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EFFECTS OF TREES ON SOIL PROPERTIES, A RESAMPLING OF J D OVINGTON'S *Pinus nigra* var *maritima* PLOTS AT BEDGEBURY, ABBOTSWOOD, AND WEST TOFTS

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, in order to gain an insight into the effects of trees on soils, Ovington sampled soils in plots which were either unplanted or planted with different species, at 5 sites. The plots had been planted for at least 17 years and, in the main, were each occupied by a single species with closed canopy. The original papers (Ovington 1953, 1954, 1955, 1956a, 1956b, 1958a, 1958b) did not present a statistical analysis of the data.

In 1974, plots at three of the 5 sites (Bedgebury, Abbotswood and West Tofts), which had not been felled and replanted, were resampled by members of ITE and the Forestry Commission to identify changes in soil and litter chemical characteristics occurring since 1951. Unfortunately, the plots which had been felled usually had the best-grown trees, and their soils would have been expected to show the largest changes. None of the existing plots received fertilizers on planting or subsequently, and none has had herbicide applications at any stage.

The only species planted at all 3 sites was *Pinus nigra* var *maritima* (Ait.) Melv., the results for which are presented in this paper because they offer opportunities to examine the effect of one species in different site conditions. Differences between sites are of interest because there is evidence to suggest that a given species may have different effects on different soils. As the chemical nature of the leaf litter is an important factor in determining what effect a given species will have on a given soil, this may be explained by other observations which suggest that, for some species at least, the chemical nature of the leaf litter depends on the soil on which the tree grows.

Subsequent papers will deal with species planted at the individual sites.

2 SITES AND SAMPLING PLOTS

The soil conditions at Abbotswood and West Tofts are fairly uniform, while there are obvious variations in texture and drainage at Bedgebury. Full soil profile descriptions are given in Ovington (1953).

The Bedgebury Forest Plots are located 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 leaching of the surface horizons and gleying of the subsoils becomes more noticeable to the south-east. 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 forms hard lumps upon drying that are difficult to break. Drainage is imperfect, so that the soil frequently becomes waterlogged in winter, or during heavy rainfall at other times. The degree of gleying varies within plots. The upper soil is stone-free, but flattened shaly stones increase in frequency at lower depths. 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* (Mirb.) Franco and *Picea omorika* (Pančić) Purkyně.

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 shelter belt to the north-east, the site was clear-felled in 1928, and plots of a quarter acre were planted each with a single species, *P. nigra* being planted in 1934.

The Abbotswood plots are about 107 m above sea level along the eastern margin of forest on the relatively steep western slopes of a small north-to-south valley, on the rim outcrop of Old Red Sandstone. The soil is a fairly coarse sandy loam, generally becoming coarser down the profile, average depth 80 cm. In some profiles, narrow bands of reddish clay occur. The soil is more or less stone-free, except for scattered pebbles, and freely-drained, with no evidence of waterlogging. Ovington (1953) found the pH to be just over 4, increasing slowly with depth. There was no evidence of podzolization. This area is said to have previously carried a fairly uniform crop of mature beech standards, with a sprinkling of oak standards, probably planted about 1806. There was a small relict woodland on the upper slopes (Ovington 1953). *P. nigra* was planted here in 1906.

The West Tofts area, altitude 30-46 m, is flat, and the soil, except for the underlying chalky boulder clay, is sandy throughout. The lowermost light yellow chalky clay, at an average depth of 70 cm, is compact and few roots penetrate it. Ovington (1953) stated that, except for the lowermost reddish layer, the sandy soil had no clearly-defined horizons, but showed a gradual change from greyish-brown above to a yellowish-brown and finally a yellow colour below. Chalk particles and flints were present throughout the profile. The pH varied with depth from 5 to 8.5. This area was formerly part of the Breckland heath; it was ploughed and planted in 1930. Ovington noted that oak regeneration occurred in all the plots except that planted with *Pseudotsuga menziesii* (Mirb.) Franco.

Within each plot, 5 profiles were sampled. Original manuscript tables at Merlewood showed that the depths of 2 of the soil layers in Ovington's published pH data for Bedgebury (Ovington 1953) were incorrect. His 45 to 50 cm should read 40-45 cm, and his 65 to 70 cm should read 55 to 60 cm. At West Tofts, for extractable Na, K, Ca, Mg, P, his 40-45 cm should read 45-50 cm and 55-60cm should read 65-70 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 common sampling depths for the soil variables were: 0-5, 5-10, 15-20, 25-30, 40-45 (Bedgebury only), 45-50 (Abbotswood and West Tofts), 65-70 (A and W.T.).

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 (LOI), total N, total Na, K, Ca, Mg, P.

Soil samples: pH, LOI, total N, extractable Na, K, Ca, Mg, P. 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 results to produce a 1951 equivalent for comparison. Details are given in the Appendix.

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. Although Ovington sampled at 5 locations within each plot, he published only the mean values and gave no indication of the variance within plots. In order to compare plot means between years, an estimate of the within-plot variance is needed. In the present work, we must assume that the within-plot variances in Ovington's samplings were the same as those in the 1974 samplings, although this is not altogether satisfactory.

To obtain a pooled within-plots estimate of the variance for between-years comparisons, a one-way analysis of variance was carried out on all the 1974 data for each site, soil depth (or L or F/H layer) and chemical element, separately.

