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Nutrient Deficiencies of Conifers in British Forests

An Illustrated Guide

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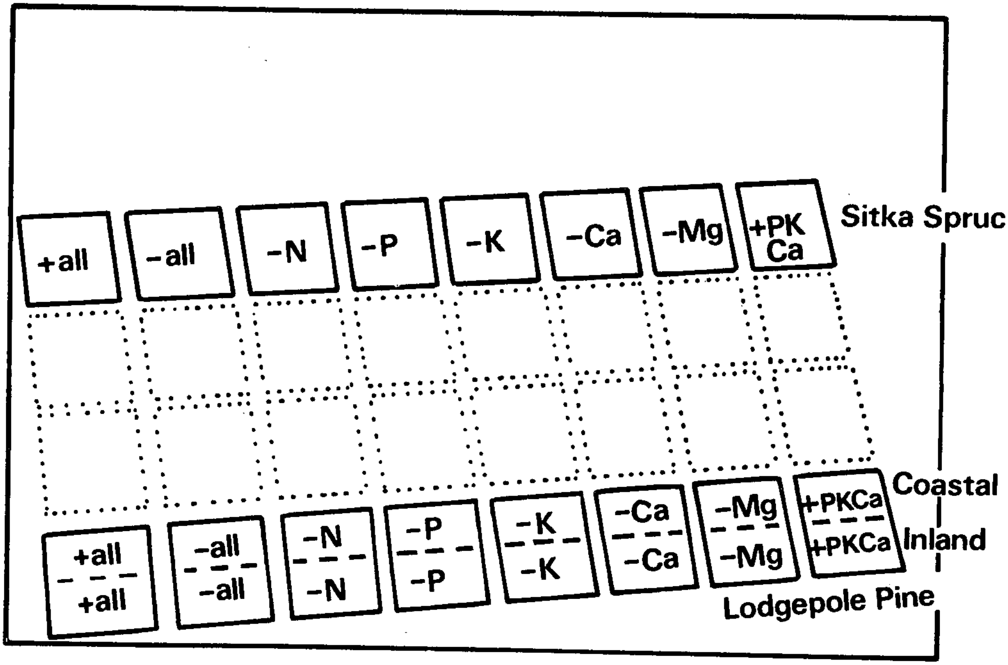

PLATE 1. (Front cover). The photograph shows a deficiency garden (experiment 7/67) at Eddleston, Glentress Forest, 12 miles south of Edinburgh. The site is an upland raised bog with 7 m of peat overlying boulder clay. *Calluna vulgaris* is uniformly dominant with frequent *Erica tetralix, Trichophorum caespitosum, Eriophorum vaginatum* and *Sphagnum* species.

The Sitka spruce and the inland and coastal origins of Lodgepole pine are 11 years old. Five of the plots of each species have been top-dressed regularly with combinations of four out of the five nutrient elements, namely nitrogen, phosphorus, potassium, calcium and magnesium, so as to induce deficiency symptoms. There are additional plots of + All (received NPKCaMg), − All (no fertiliser added), and + PKCa (standard top-dressing with rock phosphate and potassium chloride).

Of particular note are the following: The slight yellowing of nitrogen deficiency in the + PKCa plots of Sitka spruce; the yellow of the − K plots of all species; the patchy growth of the − P and − All plots of Sitka spruce; and the recent windblow in the coastal Lodgepole pine. *(30536)*

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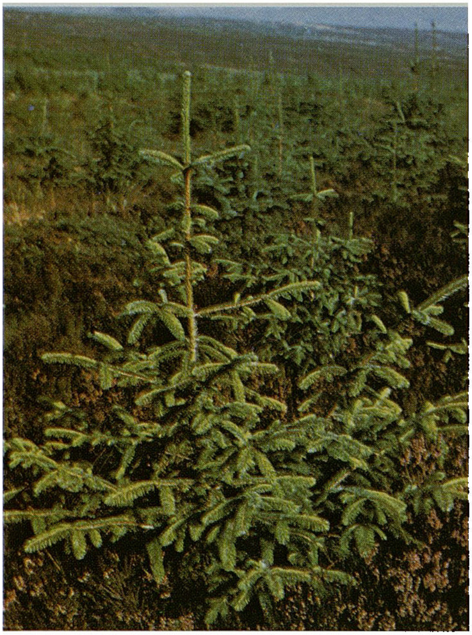

