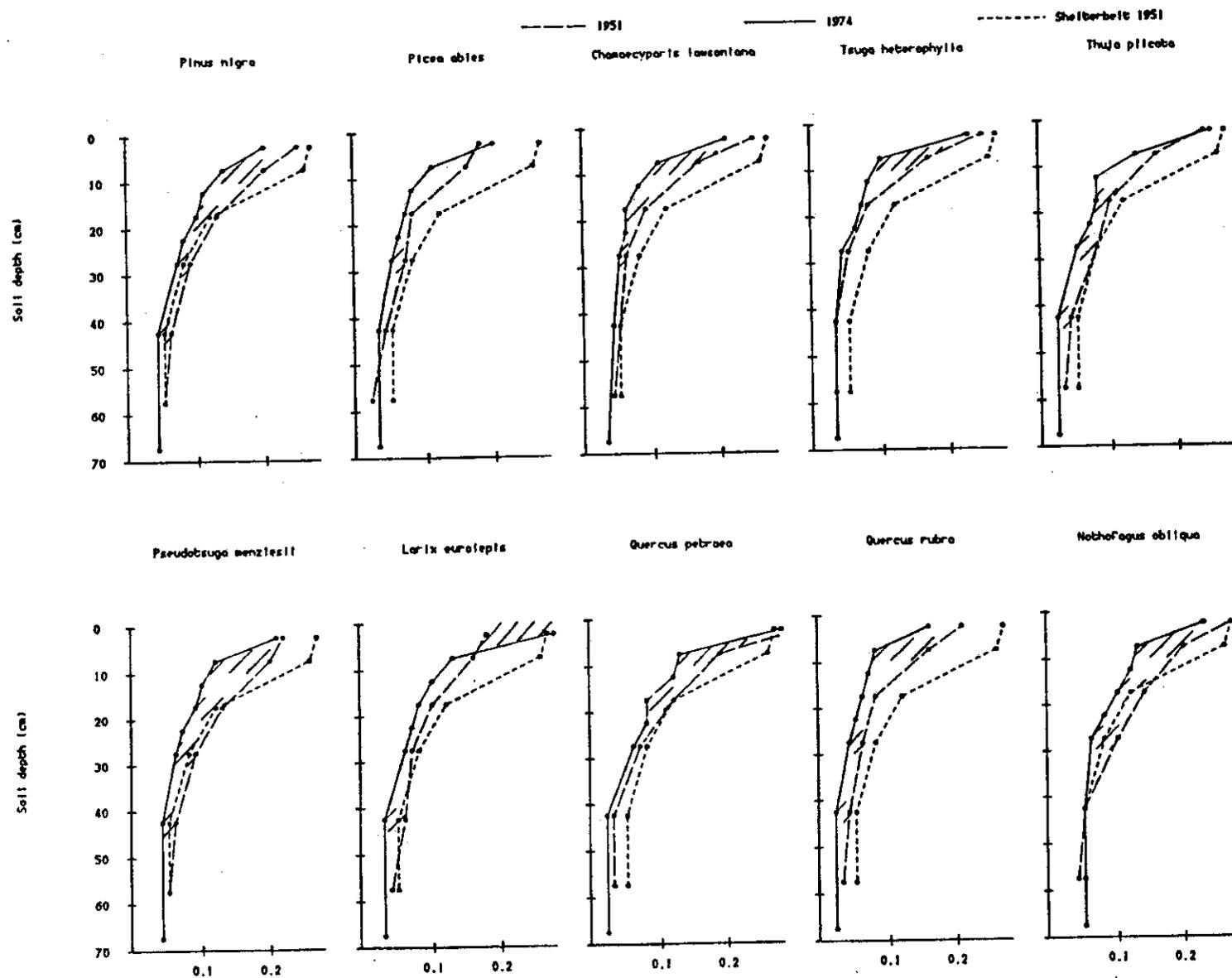


Figure 5. Total nitrogen at different depths under different species in 1951 and 1974. Differences significant at $p < 0.05$ are hatched.

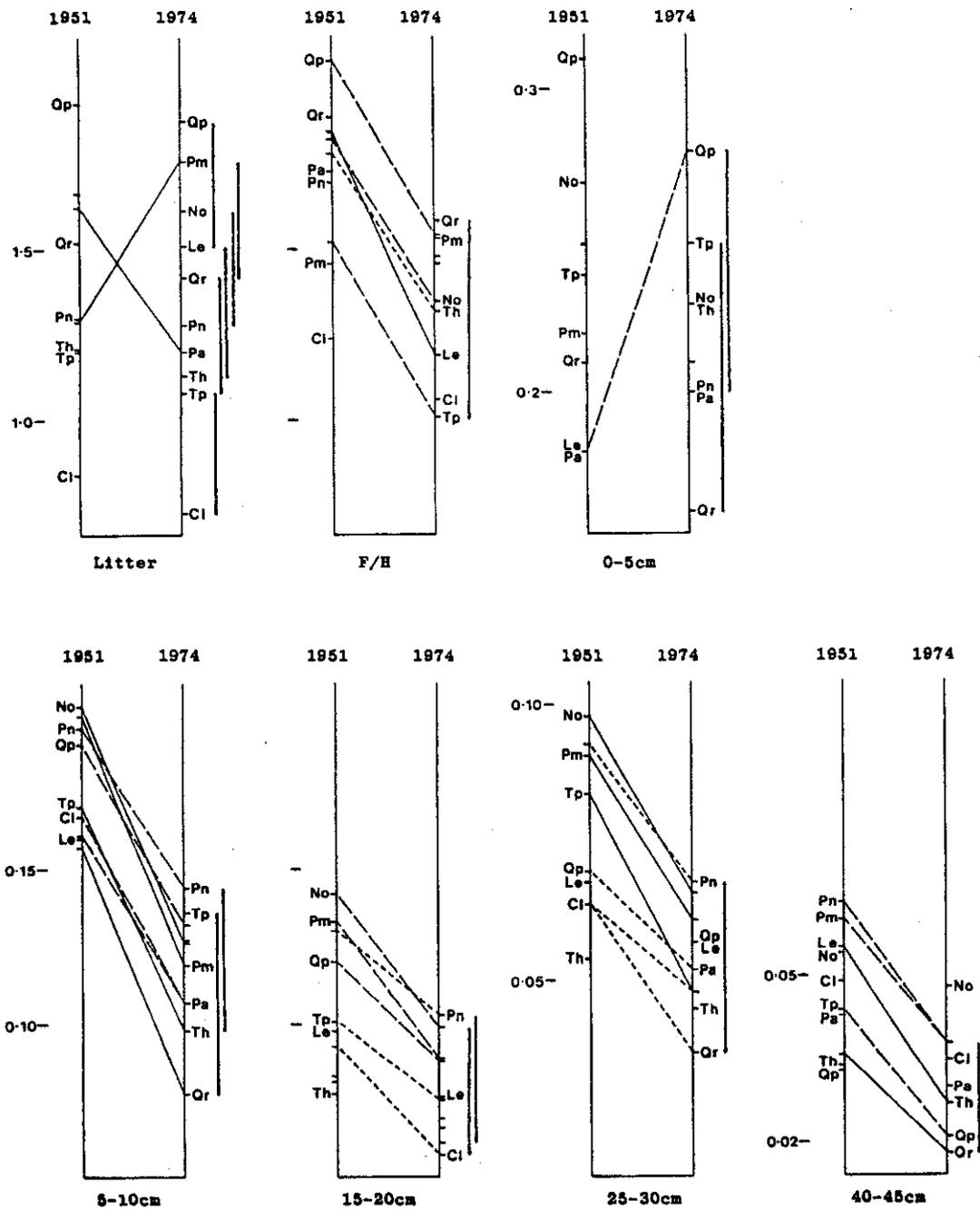


Figure 6. Changes in total nitrogen between 1951 and 1974 under different species (names abbreviated) at different depths, significant at $p < 0.05$ - - - - , $p < 0.01$ — — — — , $p < 0.001$ ————. The vertical lines link species not significantly different in 1974 (Tukey's HSD $p < 0.05$).