Comparisons were made between plot means in 1951 and 1974 using Tukey's honestly significant difference. That test was also used to look for differences, for Bedgebury only, between *Pinus nigra* and shelterbelt in 1951. In the absence of untreated plots which might be used in a similar way to 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. Tests of differences between sites were made in a similar manner.

A principal component analysis was carried out on the correlation matrix of the data for the 8 chemical variables (means of plot replicates) for both years, for all the soil layers common to both samplings, for all 3 sites. 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.

4 RESULTS AND DISCUSSION

4.1 Analysis of variance

The means of the variables for the L and F/H layers are given in Table 1. The means of the variables over all common soil depths are shown in Table 2, they illustrate overall differences between the sites. The results for the different depths are plotted in Figure 1 (pH, loss-on-ignition, total nitrogen), Figure 2 (extractable potassium, calcium, magnesium), and Figure 3 (extractable sodium and phosphorus). The depths at which the 1951 and 1974 mean values are significantly different at $p < 0.05$ are cross-hatched.

pH: At all the common campling depths, soils under *P. nigra* at West Tofts are significantly ($p < 0.001$) less acid than those at Bedgebury and Abbotswood (Table 2 and Figure 1). Between 1951 and 1974, there were significant increases in pH at all depths sampled between 10 cm and 45 cm at Bedgebury, where the gains were between 5% and 9% of the 1951 value, and between 25 cm and 70 cm at West Tofts, where the gains were 7% to 12%. There were no significant changes at Abbotswood, but in 1974 the trees were 40 years old at Bedgebury and 44 years old at West Tofts, whereas they were already 45 years old in 1951 at Abbotswood. There was no significant difference in pH between Bedgebury in 1974 and Abbotswood in either year for any of the 4 common sampling depths. Ovington (1953) noted that in 1951 the upper mineral soil under all conifers except *P. nigra* was more acid than the deeper soil at Bedgebury. The increase in pH at the greater depths together with the small, non-significant, decreases at 0-5 cm and 5-10 cm under *P. nigra* meant that by 1974 this anomaly had disappeared. The relatively high pH of the surface soil under *P. nigra* at Bedgebury in 1951 was associated with a large content of extractable calcium which had decreased significantly ($p < 0.001$) by 1974. Ovington also found that fresh *P. nigra* leaves had a lower pH (3.86) than those of the other species at Bedgebury in 1951, and *P. nigra* soil had one of the largest accumulations of surface organic matter at Bedgebury and West Tofts. It seems unusual that these conditions should be associated with high pH and extractable calcium content in the upper soil layers in 1951. At Bedgebury, *P. nigra* appears to have been planted on an unusually calcareous plot. Evidence to be presented in a later paper suggests that there was a large amount of within-plot variation at Bedgebury which limits the between-species comparisons that can be made.

The significant increases in pH at the greater depths at Bedgebury and West Tofts is difficult to explain, and may be due to spatial variation between the 2 samplings.

Loss-on-ignition: In 1974, the loss-on-ignition of the F/H layer was significant lower ($p < 0.05$) at West Tofts than at Bedgebury but there were no significant differences between sites for the L layer (Table 1). The loss-on-ignition of soils under *P. nigra* was also significantly ($p < 0.001$) lower at West Tofts than at Bedgebury or Abbotswood at all 4 common sampling depths. Loss-on-ignition of Abbotswood soil was significantly lower than that at Bedgebury only at 25-30 cm ($p < 0.05$).

There were no significant differences in loss-on-ignition between 1951 and 1974 for the L and F/H layers at any of the 3 sites. However there were decreases at most soil depths at all 3 sites (Figure 1), but the differences were significant only at 40-45 cm at Bedgebury (-31%) and between 5 cm and 30 cm at West Tofts (-26% to -51%).

Total nitrogen: At West Tofts in 1974 there was significantly less total nitrogen in both the L and F/H layers than in those at Bedgebury, and less in the F/H layer than in that at Abbotswood (Table 1). The total nitrogen content of soil at all 4 common sampling depths was significantly lower ($p < 0.001$) at West Tofts than at Bedgebury and Abbotswood but only at 5-10 cm was the total nitrogen content of Abbotswood soil significantly lower ($p < 0.05$) that at Bedgebury.

There was a significant increase in total nitrogen for Abbotswood L layer (+ 83%), and for L (+ 130%) and F/H (+ 64%) layers at West Tofts. There were significant decreases in total nitrogen (Figure 1) between 1951 and 1974 at all depths at Abbotswood (-23% to -47%), and at all depths below 5 cm at Bedgebury (-21% to -40%). At West Tofts, however, there was a significant decrease only at 15-20 cm (-56%) and a significant increase at 65-70 cm (+70%).

Potassium: In 1974 there were no significant site differences between the total potassium contents of the L layers, but the F/H layer at West Tofts contained significantly less than the other sites (Table 1). At all 4 common sampling depths, extractable potassium content was significantly ($p < 0.001$) lower at West Tofts than at the other 2 sites, and at 0-5 cm was significantly ($p < 0.05$) lower at Abbotswood than at Bedgebury.

At Abbotswood, there was a significant decrease in total potassium in the L layer (-41%) and a significant increase in the F/H layer (+75%) from 1951 to 1974. There were no significant changes in extractable potassium between 1951 and 1974 in the West Tofts soils (Figure 2). At Abbotswood, there were significant increases (74% to 116%) at all depths sampled below 15 cm. At Bedgebury, there was a significant decrease (-24%) at 0-5 cm and significant increases at 25-30 cm (+148%) and 40-45 cm (+125%), which have tended to reduce the difference between surface and deeper soils noted by Ovington (1958).