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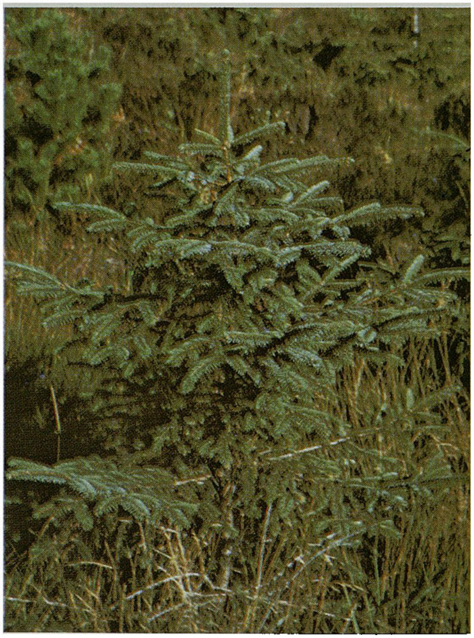

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NUTRIENT DEFICIENCIES OF CONIFERS IN BRITISH FORESTS
AN ILLUSTRATED GUIDE

by W. O. Binns, G. J. Mayhead, J. M. MacKenzie

Forestry Commission

INTRODUCTION

The use of fertilisers in British forestry has increased greatly in the last decade (Binns, 1975; Mayhead, 1976); in particular the area of forest top-dressed each year has increased and large-scale operations seem likely to continue. The correct timing of these operations is important, for investing money in fertilising before it is needed is wasteful, while waiting until nutrient deficiency is obvious means a loss of timber and revenue. The early recognition of deficiency symptoms should therefore assist in planning fertiliser programmes, whether top-dressings are part of a regime or are prescribed after chemical analysis of the foliage. This guide is intended to help foresters to recognise in the forest those nutrient deficiencies which have been found to be important in Britain. Fertilising itself is not discussed as this has been covered by Everard (1974).

Most of the information in the guide comes from research on stands of Sitka spruce *(Picea sitchensis* (Bong.) Carr.), Lodgepole pine *(Pinus contorta* Douglas ex Loud.) and Scots pine *(Pinus sylvestris* L.), with a top height of less than 5 m (mean height 3·5 m), and the nutrient concentrations quoted are for foliage from the uppermost whorl of branches in such trees, although the deficiency symptoms described hold good for forest stands of all ages. More limited studies of Norway spruce(*Picea abies* (L.) Karst.), Corsican pine (*Pinus nigra* var. *maritima* (Ait.) Melville). Douglas fir (*Pseudotsuga menziesii* (Franco) Mirb.), Western hemlock (*Tsuga heterophylla* (Raf.) Sarg.), Japanese larch (*Larix kaempferi* (Lambert) Carr.) and Hybrid larch (*Larix* x *eurolepis* Henry) have also been made, and ascertained deficiency symptoms are described.

Throughout the text it should be appreciated that the deficiency symptoms described are visible manifestations of nutrient imbalance. The addition of a fertiliser to correct an evident deficiency of one element may induce another imbalance which will then produce different deficiency symptoms.

THE ESSENTIAL NUTRIENTS

The major (or macro-nutrient) elements essential for plant growth are nitrogen, phosphorus, potassium, magnesium, calcium and sulphur. However, as no deficiency of calcium or sulphur severe enough to affect the growth of forest stands has yet been found in Britain, only the first four are discussed. Only one trace element, copper, is included as no deficiencies of the others severe enough to affect the appearance or growth of trees on acid soils in Britain have yet been found (there have been

PLATE 2. (Opposite). Sitka spruce four and six years old showing nutrient deficiencies. Nutrient concentrations as per cent oven dry weight.