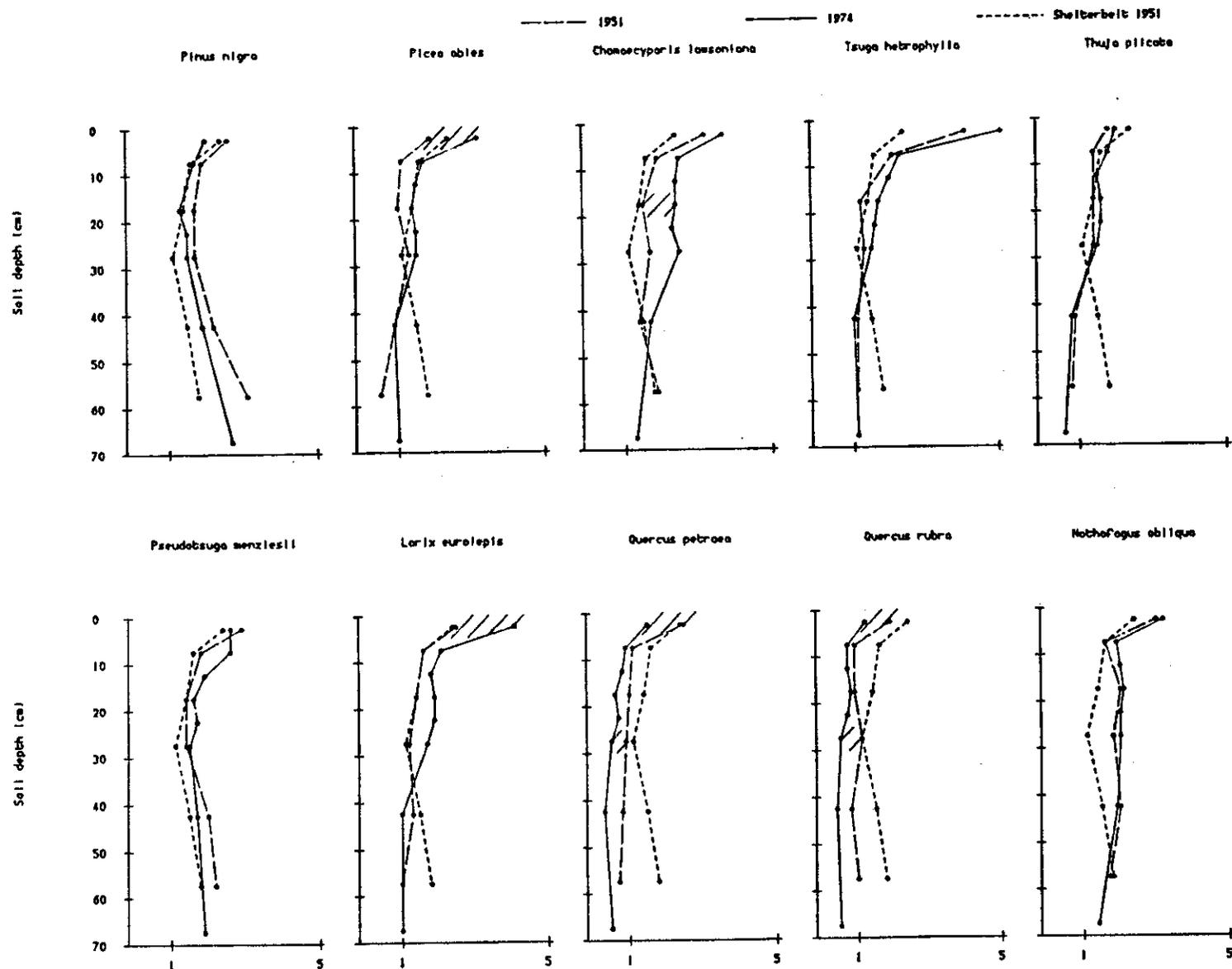


Figure 7. Extractable sodium at different depths under different species in 1951 and 1974. Differences significant at $p < 0.05$ are hatched.

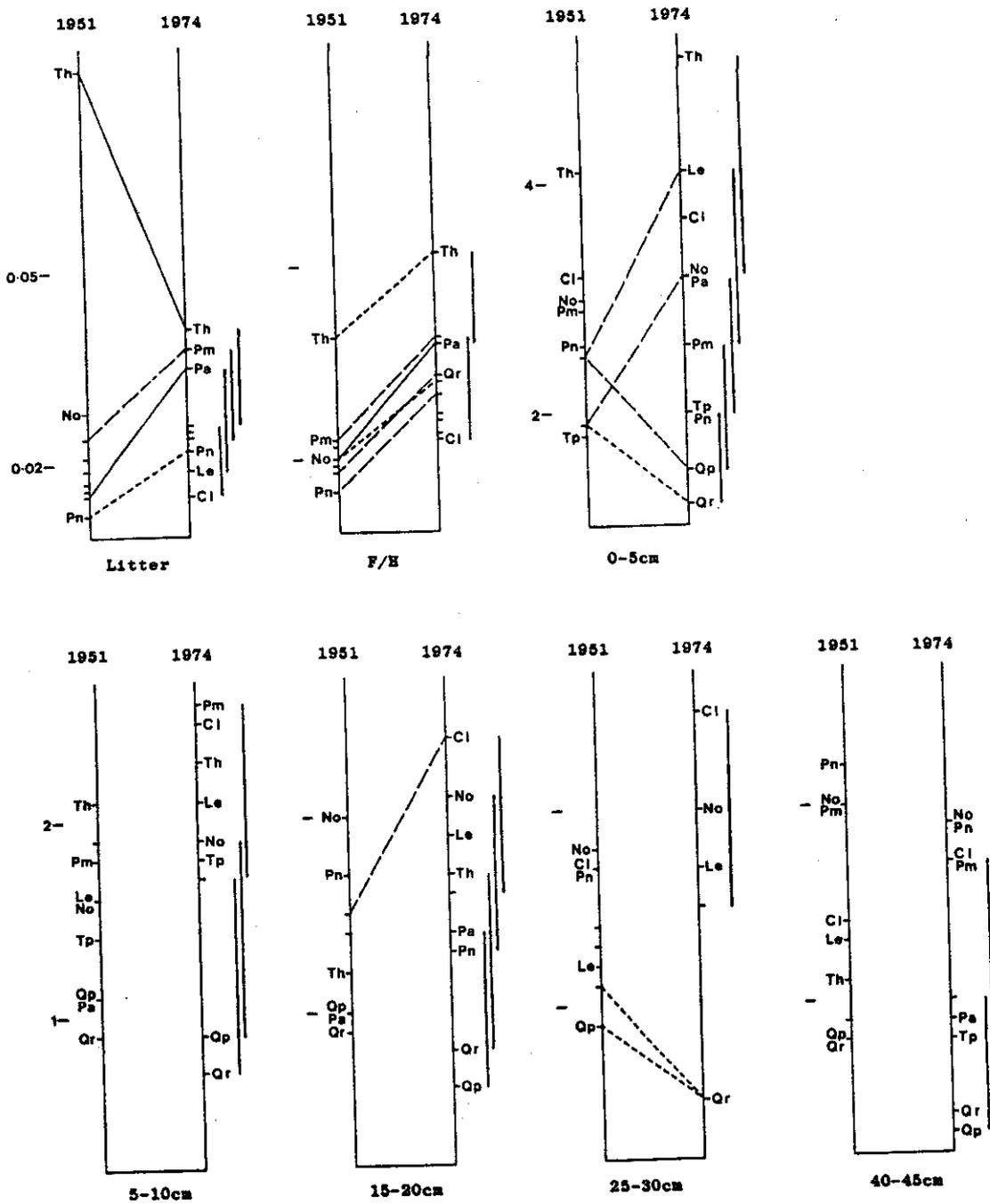


Figure 8, Changes in sodium between 1951 and 1974 under different species (names abbreviated) at different depths, significant at $p < 0.05$ - - - -, $p < 0.01$ — —, $p < 0.001$ ———. The vertical lines link species not significantly different in 1974 (Tukey's HSD $p < 0.05$).

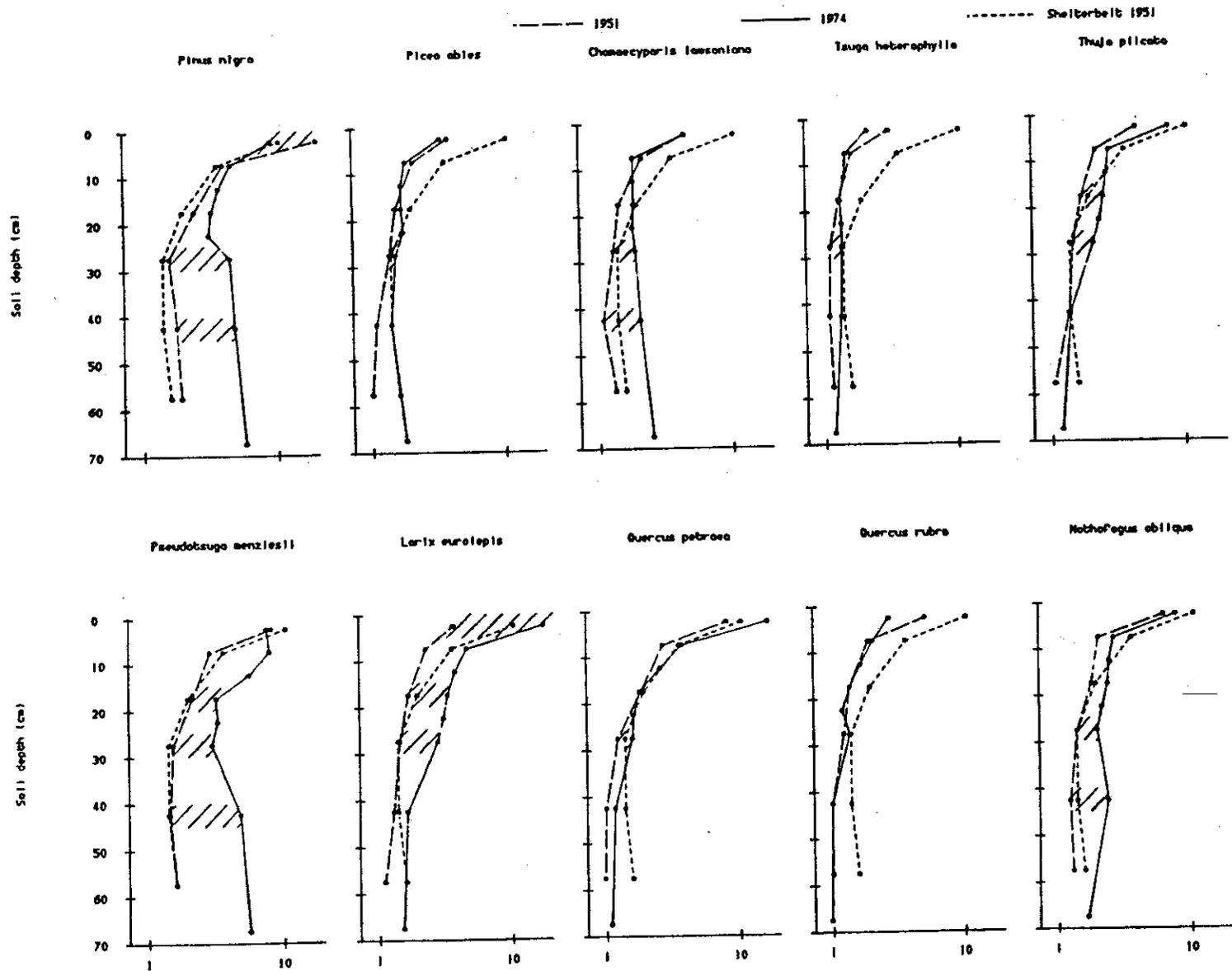


Figure 9. Extractable potassium at different depths under different species in 1951 and 1974. Differences significant at $p < 0.05$ are hatched.