Calcium: In 1974 there were no significant site differences between the total calcium contents of the L layers but the F/H layer at Bedgebury contained significantly more than the other sites (Table 1). At all 4 common sampling depths, the extractable calcium of soil under *P. nigra* at West Tofts was significantly greater than at the other 2 sites ($p < 0.05$ at 0-5 cm, $p < 0.001$ at other depths).

At West Tofts, from 1951 to 1974, there was a significant decrease in total calcium in the L layer (-45%) and F/H layer (-68%). There were significant decreases in extractable calcium (Figure 2) between 0 and 20 cm at Bedgebury (-60% to -70%) and between 5 cm and 30 cm at West Tofts (-35% to -81%). At Abbotswood, there were significant decreases at 5-10 cm (-65%), 15-20 cm (-47%), and 45-50 cm (-43%), but an increase at 65-70 cm (+80%). The decreases in the upper mineral soils considerably reduced the relatively high levels of extractable calcium noted by Ovington (1958) at Bedgebury and Abbotswood.

Magnesium: In 1974 the total magnesium content of the L layers was significantly greater at Bedgebury than at West Tofts, but for the F/H layers was significantly greater at Abbotswood than at the other sites (Table 1). There were several significant differences between sites, but they were not consistent over the depths sampled. The extractable magnesium content was greater at Bedgebury and Abbotswood than at West Tofts at 0-5 cm ($p < 0.001$) and greater at Bedgebury than at the other sites at 15-20 cm ($p < 0.05$) and 25-30 cm ($p < 0.001$).

From 1951 to 1974, there were significant decreases in total magnesium in the F/H layer at Bedgebury (-54%) and the L layers at Abbotswood (-32%) and West Tofts (-45%). There were significant decreases in extractable magnesium (Figure 2) at all depths down to 30 cm at Bedgebury (-63% to -77%), at all depths down to 50 cm at Abbotswood (-54% to -76%), and at all depths down to 30 cm at West Tofts (-50% to -85%). In spite of decreases in the lower sampling depths, the deeper soil at Bedgebury in 1974 was still relatively rich in extractable magnesium.

Sodium: At Bedgebury in 1974 there was significantly more total sodium in the L layer than at the other 2 sites, and more in the F/H layer than at West Tofts (Table 1). At 0-5 cm, 5-10 cm and 25-30 cm there was significantly ($p < 0.01$) more extractable sodium at Bedgebury than at West Tofts. Extractable sodium content at Bedgebury was significantly greater than that at Abbotswood at 0-5 cm ($p < 0.05$), 15-20 cm ($p < 0.05$), and 25-30 cm ($p < 0.01$).

From 1951 to 1974, there were significant increases in total sodium in L and F/H layers (83% and 97% respectively) at Bedgebury, a significant decrease in L layer (-66%) and increase in F/H layer (73%) at Abbotswood. The largest change in extractable sodium content occurred at 25-30 cm at West Tofts (-68%). At that site there were also decreases at 5-10 cm (-52%) and 15-20 cm (-38%). At Abbotswood there were decreases at 5-10 cm (-20%) and 45-50 cm (-52%). There was no significant change at Bedgebury (Figure 3).

Phosphorus: In 1974 there were no significant differences between sites in the total phosphorus content of the L layers, but the F/H layer at West Tofts contained significantly less than that at the other sites (Table 1). Extractable phosphorus content at all 4 common sampling depths was lower at Bedgebury than at Abbotswood or West Tofts ($p < 0.01$). At Abbotswood, extractable phosphorus content was lower than at West Tofts for the 3 lowermost sampling depths ($p < 0.001$ at 5-10 cm, $p < 0.01$ at 15-20 cm, $p < 0.05$ at 25-30 cm).

From 1951 to 1974, there was a significant increase in total phosphorus content of L (+105%) and F/H (+49%) layers at Abbotswood. At Bedgebury, there was a significant decrease (-82%) in extractable phosphorus at 40-45 cm (Figure 3). There were significant increases at Abbotswood at 15-20 cm (+158%) and 25-30 cm (+177%), and a significant decrease at 15-20 cm (-48%) at West Tofts.

Shelterbelt: At Bedgebury, Ovington sampled the shelterbelt, which was a remnant of the original cover of the site and provides a useful reference point. The 1951 values for the variables in the soil under *P. nigra* showed few significant differences from those under the shelterbelt. Under *P. nigra* pH was significantly lower at 15-20 cm, extractable calcium was significantly greater at 0-5 cm, 5-10 cm, and 15-20 cm, and extractable magnesium was significantly greater at 40-45 cm. The high values for extractable calcium under *P. nigra* are suspicious, and may be due to within-site variation. Anderson (pers. comm.) believes that parts of the Bedgebury site were marled at some time before planting, but as there is no record of this, its extent is unknown. For pH, loss-on-ignition, total nitrogen, extractable calcium at 0-5 cm, extractable magnesium above 30 cm depth, and extractable phosphorus at 0-5 cm and 5-10 cm, the results (Figures 1 to 3) suggest that the direction of change may have altered between the

1951 and 1974 samplings. When Ovington sampled in 1951, the *P. nigra* trees had been planted for only 17 years. No doubt the clearance of the original coppice prior to planting would have initiated changes in the soils, and for the first 10 years or so after planting the trees would have been too small to have had much effect on the soil. By 1974, the effects of *P. nigra* were becoming clearer.