TOP		*N*	*P*	*K*	BOTTOM		*N*	*P*	*K*
Left	N-deficient (6 yrs)	0·73	0·23	1·16	*Left*	K-deficient (4 yrs)	2·26	0·22	0·40
Right	P-deficient (6 yrs)	1·16	0·07	0·53	*Right*	Healthy (4 yrs)	2·28	0·27	1·25

The concept of 'balance' is illustrated by the K concentrations for the P- and K-deficient trees.

some instances of induced iron deficiency on chalk soils). A knowledge of the main functions of these nutrients is useful in helping to understand the effects produced by deficiencies; the sections on the roles of these nutrients which follow are based on the publications of Wallace (1951), Steward (1963), and Baule and Fricker (1970).

NITROGEN

Role Nitrogen is an essential constituent of all living plants. Nitrogen compounds make up a large part of protoplasm, the living substance of plant cells, and therefore control the production of tissue, including wood. The growth of tree roots is also strongly stimulated by higher concentrations of nitrogen in the soil. Some nitrogen compounds are mobile in plants and this enables the tree to draw on stored reserves, for example in the wood, and to transfer them to the needles when there is a shortage of available nitrogen in the soil.

Deficiency Symptoms Chlorophyll, the green colouring matter of plants, contains nitrogen so that a shortage of this element leads to a lightening of the usual dark green of all forest species. The leading shoot often becomes thin and spindly. In more severe cases the foliage can turn to yellow-green or even yellow. Needles are shorter and lighter in weight than normal; and discoloration is uniform over the whole length of the needle. Nitrogen-deficient trees usually show the symptoms over the whole live crown and not on certain specific areas as, for example, in potassium deficiency (see Plates 2 to 8).

Nitrogen deficiency can have a sudden and serious effect on young stands of Sitka spruce, particularly in the presence of vigorous heather (*Calluna vulgaris* L.) when height growth can be halved from one year to the next (see Plate 2). Other species such as Norway spruce, Douglas fir and Western hemlock can also be affected in this way. It appears that the normal mycorrhizal associations with tree roots are inhibited in some way by heather roots so that a slight nitrogen deficiency becomes severe (Handley, 1963). Heather competes less seriously with young pines, and any nitrogen deficiency normally disappears when the closing canopy shades out the ground vegetation. Reduced height growth is most obvious on the poorer peats and sandy heaths. On sand dunes, where the most extreme nitrogen deficiencies occur, pines may hold only one year's needles.

PHOSPHORUS

Role Phosphorus plays a key role in the energy-transferring processes of the cell and is involved in many biosynthetic reactions; therefore deficiency always results in restricted growth. Phosphorus is also of special importance in root development and in the ripening of seeds and fruits. Because phosphorus is much less mobile in the plant than nitrogen or potassium, it cannot be so easily withdrawn from older tissues to benefit the young emerging needles. Many phosphorus-deficient soils are dominated by heather and since, as explained above, vigorous heather is often associated with severe nitrogen deficiency, phosphorus and nitrogen deficiencies often occur together in forest stands.

Deficiency Symptoms The symptoms are similar for all species: poor height growth coupled with much reduced needle length and

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PLATE 3. (Opposite). Scots pine six years old showing nutrient deficiencies. Nutrient concentrations as per cent oven dry weight.

TOP		*N*	*P*	*K*	BOTTOM		*N*	*P*	*K*
Left	N-deficient	0·87	0·15	1·25	*Left*	K-deficient	1·25	0·16	0·40
Right	P-deficient	1·82	0·11	0·64	*Right*	Healthy	1·99	0·14	0·84