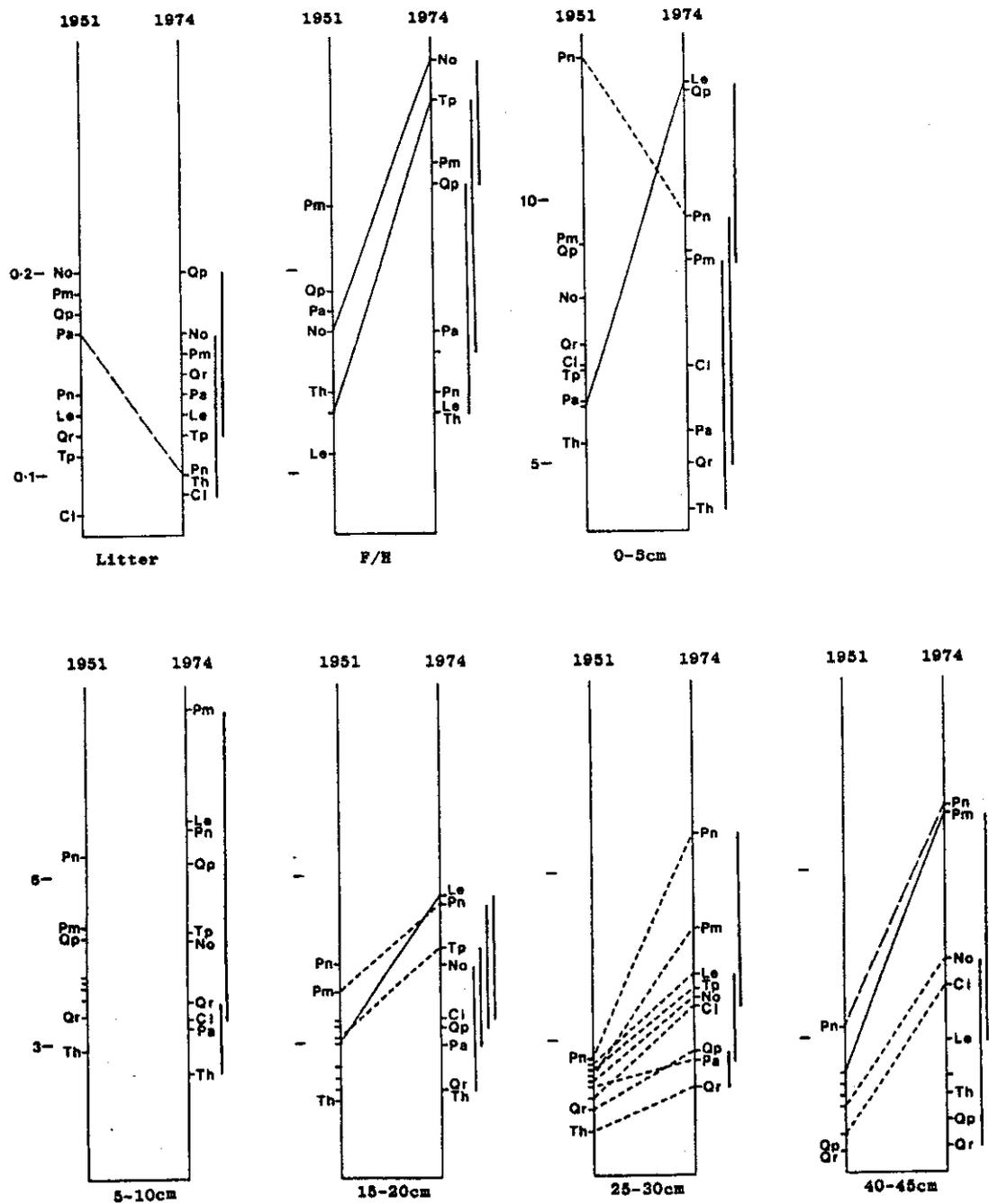


Figure 10. Changes in potassium between 1951 and 1974 under different species (names abbreviated) at different depths, significant at $p < 0.05$ - - - -, $p < 0.01$ — —, $p < 0.001$ ———. The vertical lines link species not significantly different in 1974 (Tukey's HSD $p < 0.05$).

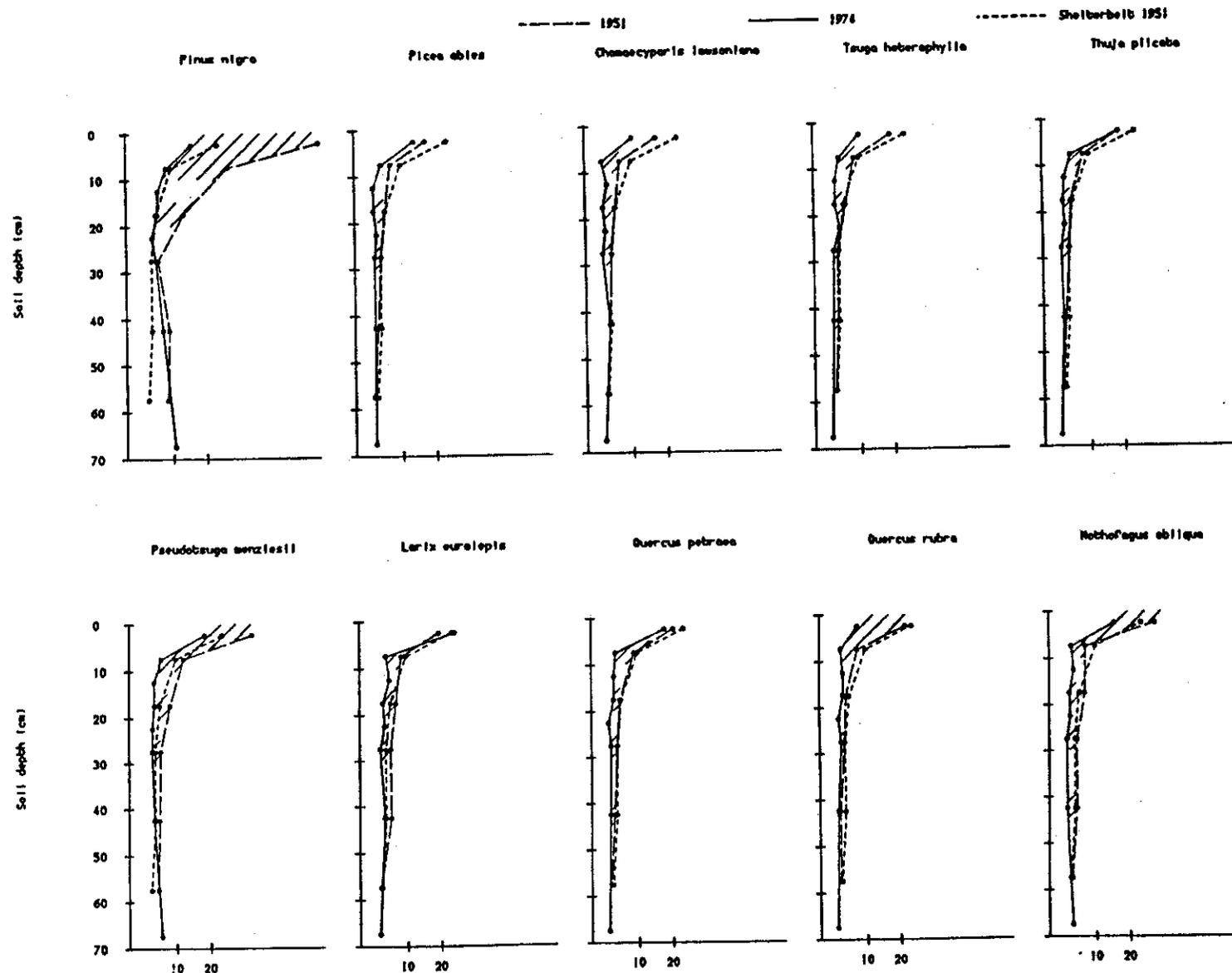


Figure 11. Extractable calcium at different depths under different species in 1951 and 1974. Differences significant at $p < 0.05$ are hatched.