4.2 Principal component analysis

A summary of the data is given in Table 3. Extractable calcium shows most variation (C.V. 194%). The remaining variables have coefficients of variation ranging from 31% (pH) to 96% (extractable phosphorus). The lower half-matrix of correlation coefficients (Table 4) shows that many of the variables are significantly inter-correlated.

Only the first 2 eigenvalues are of practical importance, together they account for 82% of the total variance (Table 5). The first component, accounting for 61% of the total variance, contrasts loss-on-ignition, total nitrogen, extractable potassium and magnesium with pH and extractable phosphorus (Table 6). The second component, accounting for 21% of the total variance, is due chiefly to extractable sodium and calcium, which together account for 70% of the variance in that component.

The first and second component values are plotted in Figure 4, which emphasizes the differences between sites. All sampling depths at West Tofts had larger first component values than any depths at Bedgebury or Abbotswood, due to the soils at West Tofts having lower loss-on-ignition, total nitrogen, and extractable potassium and magnesium values, as well as higher pH and extractable phosphorus. Most depths, particularly the upper depths at Bedgebury and Abbotswood, show an increase in first component value with time due to decreases in loss-on-ignition, total nitrogen, and extractable magnesium, as well as increases in pH and extractable phosphorus. All depths at all sites, except West Tofts 65-70 cm, show increases in second component values from 1951 to 1974, due chiefly to decreases in extractable sodium and calcium.

5 CONCLUSIONS

Although the lack of plot replication makes it impossible to allow for within-site variation between the 1951 and 1974 samplings, there seem to be clear indications that there are significant differences in the chemical nature of the L and F/H layers under *Pinus nigra* at Bedgebury, Abbotswood and West Tofts, which presumably reflect different responses of the species to the different soil parent materials. Overall soil at West Tofts had a higher pH, lower loss-on-ignition, total nitrogen, extractable potassium and magnesium, and higher extractable calcium and phosphorus than the soils at the other 2 sites.

There also seem to be clear effects of *P. nigra* on the soils, the effects differing at the different sites. From 1951 to 1974, there has been an increase in pH at depths below 10 cm at Bedgebury and below 25 cm at West Tofts, but there is little evidence of increased acidification of, or organic matter accumulation in, the surface mineral soil. The decrease in loss-on-ignition at 0-30 cm at West Tofts, though statistically significant, is small. Significant decreases in total nitrogen occurred in the upper parts of the profiles at all 3 sites, the decreases being greater and occurring at greater depths at Bedgebury and Abbotswood. When comparing soils under

P. nigra and *P. sylvestris* with neighbouring oak or oak/hornbeam stands, Petkov (1979) found indications of a slight acidification of the 0-5 cm layer and a decrease in the contents of humus and of total nitrogen under the pine plantations.

The clearest effect has been the changes in the readily-exchangeable elements potassium, calcium and magnesium. At Bedgebury and Abbotswood, the amounts of extractable potassium below 20 cm depth increased appreciably, possibly as a result of increased weathering of soil mineral material. All three sites show quite large decreases in extractable calcium and magnesium, possibly accentuated by leachates from the canopy and humus layers. In a later paper we shall discuss the relative magnitudes of these effects between species on the individual sites.

The principal component plot illustrates both the differences between sites and the trends with time. It is clear that the soils at Bedgebury and Abbotswood are more alike than either is like West Tofts, and that in the 2 dimensions plotted all 3 sites show a trend toward the same point.

6 SUMMARY

1. Soils at Bedgebury, Abbotswood, and West Tofts which were planted with *P. nigra* in 1934, 1906 and 1930 respectively, were sampled and analyzed in 1951 and 1974.

2. Soils at Bedgebury and Abbotswood are more alike than either is like West Tofts, due to differences in soil parent material. At Bedgebury there is a compact silty clay, at Abbotswood there is a fairly coarse sandy loam, and at West Tofts a sandy soil overlies chalky boulder clay.

3. pH increased at depths below 10 cm at Bedgebury and below 25 cm at West Tofts, but there is little evidence of increased acidification of the surface mineral soil, or of organic accumulation there over the period 1951-1974.

4. Significant decreases in total N occurred in the upper parts of the profiles at all 3 sites, the changes being greater, and occurring at greater depths, at Bedgebury and Abbotswood.

5. The clearest effect was in the readily-exchangeable elements K, Ca, Mg. At Bedgebury and Abbotswood there were large increases in extractable K below 20 cm depth. There were large decreases in extractable Ca and Mg at all 3 sites.

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Table 1. Means of the variables for the L and F/H layers under *Pinus nigra* at Bedgebury (B), Abbotswood (A) and West Tofts (WT), showing changes between 1951 and 1974.

Variable % OD		L layer B		L layer A		L layer WT		F/H layer B		F/H layer A		F/H layer WT	
LOI	1951	97.61		97.20		97.50		85.27		90.15		69.59	
	1974	96.50		96.50		96.60		87.60		80.00		69.00	
Total N	1951	1.30		0.65	**	0.37	***	1.69		1.33		0.64	**
	1974	1.28		1.19		0.85		1.48		1.61		1.05	
Total Na	1951	0.01	*	0.03	*	0.01		0.02	**	0.01	*	0.02	
	1974	0.02		0.01		0.01		0.03		0.02		0.02	
Total K	1951	0.14		0.22	**	0.14		0.14		0.10	**	0.07	
	1974	0.10		0.13		0.09		0.14		0.17		0.05	
Total Ca	1951	0.59		0.56		1.97	***	0.54		0.28		0.98	***
	1974	0.62		0.60		0.59		0.50		0.30		0.31	
Total Mg	1951	0.07		0.08	*	0.06	*	0.08	***	0.07		0.04	
	1974	0.05		0.05		0.03		0.04		0.06		0.03	
Total P	1951	0.07		0.05	***	0.05		0.10		0.07	**	0.07	
	1974	0.09		0.10		0.07		0.11		0.11		0.06	