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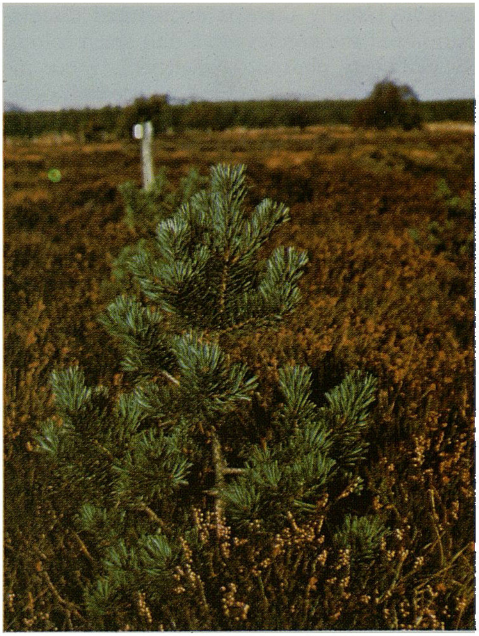

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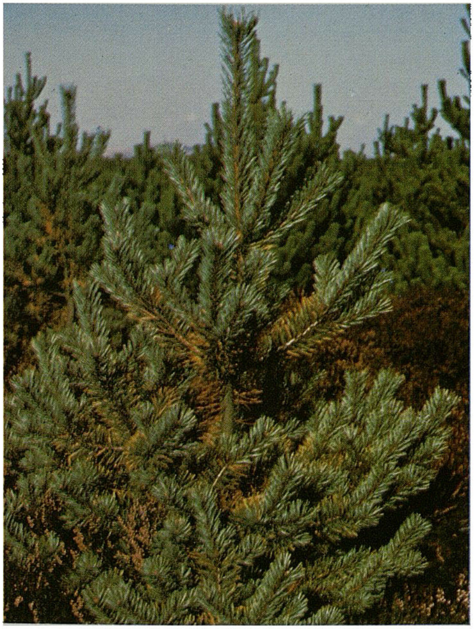

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weight. Usually there is no marked discoloration but the needles are a dull green colour. In extremely phosphorus-deficient spruce the needles often become closely adpressed to the stem giving rise to a scaly or lizard-like appearance. Form usually remains good in phosphorus-deficient trees, though in long standing instances Sitka spruce, Scots pine and Douglas fir may tend to lose their apical dominance. Extremely phosphorus-deficient larches look as if they are suffering from severe exposure. As deficiency increases, the tree holds fewer and fewer needles so that, in extreme cases, only the foliage of the current year remains. Unlike nitrogen deficiency, phosphorus deficiency develops gradually with a correspondingly slow decline in growth. On some organic soils, extreme phosphorus-deficiency in Sitka spruce is accompanied by nitrogen deficiency because the low supply of phosphorus and other elements limits nitrogen mineralisation. This leads to the yellowing described above, so that nitrogen deficiency alone might be suspected. In such cases both deficiencies can sometimes be cured by application of phosphorus fertiliser alone.

POTASSIUM

Role Potassium is not a constituent of the organic compounds involved in plant metabolism but is essential in the growth processes, being directly engaged in photosynthesis, the formation of carbohydrates, and the synthesis of proteins. It also plays an important part in regulating water conditions within the plant by increasing the osmotic pressure, helping absorption of water, and preventing wilting. Thus plants adequately supplied with potassium can better resist drying winds and frost. As potassium functions more as a regulator of growth than as a direct contributor, potassium deficiency often causes a change in growth habit. Potassium is very mobile within the plant and, because it is required in greater concentrations where growth is active, is withdrawn from the older needles and transferred to the younger ones.

Deficiency Symptons Although potassium is not a constituent of chlorophyll, a symptom of the deficiency is loss of needle colour. This is attributed to the inhibition of photosynthesis and to a consequent disappearance of the chlorophyll. This effect is greater at low temperatures, thus discoloration is more pronounced in winter. The form of young trees is usually affected and, in chronic deficiency, death of the apical bud on the leading shoot and on upper side branches, coupled with continued lateral growth, can result in a stunted or deformed bushy habit. Yellowing is not however always allied with reduced height growth, particularly in stands with a mean height over about 2m (see Plate 7).