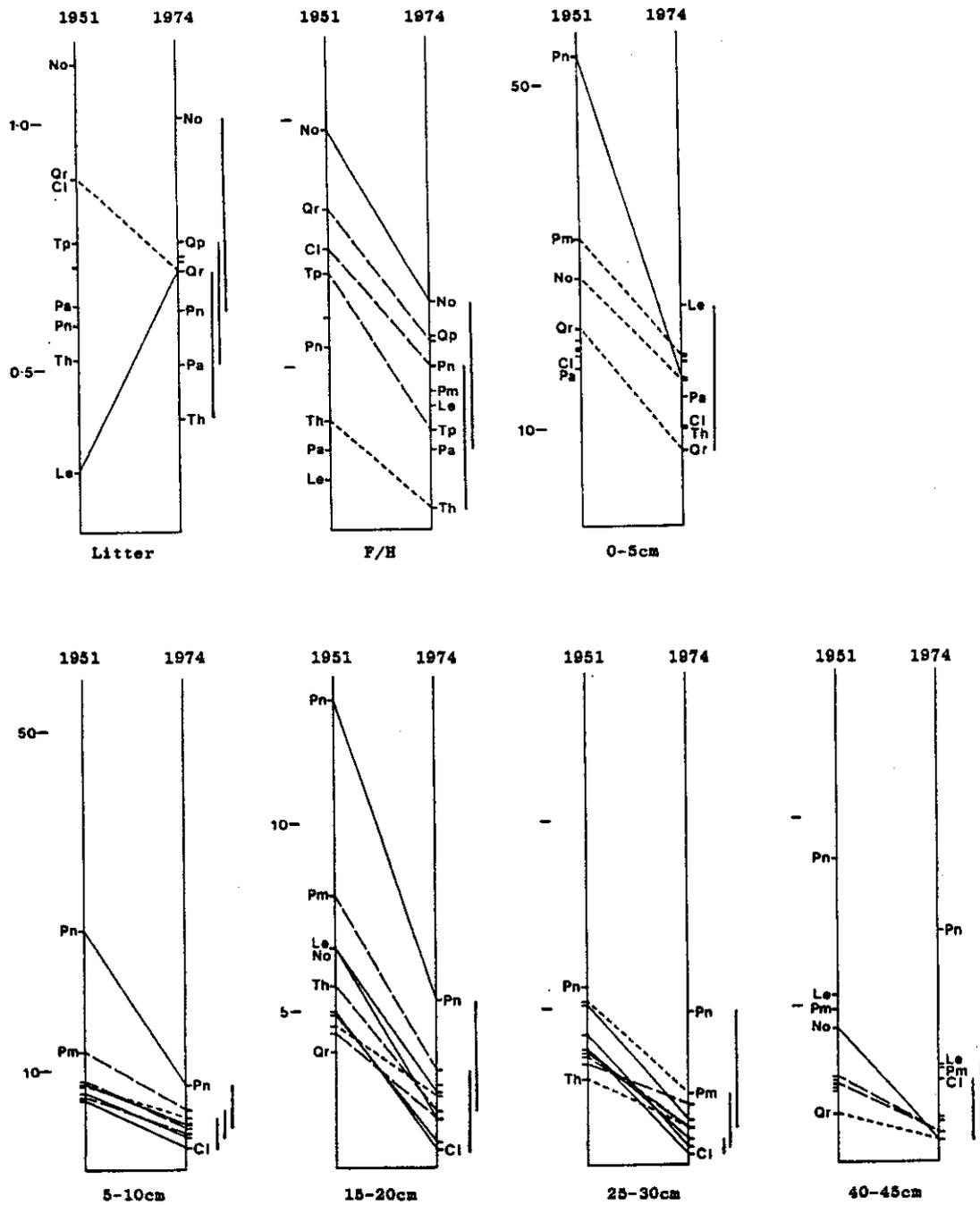


Figure 12. Changes in calcium between 1951 and 1974 under different species (names abbreviated) at different depths, significant at $p < 0.05$ - - - -, $p < 0.01$ — — —, $p < 0.001$ ———. The vertical lines link species not significantly different in 1974 (Tukey's HSD $p < 0.05$).

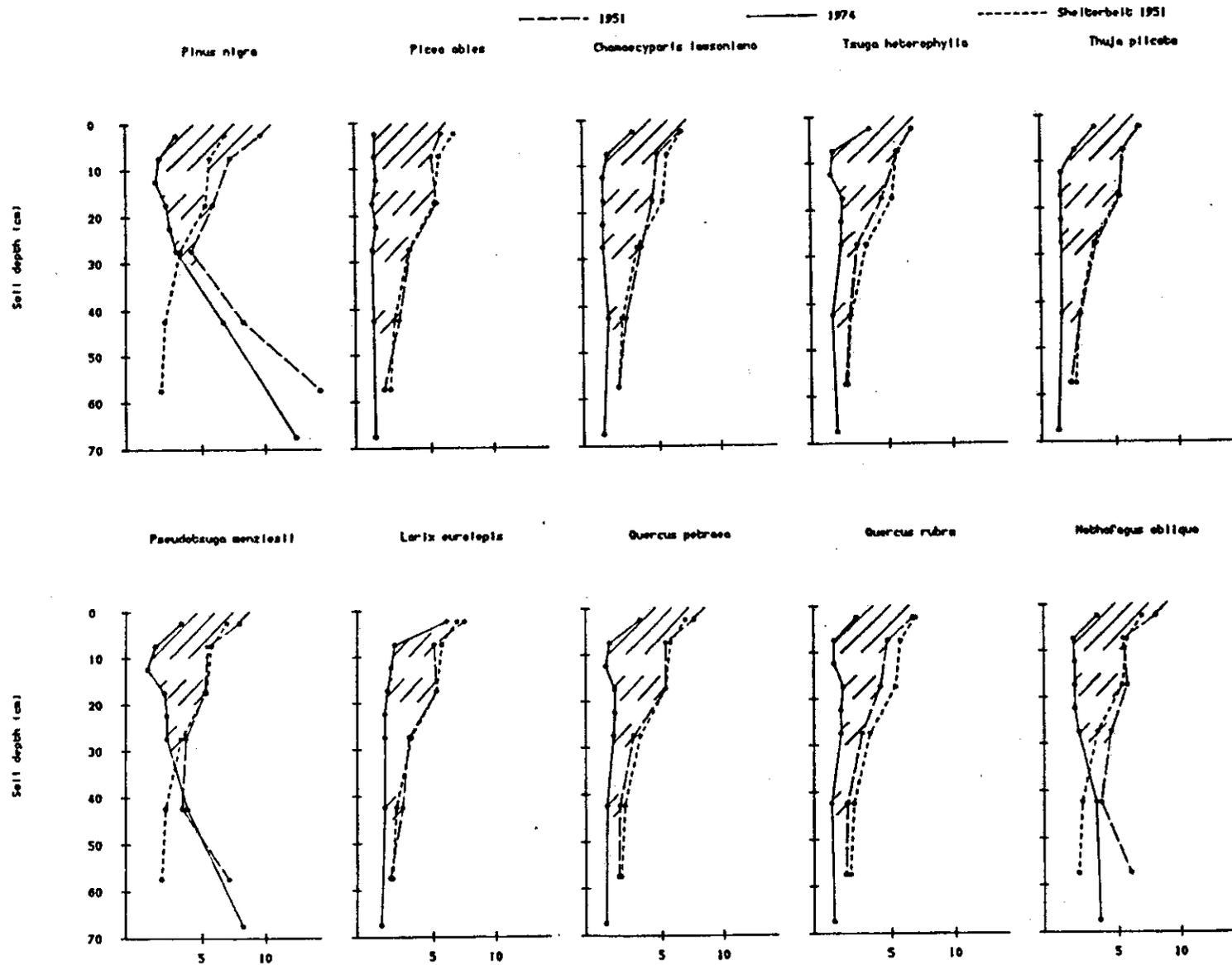


Figure 13. Extractable magnesium at different depths under different species in 1951 and 1974. Differences significant at $p < 0.05$ are hatched.

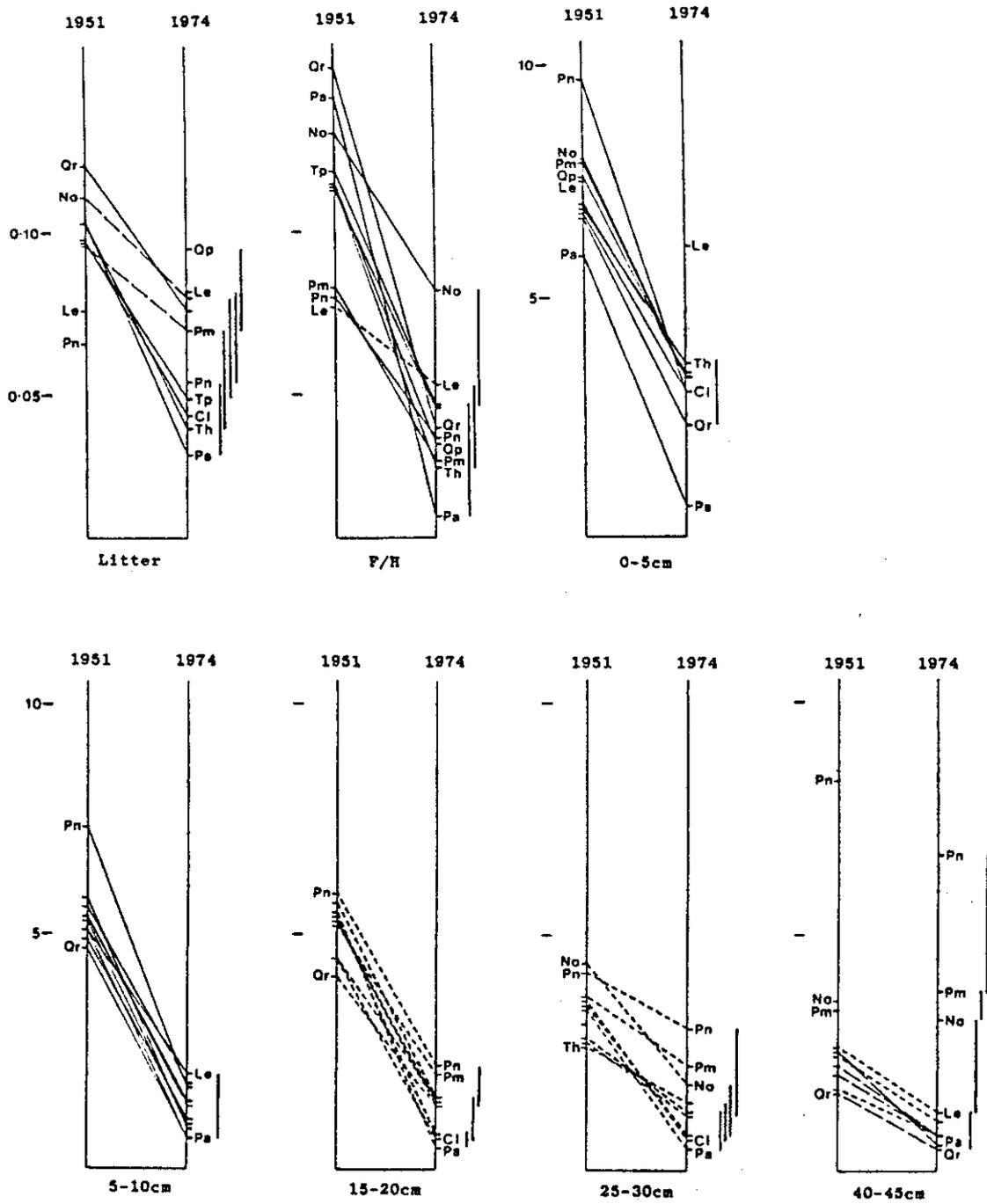


Figure 14. Changes in magnesium between 1951 and 1974 under different species (names abbreviated) at different depths, significant at $p < 0.05$ - - - -, $P < 0.01$ — — —, $p < 0.001$ ———. The vertical lines link species not significantly different in 1974 (Tukey's HSD $p < 0.05$).