Significant differences (1974 only)

	L	F/H
LOI	NS	B > WT*
Total N	B > WT*	B > WT**, A > WT***
" Na	B > A*, B > WT*	B > WT*
" K	NS	B > WT**, A > WT***
" Ca	NS	B > WT*, B > A*
" Mg	B > WT*	A > B* A > WT**
" P	NS	B > WT***, A > WT***

NS - no significant difference

* significant difference p ≤ 0.05

** " " p ≤ 0.01

*** " " p ≤ 0.001

Table 2. Means of the variables over all common soil depths sampled under *Pinus nigra* at Bedgebury (B), Abbotswood (A), and West Tofts (WT) 1951 and 1974, showing differences between sites.

Soil variable		1951	1974
pH	B	4.23	4.35
	A	4.36	4.36
	WT	7.49	7.75
LOI % OD	B	6.40	5.58
	A	4.50	3.80
	WT	1.21	0.83
Total N % OD	B	0.15	0.11
	A	0.12	0.08
	WT	0.02	0.02
Extractable Na	B	2.02	1.68
	A	1.02	0.80
	WT	1.25	0.85
Extractable K	B	5.88	7.23
	A	4.87	8.03
	WT	0.68	1.12
Extractable Ca	B	21.56	8.28
	A	8.38	5.63
	WT	228.65	103.00
Extractable Mg	B	7.08	3.32
	A	4.57	1.72
	WT	2.18	0.92
Extractable P	B	0.08	0.13
	A	0.77	1.07
	WT	2.97	2.37

Table 3. Minima, maxima, means, standard deviations, and coefficients of variation of variables for soil under *Pinus nigra* at all 3 sites, 1951 and 1974. (Data for principal component analysis).

Variable	Min.	Max.	Mean	SD	CV %
pH	3.95	8.47	5.49	1.71	31
LOI % OD	0.60	9.60	3.59	2.64	74
Total N % OD	0.01	0.25	0.08	0.07	88
Extractable Na	0.50	2.60	1.24	0.58	47
Extractable K	0.50	12.70	4.52	3.33	74
Extractable Ca	2.00	588.70	65.39	127.02	194
Extractable Mg	0.50	9.70	3.19	2.59	81
Extractable P	0.01	4.23	1.30	1.24	96

Extractables are expressed as mg/100 g.

Table 4. Lower half-matrix of correlation coefficients for soil variables measured under *Pinus nigra* at all 3 sites in 1951 and 1974.

	pH	LOI	N	Na	K	Ca	Mg
pH	1						
LOI % OD	-.728***	1					
Total N % OD	-.65***	.944***	1				
Extractable Na	-.157	.558***	.449**	1			
Extractable K	-.756***	.757***	.694***	.268	1		
Extractable Ca	.659***	-.375*	-.328	.311	-.484**	1	
Extractable Mg	-.476**	.719***	.685***	.643***	.407*	-.151	1
Extractable P	.882***	-.657***	-.564***	-.245	-.639***	.621***	-.477**

* P = < 0.05

** P = < 0.01

*** P = < 0.001

Table 5. Eigenvalues of the correlation matrix for soil variables measured under *Pinus nigra* at Bedgebury, Abbotswood and West Tofts, in 1951 and 1974.

Component	Eigenvalue	Percentage of variance	
		Component	Cumulative
1	4.86	60.8	60.8
2	1.70	21.2	82.0
3	0.50	6.3	88.3
4	0.43	5.3	93.6
5	0.22	2.7	96.3
6	0.19	2.3	98.6
7	0.08	1.0	99.6
8	0.03	0.3	99.9

Table 6. Orthonormal eigenvectors of the first 2 components of the correlation matrix for soils under *Pinus nigra* at Bedgebury, Abbotswood and West Tofts, in 1951 and 1974.

Variable	Eigenvector for component	
	1	2
pH	0.40*	-0.26
LOI % OD	-0.43*	-0.15
Total N % OD	-0.40*	-0.15
Extractable Na	-0.21	-0.62*
Extractable K	-0.38*	0.12
Extractable Ca	0.25	-0.57*
Extractable Mg	-0.33*	-0.35
Extractable P	0.38*	-0.22

* indicates that an eigenvector element is equal to or greater than 0.75 times the largest (absolute) value.