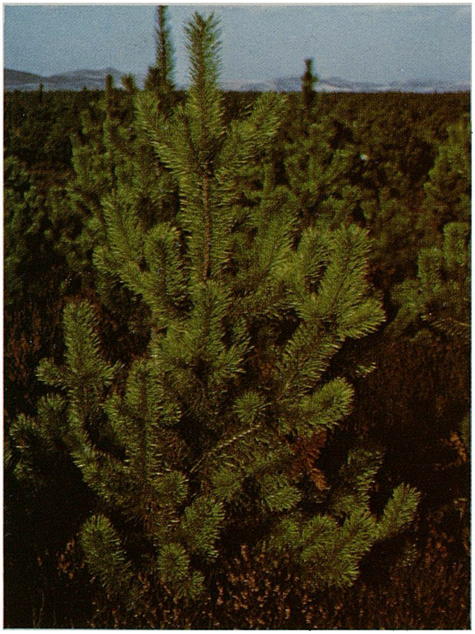
Spruces: The first symptom seen on the most infertile peats is poor development of the terminal bud, usually in the second or third year after planting. Discoloration to a pale straw-yellow develops, usually in the third or fourth year, but sometimes in the second year on current foliage if growth is vigorous.

On young plants the yellowing shows as two distinctive forms dependent on the severity of the deficiency and on the balance of nutrients within the plants:

a. In moderate deficiency, yellowing is confined to the needles at the tips of current shoots. Individual needles show a gradual chlorosis from the green base to the tip, which can become purple or even brown (see Plate 7). These symptoms on individual

PLATE 4. (Opposite). Inland Lodgepole pine four and six years old showing nutrient deficiencies. Nutrient concentrations as per cent oven dry weight.

TOP		*N*	*P*	*K*	BOTTOM		*N*	*P*	*K*
Left	N-deficient (6 yrs)	0·88	0·16	0·55	*Left*	K-deficient (4 yrs)	1·51	0·14	0·27
Right	P-deficient (6 yrs)	1·34	0·06	0·37	*Right*	Healthy (6 yrs)	1·92	0·18	0·60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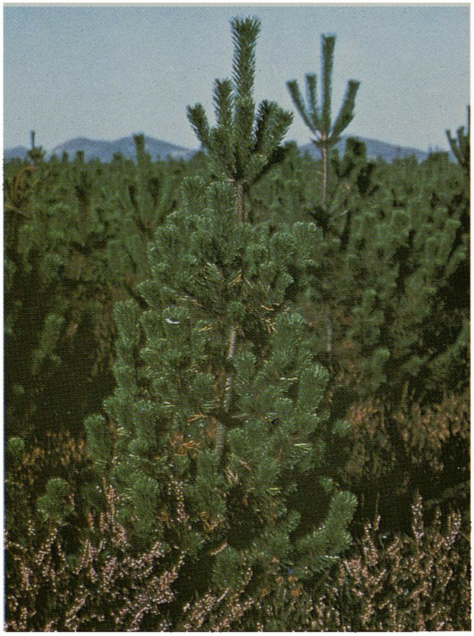
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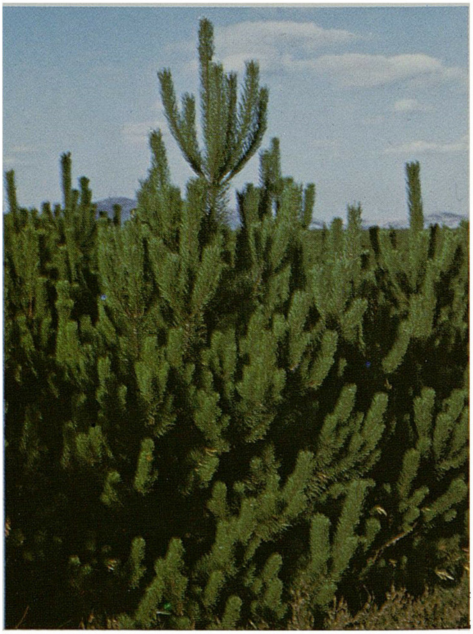
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needles can be quite pronounced towards the end of the growing season.

b. In more severe deficiency, all the needles on the current shoot are affected, showing the same gradually increasing chlorosis from base to tip on each needle. This together with a paler yellow colour distinguishes it from nitrogen deficiency (see Plate 7). This discoloration, due to the disappearance of the chlorophyll, is often more pronounced in winter. Where yellowing in the upper foliage of 2-3 year old Sitka spruce is very obvious, lower branches covered and sheltered by ground vegetation may remain a normal healthy blue-green colour.

