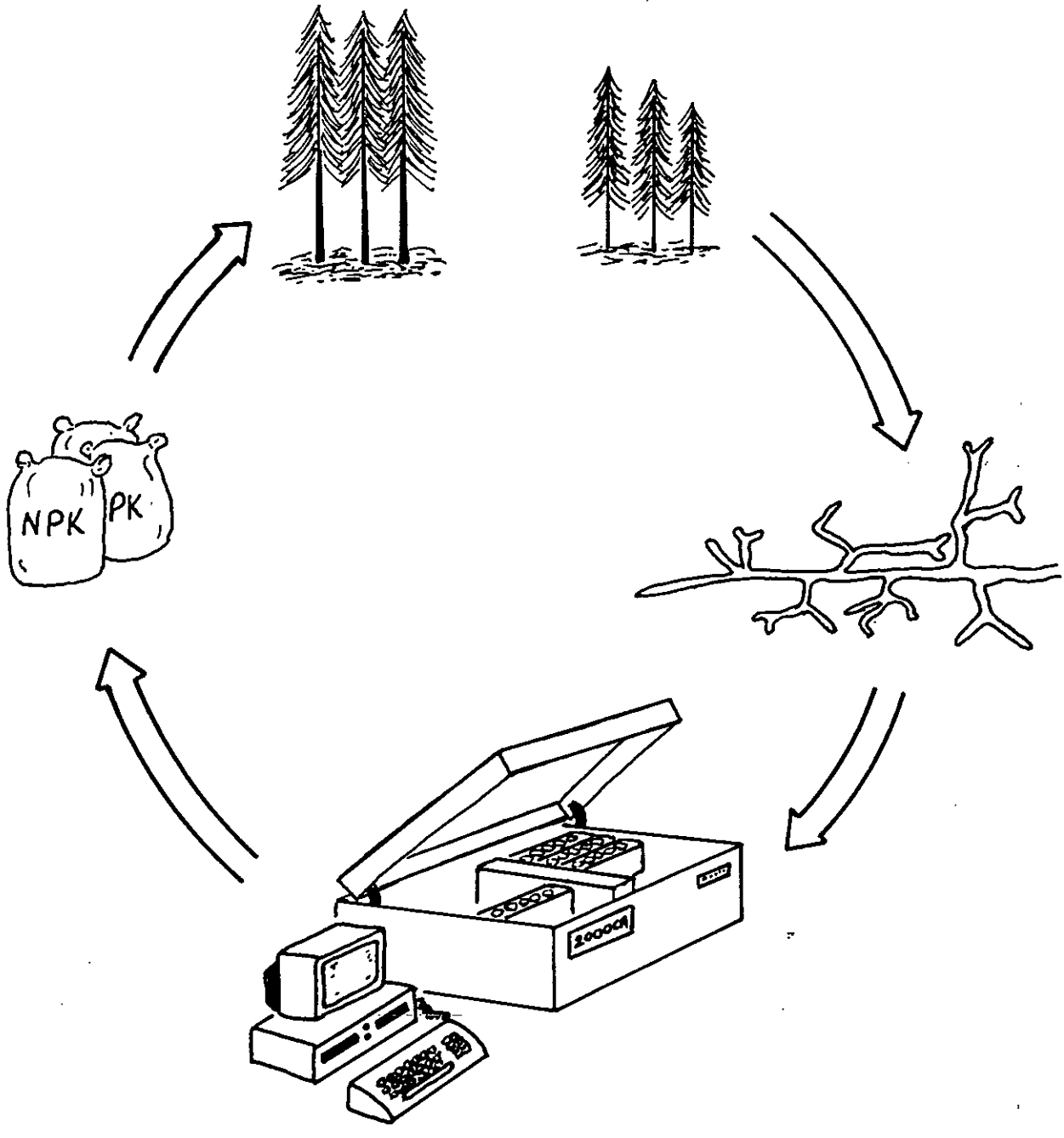
Detection of Nutrient Deficiency in Forest Stands: A New Technique



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DETECTION OF NUTRIENT DEFICIENCY IN FOREST STANDS:

A NEW TECHNIQUE

A F Harrison

J Dighton

H E Jones

P Ineson

Institute of Terrestrial Ecology
Merlewood Research Station
Grange over Sands
Cumbria LA11 6JU

Tel: Grange over Sands (04484) 2264/5

Telex: 65102

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THE PROBLEM

Upland soils planted to commercial forest trees are frquently unable to supply nutrients in sufficient quantities to allow trees to attain their optimum growth rate under the prevailing climatic conditions. These soils are said to be nutrient deficient and require fertilizing.