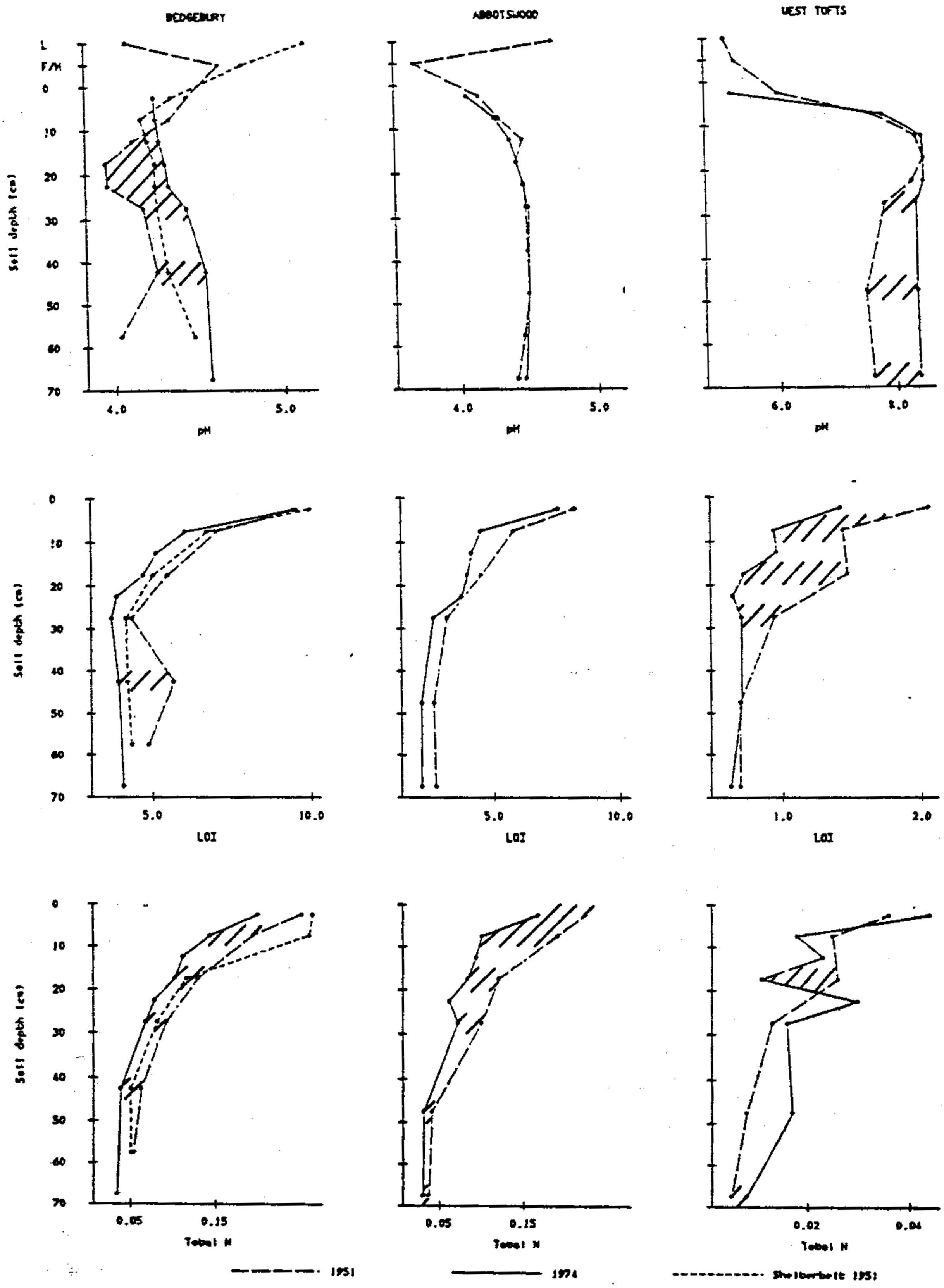


Figure 1. pH, loss-on-ignition, and total nitrogen at different depths under *Pinus nigra* at Bedgebury, Abbotswood, and West Tofts, 1951 and 1974. Differences significant at $p < 0.05$ are hatched.