On larger trees the yellowing does not normally show on current foliage, but is confined to the older needles and often to the lower branches, in marked contrast to nitrogen deficiency. Furthermore, as the chlorosis tends to be more obvious on the upper surface of needles and there is normally no reduction in needle size, potassium deficiency may be less easy to detect from the ground in pole-stage stands except by examining the lower foliage on ride-side trees.

Potassium deficiency becomes more obvious when growth is vigorous, for example when increased by plentiful supplies of nitrogen and phosphorus; in these instances there is no reduction in needle size or shoot extension. This nutrient imbalance commonly causes distorted growth which, combined with the lack of apical bud development, can produce very poor stem form. In some extreme cases lateral growth continues with no terminal growth, forming a rosette pattern. Form appears to be influenced by the genetic makeup of the plant and in the early years a general site deficiency of potassium may exaggerate this feature and lead to much tree-to-tree variation in stem form. Severe distortion of stem form is rarely seen in Norway spruce, but exact comparison is difficult because this species is not often planted today on sites where severe potassium deficiency is likely.

Potassium deficiency can be ephemeral, particularly in young trees, and symptoms can disappear as the supply of other nutrients decreases (e.g. phosphorus from fertiliser or nitrogen from the flush following ploughing); in other words a temporary induced deficiency rights itself. On some site types the concentration of potassium in the needles increases with the age of the tree, which makes it difficult to prescribe treatment with confidence.

Pines: The needle symptoms are similar to those on spruce: chlorosis increasing gradually from base to tip. More commonly the yellowing appears confined to the terminal half of the needle, in extreme cases with reddish brown or dark brown tips (see Plate 8).

In coastal origins of Lodgepole pine the yellowing usually occurs only on the needles of the previous year (Plate 5), but in severe cases, particularly in young trees (less than 6 years old), current foliage also shows yellow tips. With inland origins and with Scots pine, yellowing occurs on both current and second-year needles (Plate 4); in extreme cases young inland Lodgepole pine can appear a bright canary-yellow all over. Closer examination of the needles will reveal the gradual chlorosis and the reddish brown tips, which, together with the normal needle size, should distinguish the symptoms from those of nitrogen deficiency (Plate 8). It must however be appreciated that the inland origins of Lodgepole pine are naturally a lighter green than the coastal origins; on any one site inland origins usually show deficiencies earlier than the coastal varieties.

Stem form in pines can be affected by potassium deficiency, especially in Scots pine,

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PLATE 5. (Opposite). South coastal Lodgepole pine six years old showing nutrient deficiencies. Nutrient concentrations as per oven dry weight.

TOP		*N*	*P*	*K*	BOTTOM		*N*	*P*	*K*
Left	N-deficient	0·66	0·13	0·85	*Left*	K-deficient	1·59	0·19	0·35
Right	P-deficient	1·14	0·06	0·71	*Right*	Healthy	1·61	0·20	0·90

but in Lodgepole pine the concentration usually has to be very low, or there has to be an extreme nutrient imbalance resulting from high nitrogen availability, before form is seriously affected.

MAGNESIUM

Role Magnesium is essential to the formation of chlorophyll and this is its most important function. Thus yellowing is a common symptom in magnesium-deficient trees. Like potassium, it is apparently transferred from older to younger tissues where it can be used again in the growth processes. Magnesium also plays a part in the formation of various organic compounds, in cell division, and also in the phosphorus economy of plants.

Deficiency Symptoms Magnesium deficiency is rare in forests and has only been identified on soils in southern Britain well supplied with nitrogen, phosphorus and potassium, but with a poor physical structure (it is however quite common in forest nurseries (Benzian, 1965)). Because magnesium deficiency is not usually due to a lack of the element in the soil, it is difficult to cure with magnesium fertilisers. However as the trees grow and dry the soil, the structure usually improves and the deficiency then disappears. This phenomenon occurs widely in agriculture (e.g. Harrod and Caldwell, 1965), but why magnesium should be the first element to become deficient following water-logging and root death is not clear.