Needle and soil chemical analyses are used to indicate the degree of deficiency, but both methods often produce unreliable predictions of fertilizer requirement. Except with extreme deficiency, the nutrient contents of needles at the growing apex of larger trees, particularly after canopy closure stage, are buffered by nutrients being preferentially transferred to this region. Hence trees may be deficient without nutrient content of needles indicating so. The routine methods of soil analysis do not take adequate account of the dynamic nature of nutrient cycles in forest stands.

OUR APPROACH

We, at Merlewood, are taking a different approach and are developing new biological tests (bioassays) which appear to be more sensitive than the conventional methods in detecting nutrient deficiencies in forest trees. These bioassays rely on a physiological response of fine roots, which integrates the availability of nutrient in the soil with the tree's demand for nutrients. The bioassay has been developed initially for determining phosphorus (P) deficiency, but preliminary evidence suggests that the basic principle can also be extended to detection of potassium and nitrogen deficiency.

BASIS OF THE BIOASSAY

The phosphorus-deficiency bioassay is based on the rate of metabolic uptake by roots of radioactively-labelled phosphate from a dilute phosphate solution in the laboratory. The use of radioactive phosphate is essential for the measurement of the rates of uptake into roots, as these are far below the levels detectable by chemical methods.

The uptake rate of the radioactive phosphate has been shown to be inversely related to the phosphate supply to roots, e.g. tree seedlings grown with optimum P-supply take up little radioactivity, whereas those growing with sub-optimal P-supply take up larger amounts of radioactivity. Where fertilizers have been applied to potted tree seedlings in deficient soils, the radioactive P uptake by roots in the bioassay is reduced relative to non-fertilized trees. The decrease in P uptake is an indicator of the improved growth response to fertilizer application.

The bioassay technique has been successfully applied in forest fertilizer experiments on Sitka spruce and lodgepole pine, using excised roots. Effects of differential fertilizer applications on the nutritional status of both tree species has been demonstrated using the bioassay, where increased tree growth is correlated with reduction in the rate of radioactive-P uptake by their roots but, in contrast, there are no differences in first whorl needle P-concentrations between fertiizer treatments. The response of tree roots, and the likely tree growth response to fertilizer, can be demonstrated as early as a month after application. However, at least one growing season is necessary for growth responses and for changes in needle P concentration (if a change in concentration were to occur) to become apparent.

OUR RESEARCH APPLICATIONS

Where forest trees are planted in species mixtures, there is often a beneficial effect on growth in certain combinations. The use of the phosphate bioassay in a mixture study, in the Bowland Forest (Lancashire) has revealed that the nurse effect of Scots pine on the growth of Norway spruce is partly a result of improved phosphorus nutrition.

Changes in the P nutrition of different aged stands of Sitka spruce on a peaty gley soil have been shown using the P-bioassay. Increased P demand, apparently not satisfied because of limited soil P supply, has been demonstrated in trees around, and just after, canopy closure when tree growth is most rapid. Needle P content, however, was similar across all stand ages, clearly not identifying these changes in phosphorus demand by the trees.

POTENTIAL APPLICATIONS OF THE BIOASSAY

The bioassay is proving to be a good indicator of the nutrient status of forest trees. Although relying on technically complex analysis procedures, the bioassay is easily performed with the potential for large numbers of samples to be processed rapidly.

The rapidity with which roots have been found to respond to applied fertilizer and the relationships between the bioassay response and tree growth being better than those for needle analysis, suggest that the method could be a very useful improvement in prediction of tree growth response to fertilizers, particularly with pole stage stands.

The principle by which the bioassay has been shown to work, namely the inverse relationship between P uptake and P supply to roots holds true also for upland grass species. The productivity of upland grassland swards has been found to be negatively related to P uptake by the roots of one of the component grass species in the bioassay. It is, therefore, probable that the bioassay technique could be useful in some aspects of agriculture, as well as forestry.

Although the bioassay has been developed in the first instance for detecting phosphorus deficiency, preliminary investigations suggest that we should be able to develop similarly-based bioassays for deficiency testing of all three major elements, phosphorus, potassium and nitrogen.

FINANCIAL SUPPORT

The Natural Environmental Research Council, through the Institute of Terrestrial Ecology, has funded the early development of this research. Financial support is now urgently required for the necessary larger scale field trials to test the predictive potential of these nutrient deficiency bioassays and thus their value as a management tool in commercial forestry and perhaps agriculture.

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