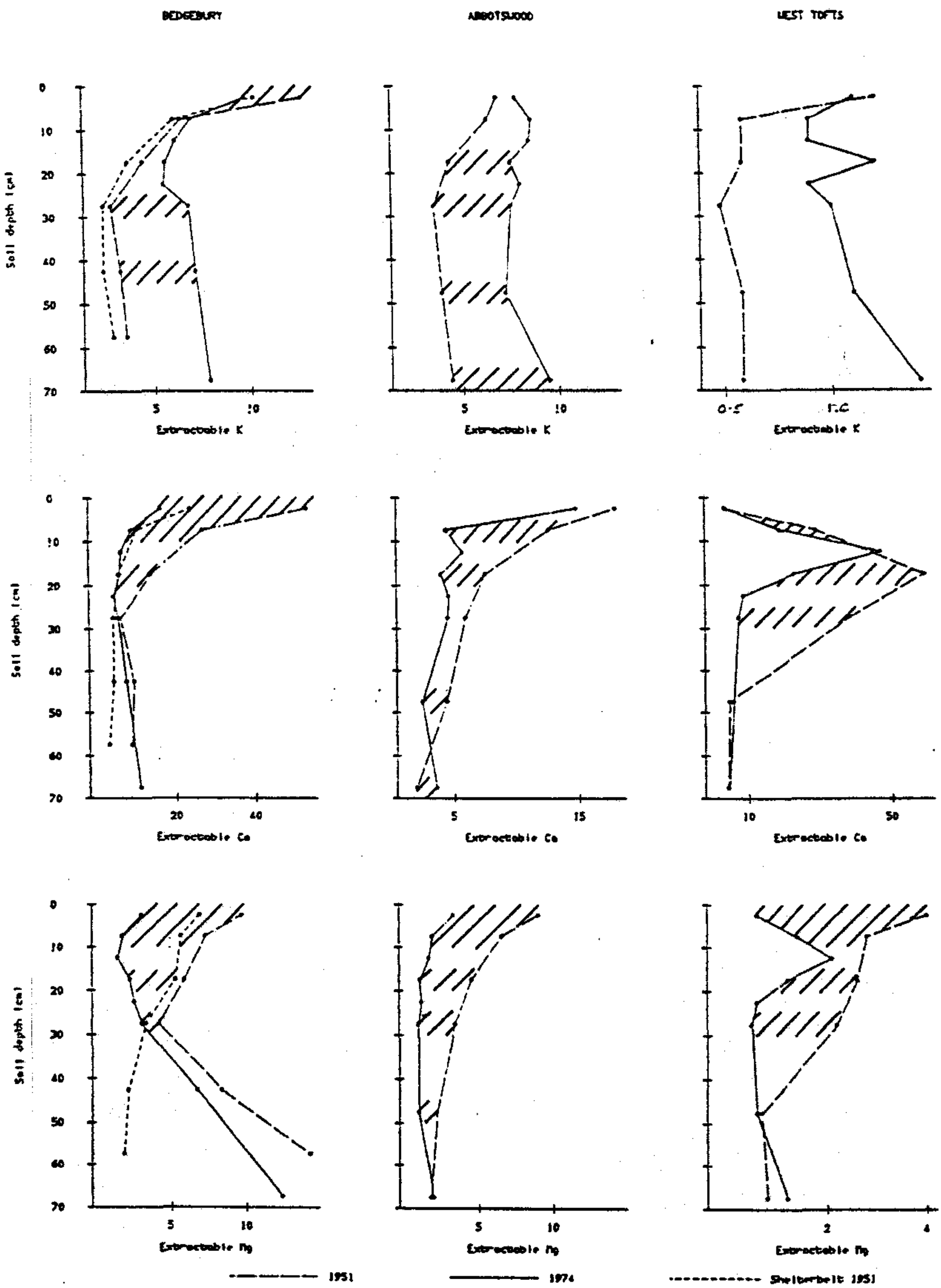


Figure 2. Extractable potassium, calcium, and magnesium at different depths under Pinus nigra at Bedgebury, Abbotswood, and West Tofts, 1951 and 1974. Differences significant at $p < 0.05$ are hatched.

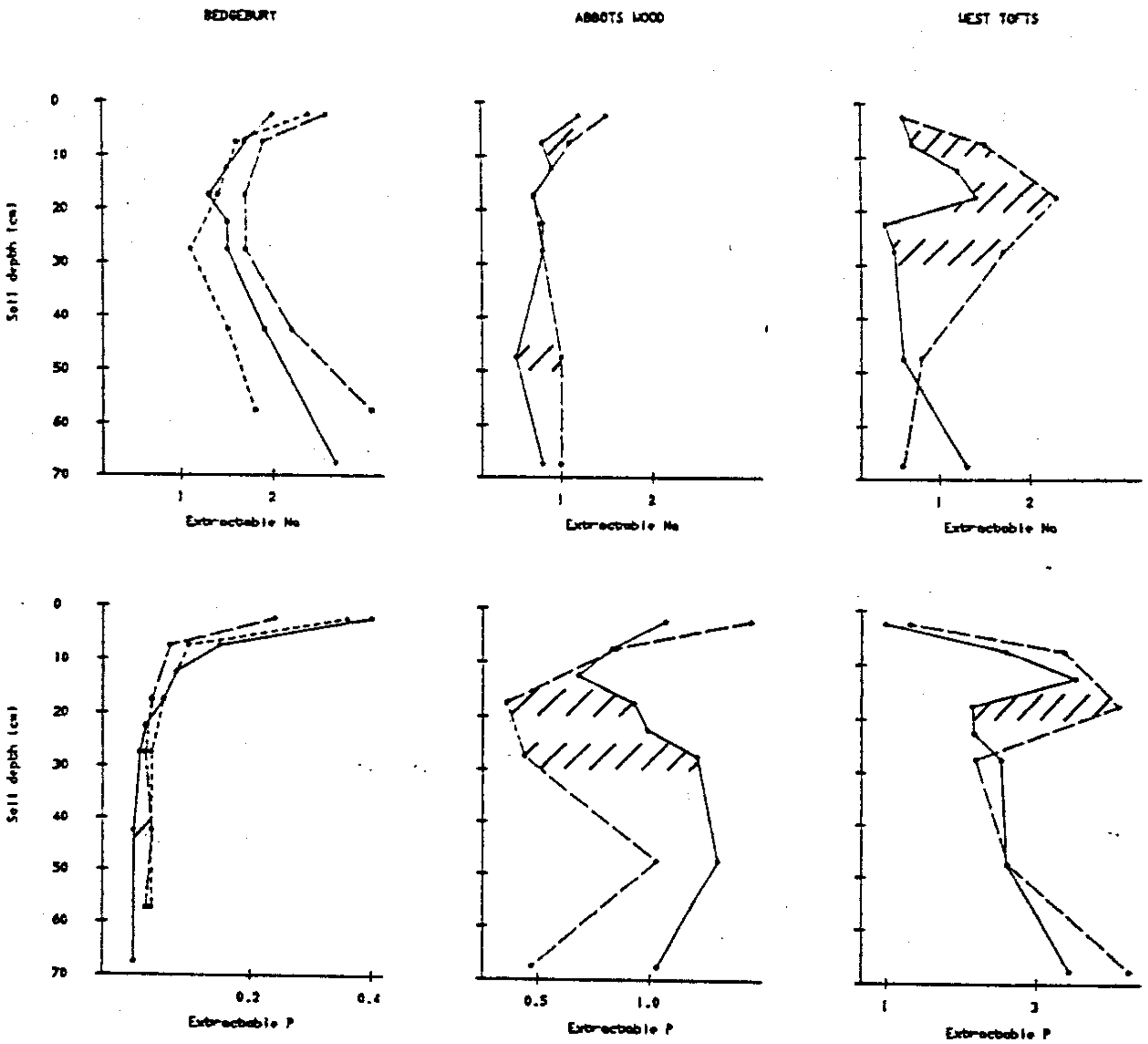
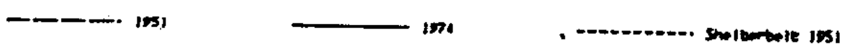