In spruces, Douglas fir and Silver firs (*Abies* species), magnesium deficiency shows up in late autumn as a yellowing of the needles of the current year at the base of the shoot. Individual needles yellow from the tip and the yellowing gradually spreads up the shoot towards the bud. In pines, the needles yellow from the tip but the progression up the shoot is less well marked; all the needles of the current year tend to yellow together with only a few greener needles clustered around the bud. The colour is a bright golden yellow. If there is doubt about the cause of yellowing, analysis of the foliage will distinguish magnesium deficiency from nitrogen or potassium deficiency. Deficiency symptoms are shown in Plate 9.

COPPER

Role Copper is a component of a number of different plant enzymes involved in essential processes in the plant. If copper is deficient, then many metabolic reactions are stopped or interrupted and irregularities in growth occur, often shown as dieback of shoots and the production of weak multiple buds.

Deficiency Symptoms In northern Europe copper deficiency in the forest was first noticed in Holland on Douglas fir (Oldenkamp & Smilde, 1966), though it had been identified earlier in a forest nursery (Benzian & Warren, 1956). It has subsequently been seen in a number of species in Britain on second rotation sites, where cultivation in the presence of added phosphorus fertiliser has produced rapid mineralisation of nitrogen with resultant very fast growth. It appears that copper uptake lags behind demand, especially in very hot weather. The effect on colour or needle size is only slight. Branches tend to droop and the leader may take a sinuous form or even point vertically downward. Sitka spruce seems to

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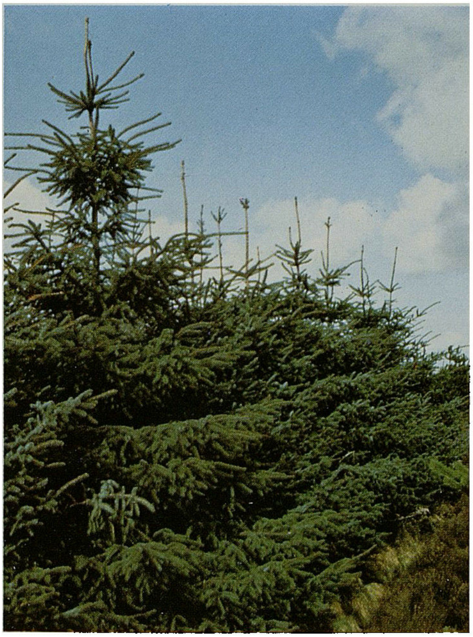
PLATE 6. (Opposite). Nitrogen deficiency in spruces. Nutrient concentrations as per oven dry weight. The concept of 'balance' is illustrated by the nutrient concentrations in the two Sitka spruce samples.

TOP		*N*	*P*	*K*
Left	Healthy Sitka spruce	1·87	0·30	1·40
Right	N-stressed Sitka spruce	1·27	0·49	1·64

BOTTOM		*N*	*P*	*K*
Left	Healthy Norway spruce	1·56	0·25	1·18
Right	N-deficient Norway spruce	0·72	0·25	0·94



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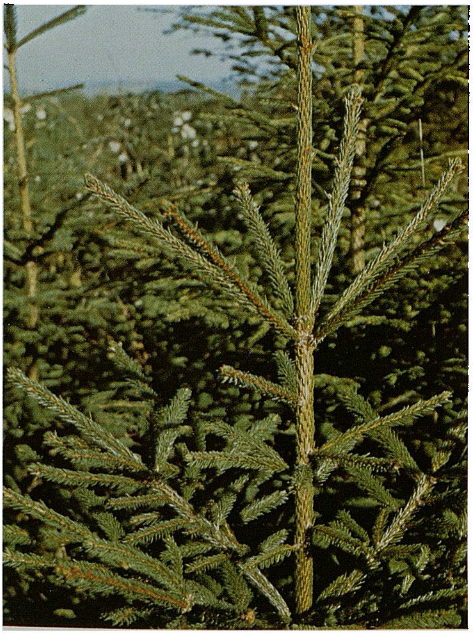