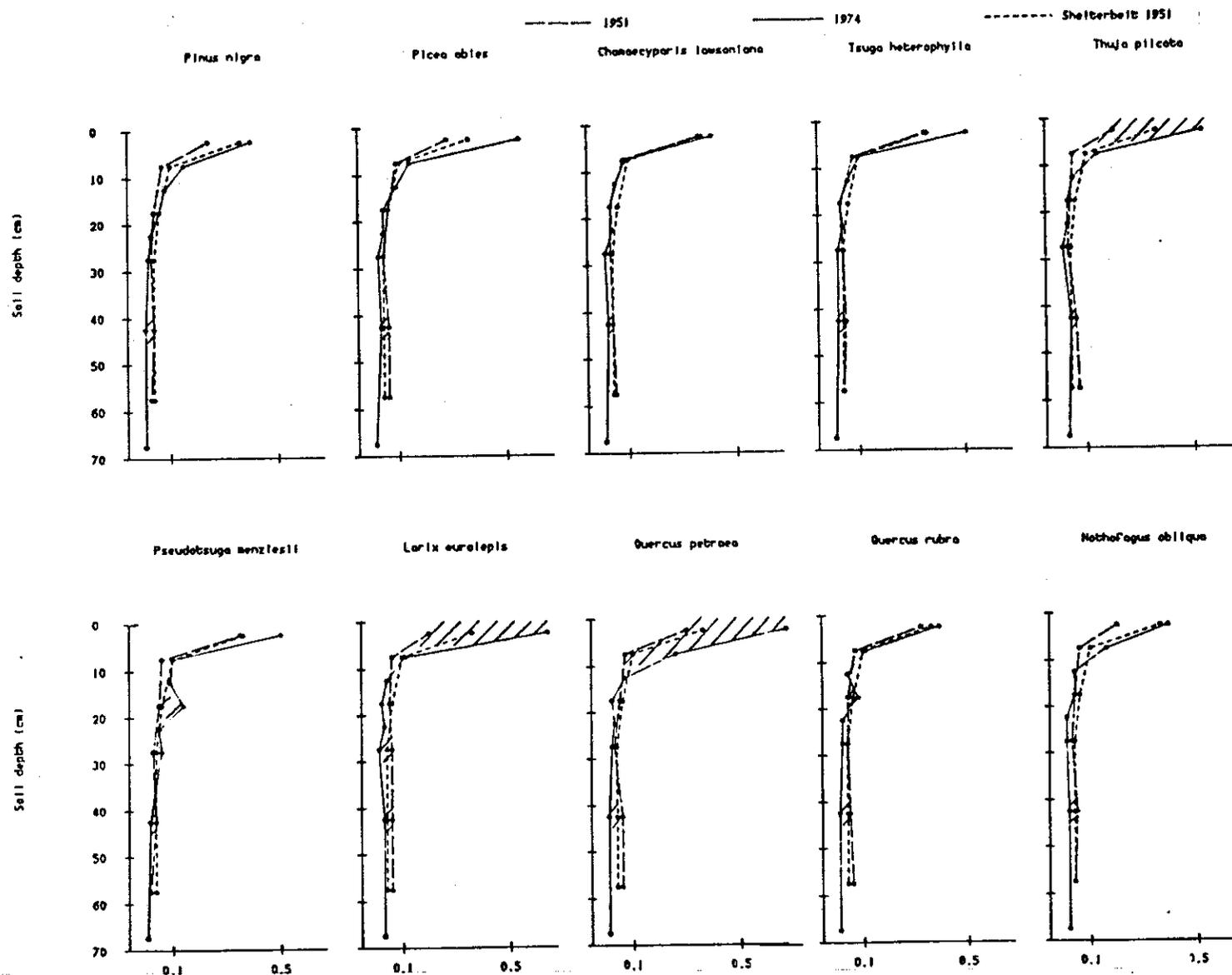


Figure 15. Extractable phosphorus at different depths under different species in 1951 and 1974. Differences significant at $p < 0.05$ are hatched.

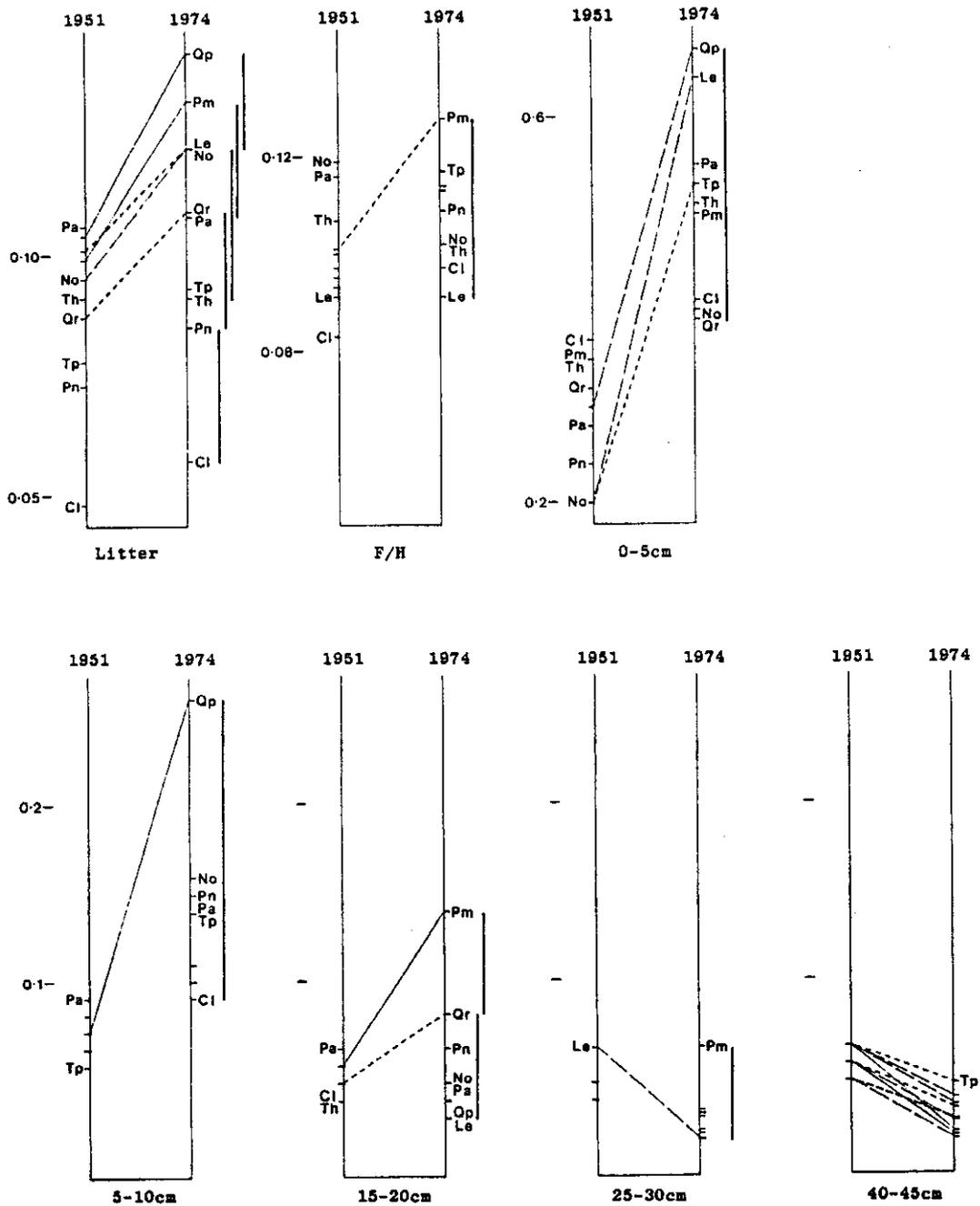


Figure 16. Changes in phosphorus between 1951 and 1974 under different species (names abbreviated) at different depths, significant at $p < 0.05$ - - -, $p < 0.01$ — —, $p < 0.001$ ———. The vertical lines link species not significantly different in 1974 (Tukey's HSD $p < 0.05$).