Figure 3. Extractable sodium and phosphorus at different depths under <u>Pinus</u> <u>nigra</u> at Bedgebury, Abbotswood, and West Tofts, 1951 and 1974. Differences significant at $p < 0.05$ are hatched.



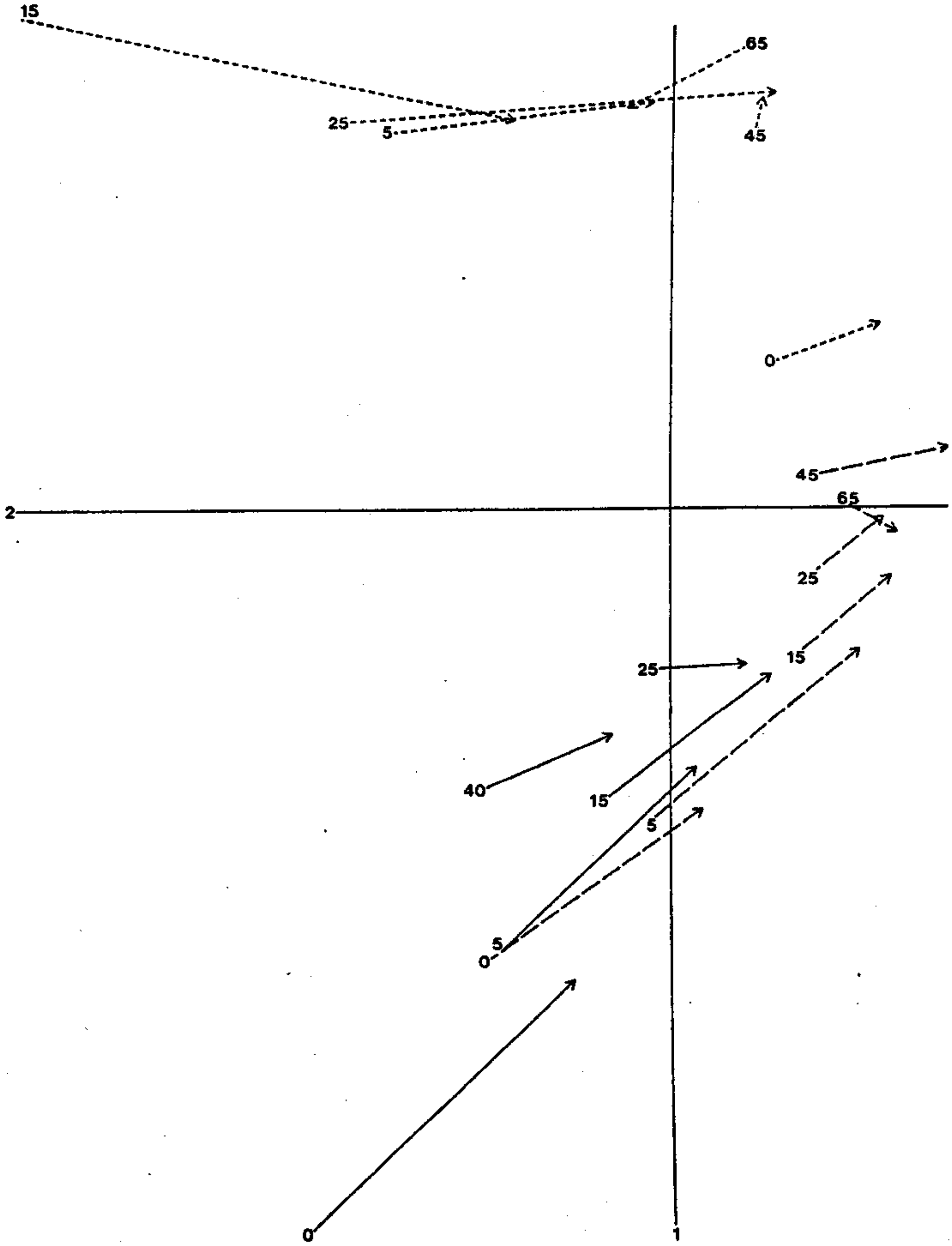


Figure 4. First and second components of the correlation matrix for the soils under Pinus nigra, showing changes from 1951 to 1974. Upper depth(cm) is given for each layer.

——— Bedgebury — — Abbotswood - - - - West Tofts

Appendix

Chemical methods

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 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:	Peroxide/sulphuric acid digest followed by:
		Na } EEL flame K } photometer	EEL flame photometer
		Ca-EDTA with murexide Mg-Titan yellow	Atomic absorption with lanthanum to suppress interference
		P-Molybdenum blue	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).	As 1951 but for 1 hour.
		Na } flame K } photometer	Flame photometer
		Ca-EDTA with murexide Mg-Titan yellow	Atomic absorption with lanthanum to suppress interference.
		P-Molybdenum blue	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.