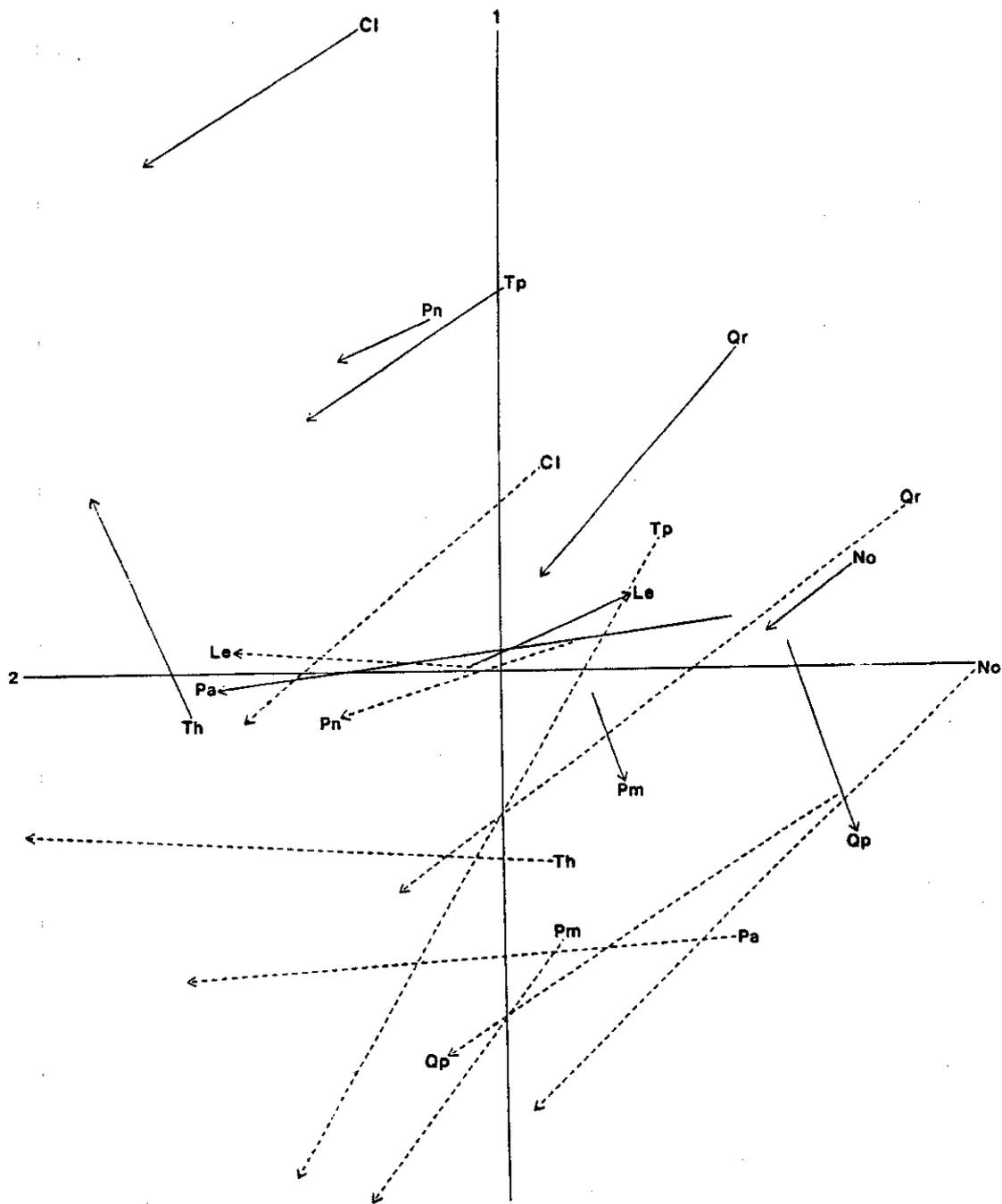


Figure 17. First and second components of the correlation matrix for the L (—) and F/H (- - -) layers under different species (names abbreviated), showing changes from 1951 to 1974.

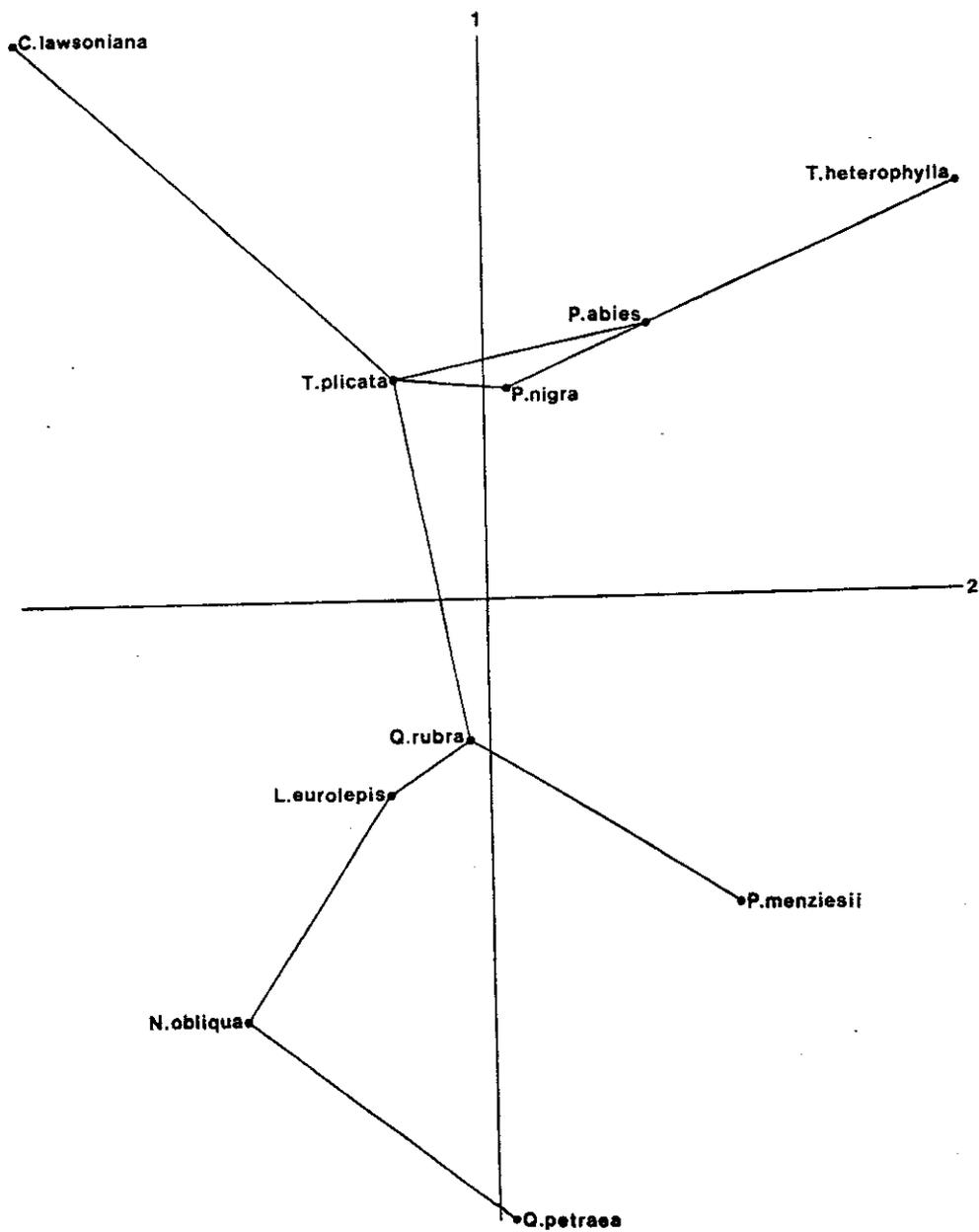


Figure 18. First and second components of the correlation matrix for the L layers under different species with the minimum spanning tree in 3 dimensions superimposed.

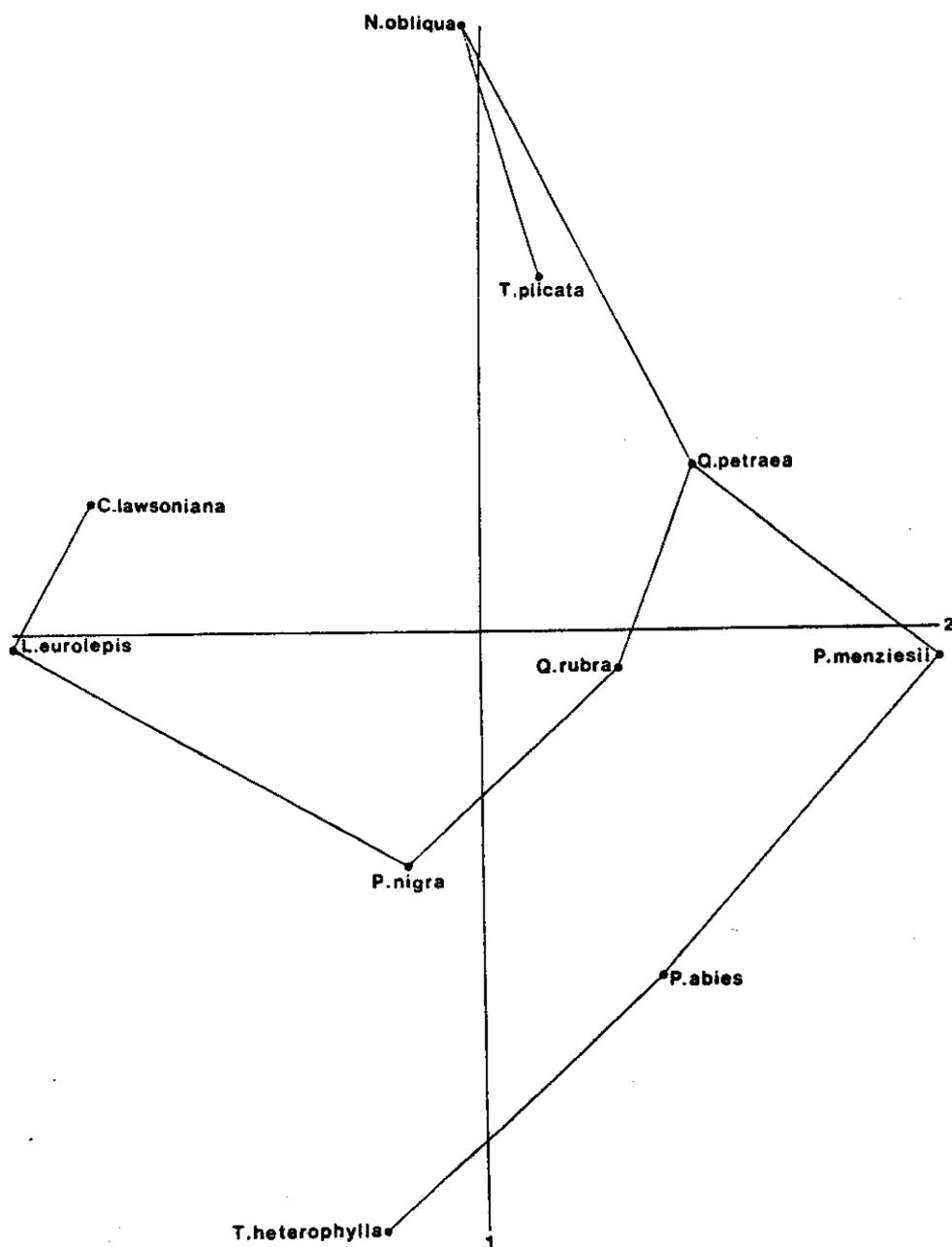


Figure 19. First and second components of the correlation matrix for the F/H layers under different species with the minimum spanning tree in 3 dimensions superimposed.

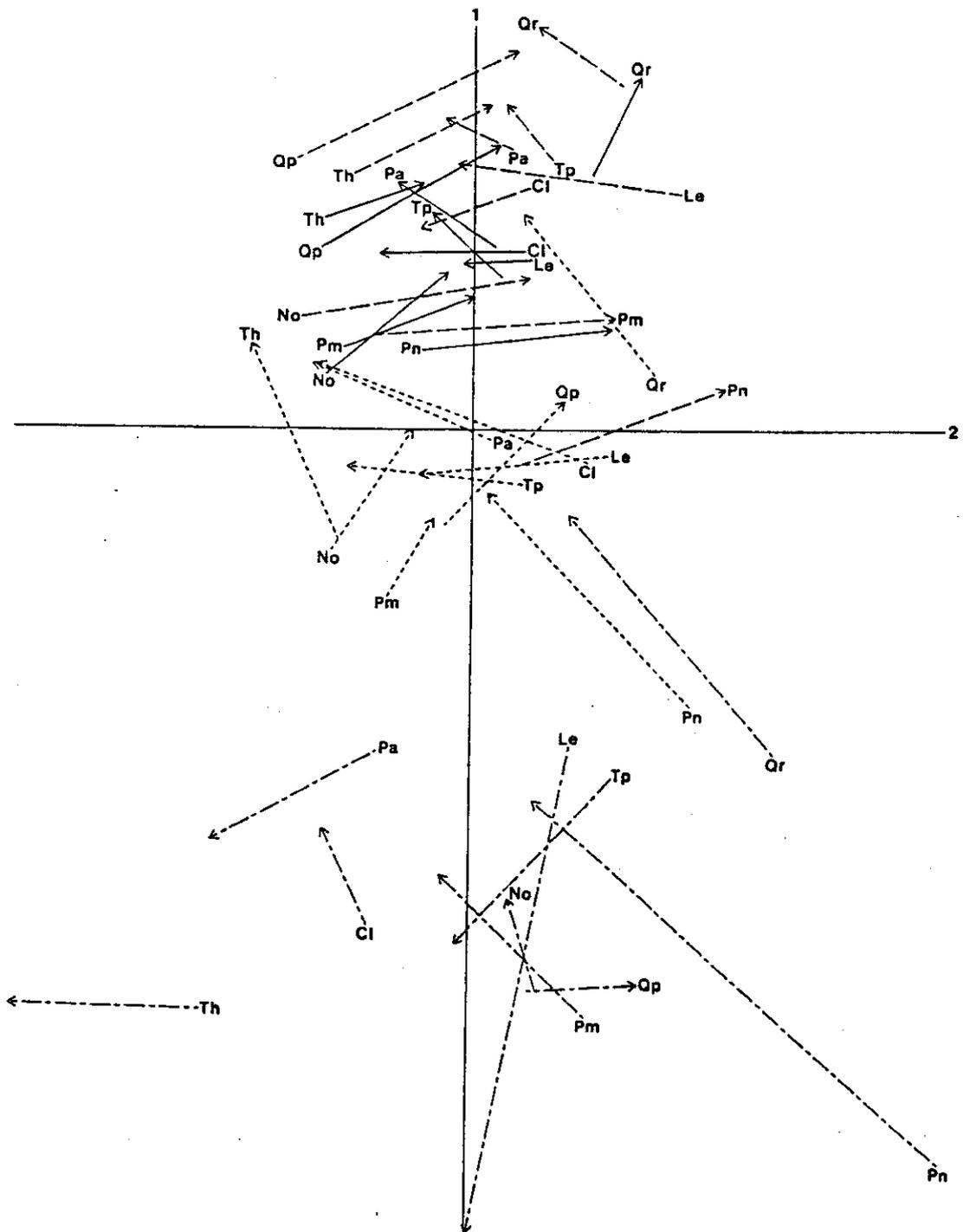


Figure 20. First and second components of the correlation matrix for the soils under different species (names abbreviated), showing changes from 1951 to 1974. — - — 0-5cm, - - - - 5-10cm, ——— 25-30cm, — · — 40-45cm (15-20cm omitted for clarity).

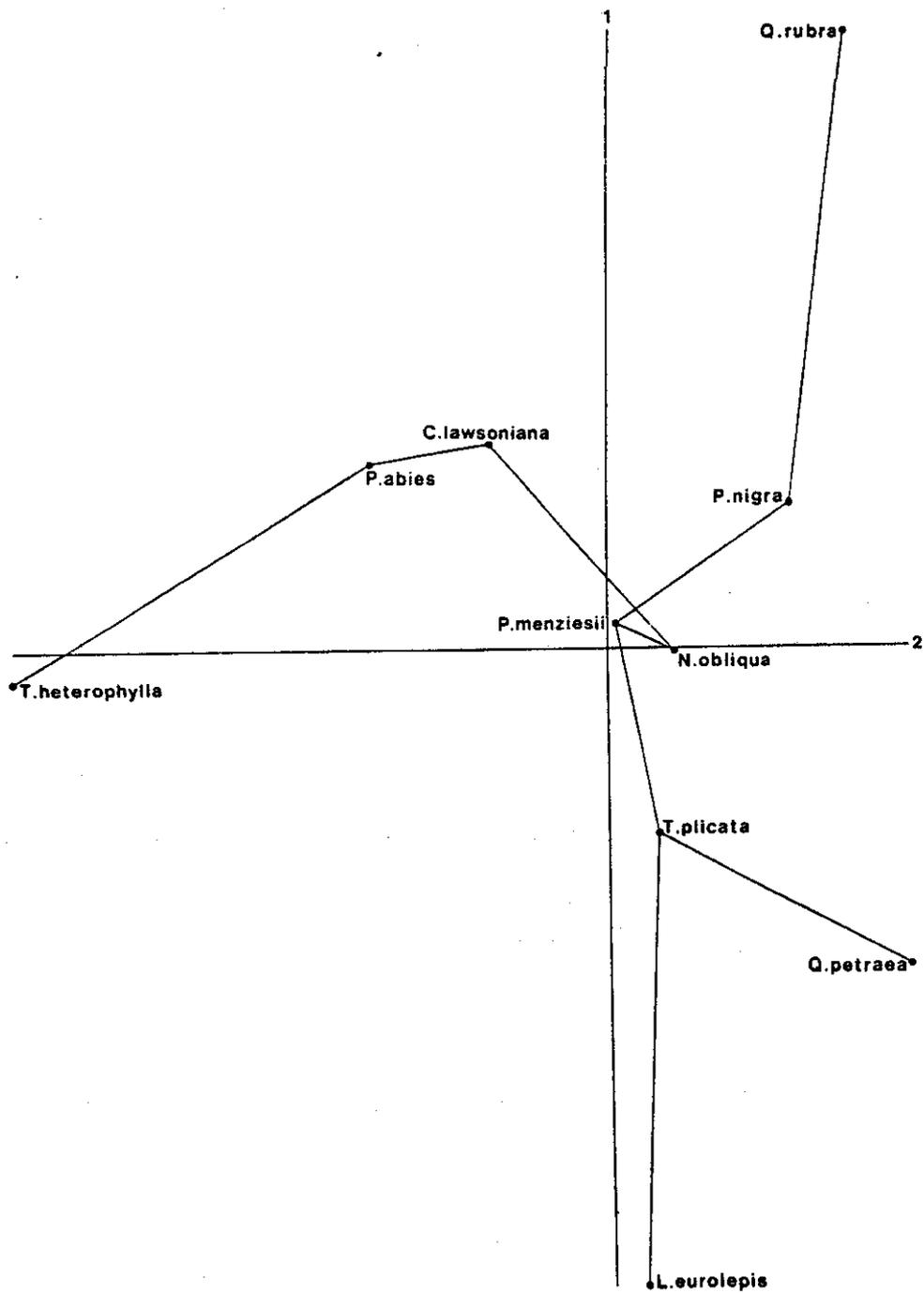


Figure 21. First and second components of the correlation matrix for 0-5cm soil under different species with the minimum spanning tree in 3 dimensions superimposed.

Appendix 1

Chemical methods

1951

1974

LOI % OD*	(all samples)	2 hrs at 800°C	2 hrs at 550°C
Total N % OD	(L and F/H)	Kjeldahl with CuSO ₄ catalyst, followed ⁴ by distillation.	Peroxide/Sulphuric acid digestion method, colorimetric determination with indophenol blue.
Total N	soil 1951 mg/100 g OD 1974 % OD	Ditto	Kjeldahl with HgO catalyst, colorimetric determination with indophenol blue.
Total minerals	(L and F/H) 1951 mg/100 g OD 1974 % OD	Nitric/Perchloric/Sulphuric acid digestion followed by: Na)EEL flame K)photometer Ca-EDTA with murexide Mg-Titan yellow P-Molybdenum blue	Peroxide/sulphuric acid digest followed by: }EEL flame photometer }Atomic absorption with lanthanum to suppress interference }Mo blue
Extractables	(soil) 1951 and 1974 mg/100 g OD	Extracted for 2 hours with 2.5% acetic acid, 25 parts to 1 part AD soil (2 mm sieve). Na) flame K) photometer Ca-EDTA with murexide Mg-Titan yellow P-Molybdenum blue	As 1951 but for 1 hour. Flame photometer }Atomic absorption with lanthanum to suppress interference. }Mo blue

* 1951 oven dry = 80°C
1974 oven dry = 105°C

Correction factors

L and F/H	Total N 1951 equivalent	=	1974 N x 0.882
soil	N 1951 equivalent	=	1974 N x 0.707
	K 1951 equivalent	=	1974 K x 1.564
	pH* 1951 equivalent	for Bedgebury add 0.3 pH units	
		for Abbotswood add 0.49 pH units	
		for West Tofts add 0.31 pH units	

* pH corrections M. Anderson, pers. comm.

1974 chemical analyses were performed by the Chemical Service at Merlewood.
1974 pH measurements were supplied by M. Anderson.

Appendix 2

1974 data for L and F/H layers and soils.

1951 data for L and F/H layer total Ca (from original records).

The data are means of 5 profiles per plot, but there were not always 5 L or F/H layers per plot.

1974 data

Variable		<i>P. nigra</i>	<i>P. abies</i>	<i>C. lawsoniana</i>	<i>T. heterophylla</i>	<i>T. plicata</i>	<i>P. menziesii</i>	<i>L. eurolepis</i>	<i>Q. petraea</i>	<i>Q. rubra</i>	<i>N. obliqua</i>
% OD											
LOI	L	96.5	88.4	89.0	95.7	92.6	93.3	93.7	94.3	93.9	92.1
	F/H	87.6	75.0	73.0	82.0	61.0	69.6	76.0	68.2	73.2	60.0
Total N	L	1.45	1.36	0.83	1.28	1.22	1.98	1.71	2.11	1.61	1.82
	F/H	1.68	1.66	1.20	1.50	1.15	1.73	1.35	1.75	1.79	1.53
Total Na	L	0.022	0.035	0.015	0.041	0.028	0.038	0.019	0.024	0.025	0.024
	F/H	0.030	0.038	0.023	0.053	0.024	0.039	0.026	0.027	0.033	0.032
Total K	L	0.099	0.140	0.094	0.095	0.115	0.160	0.132	0.200	0.150	0.172
	F/H	0.140	0.170	0.160	0.126	0.280	0.250	0.127	0.240	0.160	0.300
Total Ca	L	0.62	0.51	0.72	0.40	0.73	0.73	0.70	0.76	0.70	1.01
	F/H	0.50	0.33	0.50	0.21	0.37	0.45	0.42	0.56	0.55	0.63
Total Mg	L	0.054	0.032	0.044	0.040	0.049	0.070	0.082	0.095	0.078	0.080
	F/H	0.037	0.013	0.046	0.028	0.047	0.030	0.053	0.035	0.040	0.082
Total P	L	0.085	0.109	0.057	0.091	0.093	0.130	0.122	0.140	0.109	0.122
	F/H	0.109	0.114	0.097	0.102	0.120	0.128	0.081	0.113	0.114	0.102
Variable	Sampling										
	depth										
	(cm)										
pH	0-5	3.94	3.69	3.84	3.51	3.81	3.83	3.85	4.03	4.10	4.02
	5-10	3.95	3.79	3.87	3.74	3.79	3.92	3.89	4.09	4.05	3.94
	10-15	3.97	3.82	3.89	3.84	3.82	3.87	3.81	4.02	4.08	3.93
	15-20	4.00	3.89	3.96	3.90	3.92	3.90	3.97	4.22	4.13	3.98
	20-25	4.02	3.92	3.97	3.89	3.92	3.90	3.99	4.10	4.08	3.97
	25-30	4.12	3.93	3.97	3.96	3.96	3.96	3.99	3.99	4.24	4.01
	40-45	4.23	3.96	3.94	4.05	4.05	4.13	3.95	4.04	4.10	4.09
	65-70	4.26	4.08	4.01	4.11	4.17	4.28	4.03	4.11	4.18	4.16
LOI	0-5	9.6	11.0	9.6	13.2	11.8	9.2	12.5	11.3	6.8	11.5
% OD	5-10	6.0	5.1	4.6	3.6	6.5	5.5	5.7	5.5	3.3	6.2
	10-15	5.1	4.0	2.6	3.6	2.9	4.8	3.5	4.8	3.0	4.5
	15-20	4.7	4.7	3.1	3.6	3.3	4.6	3.8	4.2	2.8	4.8
	20-25	3.9	3.3	2.8	2.7	3.0	3.9	3.9	3.3	2.0	4.4
	25-30	3.7	2.5	3.0	2.6	3.1	3.4	3.5	2.6	1.8	3.9
	40-45	3.9	1.7	2.9	1.7	1.7	3.5	2.2	1.5	1.0	3.6
	65-70	4.1	1.8	2.4	1.4	0.9	4.4	1.8	1.2	1.1	2.3
Total N	0-5	0.28	0.28	0.30	0.32	0.36	0.29	0.39	0.39	0.22	0.33
% OD	5-10	0.20	0.15	0.15	0.14	0.19	0.17	0.18	0.19	0.11	0.15
	10-15	0.16	0.12	0.11	0.11	0.12	0.14	0.14	0.16	0.09	0.17
	15-20	0.15	0.09	0.08	0.10	0.11	0.13	0.11	0.12	0.09	0.14
	20-25	0.11	0.09	0.08	0.08	0.10	0.11	0.11	0.11	0.07	0.11
	25-30	0.10	0.07	0.07	0.06	0.07	0.09	0.08	0.08	0.05	0.09
	40-45	0.05	0.04	0.05	0.04	0.03	0.05	0.04	0.03	0.03	0.07
	65-70	0.05	0.04	0.04	0.04	0.02	0.04	0.03	0.02	0.02	0.04

1974 data

Variable	Sampling depth (cm)	<i>P. nigra</i>	<i>P. abies</i>	<i>C. lawsoniana</i>	<i>T. heterophylla</i>	<i>T. plicata</i>	<i>P. menziesii</i>	<i>L. eurolepis</i>	<i>Q. petraea</i>	<i>Q. rubra</i>	<i>N. obliqua</i>
Extract-able Na	0- 5	2.0	3.2	3.7	5.1	2.0	2.6	4.1	1.5	1.2	3.2
	5-10	1.7	1.7	2.5	2.3	1.8	2.6	2.1	0.9	0.7	1.9
	10-15	1.5	1.5	2.4	2.0	1.5	1.9	1.8	0.8	0.7	2.0
	15-20	1.3	1.4	2.4	1.7	1.6	1.6	1.9	0.6	0.8	2.1
	20-25	1.5	1.5	2.3	1.6	1.6	1.7	1.9	0.7	0.7	2.0
	25-30	1.5	1.5	2.5	1.5	1.5	1.5	1.7	0.5	0.5	2.0
	40-45	1.9	0.9	1.7	1.0	0.8	1.7	1.0	0.3	0.4	1.9
	65-70	2.7	1.0	1.3	1.1	0.6	1.9	1.0	0.5	0.5	1.4
Extract-able K	0- 5	6.2	3.6	4.4	2.6	5.8	5.7	7.8	7.7	3.2	5.8
	5-10	4.4	2.1	2.2	1.6	3.2	5.8	4.5	4.0	2.4	3.1
	10-15	3.9	1.9	2.2	1.5	3.1	4.9	4.0	3.0	1.9	2.9
	15-20	3.6	1.9	2.2	1.4	3.0	3.5	3.6	2.1	1.4	2.8
	20-25	3.5	2.0	2.1	1.4	2.7	3.6	3.5	1.9	1.1	2.6
	25-30	4.3	1.7	2.3	1.4	2.5	3.3	3.2	1.8	1.4	2.4
	40-45	4.6	1.5	2.5	1.3	1.5	4.5	1.9	1.0	0.7	2.8
	65-70	5.0	2.1	3.0	1.0	1.1	4.9	1.6	0.8	0.6	1.9
Extract-able Ca	0- 5	15.9	13.7	10.2	10.0	18.6	18.4	24.3	17.8	7.4	15.6
	5-10	8.3	3.9	1.1	3.7	4.5	5.4	3.7	3.3	2.3	2.7
	10-15	5.6	1.5	2.6	2.5	2.6	3.3	4.8	2.8	3.0	3.4
	15-20	5.3	1.5	1.3	2.3	2.1	3.4	2.8	2.7	3.0	2.1
	20-25	3.8	2.4	2.0	3.8	2.6	2.8	3.3	1.1	1.6	2.3
	25-30	4.9	1.8	1.1	1.8	1.5	2.7	2.0	1.8	2.4	1.3
	40-45	7.0	1.9	3.0	1.6	2.0	3.4	3.3	1.6	1.4	1.4
	65-70	10.6	1.9	1.5	1.1	1.1	5.4	1.8	1.1	1.1	3.0
Extract-able Mg	0- 5	3.0	0.6	3.0	3.6	3.4	3.3	6.1	3.3	2.3	3.3
	5-10	1.7	0.6	1.0	0.8	1.8	1.3	2.0	0.9	0.6	1.4
	10-15	1.4	0.7	0.6	0.6	0.7	0.7	1.7	0.6	0.6	1.5
	15-20	2.2	0.4	0.6	1.5	0.7	2.0	1.4	1.3	1.3	1.5
	20-25	2.5	0.7	0.6	1.4	0.7	2.2	1.2	1.3	1.1	1.5
	25-30	3.0	0.4	0.6	1.4	0.7	2.2	1.2	1.2	1.1	1.8
	40-45	6.7	0.5	1.0	0.7	0.7	3.8	1.2	0.7	0.4	3.2
	65-70	12.4	0.6	0.6	1.0	0.4	8.2	0.9	0.6	0.6	3.5
Extract-able P	0- 5	0.40	0.55	0.41	0.51	0.53	0.50	0.64	0.67	0.39	0.39
	5-10	0.15	0.14	0.09	0.10	0.14	0.10	0.11	0.26	0.11	0.16
	10-15	0.08	0.09	0.05	0.06	0.05	0.09	0.04	0.07	0.04	0.04
	15-20	0.06	0.04	0.03	0.03	0.03	0.14	0.02	0.02	0.08	0.04
	20-25	0.03	0.04	0.04	0.04	0.03	0.05	0.03	0.03	0.02	0.01
	25-30	0.02	0.02	0.01	0.02	0.01	0.06	0.01	0.02	0.02	0.01
	40-45	0.01	0.03	0.02	0.02	0.04	0.02	0.03	0.01	0.01	0.02
	65-70	0.01	0.01	0.01	0.01	0.02	0.01	0.03	0.01	0.01	0.02

1951 L and F/H layer total calcium

	Litter	F/H
<i>P. nigra</i>	0.59	0.54
<i>P. abies</i>	0.63	0.33
<i>C. lawsoniana</i>	0.89	0.74
<i>T. heterophylla</i>	0.52	0.39
<i>T. plicata</i>	0.76	0.69
<i>P. menziesii</i>	0.71	0.60
<i>L. eurolepis</i>	0.29	0.27
<i>Q. petraea</i>	0.71	0.60
<i>Q. rubra</i>	0.89	0.82
<i>N. obliqua</i>	1.12	0.98

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