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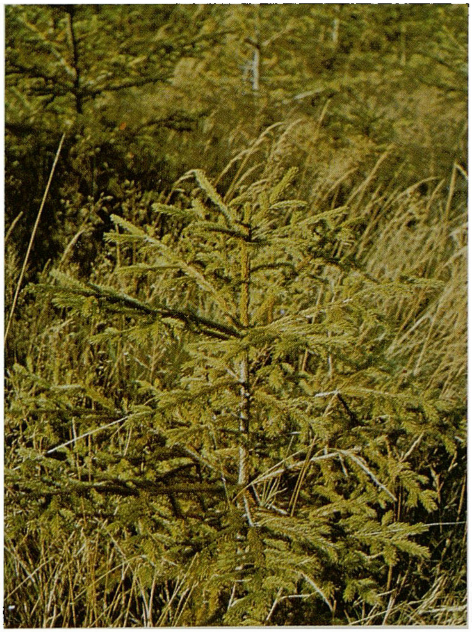

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recover reasonably well and unaided from even the more extreme deficiencies as the flush of nitrogen dies away and growth rates slow down, in contrast to Douglas fir which shows the evidence of deficiency for a long time. Pines exhibit only a slight sinuosity of the leader, but Western hemlock produces very bushy plants with multiple leaders. Treatment with copper sulphate (at about 17 kg Cu/ha) has proved effective in Holland, particularly in preventing deficiency, but this is very expensive; copper deficiency is therefore probably best prevented by withholding phosphorus fertiliser for several years on any heathland site on which it has been found to be serious, so that the limiting factor is phosphorus. Phosphorus fertiliser can then be applied by top-dressing at a later stage when the flush of nitrogen has died away and the danger of copper deficiency has passed. Symptoms are shown in Plate 10.

MULTIPLE DEFICIENCIES

Deficiencies of more than one element can be as common in the forest as single deficiencies, and often the symptoms of one deficiency such as nitrogen may mask the symptoms of another such as potassium. Three common multiple deficiencies are:

a. NP deficiencies in young spruce on ironpan or peaty gley soils where heather is dominant.
b. PK deficiencies in young pine on poorer hill peat and raised bog soil-types
c. NPK deficiencies in young spruce on hill peat and raised bog soil-types where heather is dominant, especially on soils derived from parent material of the Moine rocks (Precambrian era).

INDUCED DEFICIENCIES

An abundance of one or two elements after planting can promote rapid early growth and this may induce a shortage of another element. In southern Britain potassium and copper deficiency can both be induced by the rapid mineralisation of nitrogen from organic matter in cultivated soils in the presence of added phosphorus fertiliser. Nutrient deficiencies can also be induced by poor physical soil conditions, such as induration, bad drainage or poor aeration, and if these constitute the primary limiting factor then any chemical treatment will be largely ineffective or, at best, short-lived. The induced deficiency symptoms normally disappear if the true limiting factor is removed. Nitrogen deficiency is the most common of those induced in this way.

FOLIAR NUTRIENT LEVELS

Table 1 lists the nutrient concentrations in the foliage below which deficiency symptoms occur and above which they are never seen. Values in between are described as marginal. These boundaries cannot be defined precisely, and deficiency symptoms are occasionally seen in stands with nutrient concentrations in the marginal range. If a nutrient deficiency is limiting growth, then a response to fertiliser is certain for stands with deficient concentrations and possible for those with marginal concentrations. Although profitable growth increases have occasionally followed the addition of phosphorus fertiliser to stands with apparently optimum phosphorus concentrations in the foliage, the likelihood of economic responses in trees with optimum nitrogen and potassium concentrations is low.

PLATE 7. (Opposite). Potassium and nitrogen deficiencies in Sitka spruce.

TOP

Left K-deficiency in 15 year old trees showing normal height growth.

Right Needle-tip symptoms of K-deficiency.

BOTTOM

Left K-deficient shoots

Right N-deficient shoots

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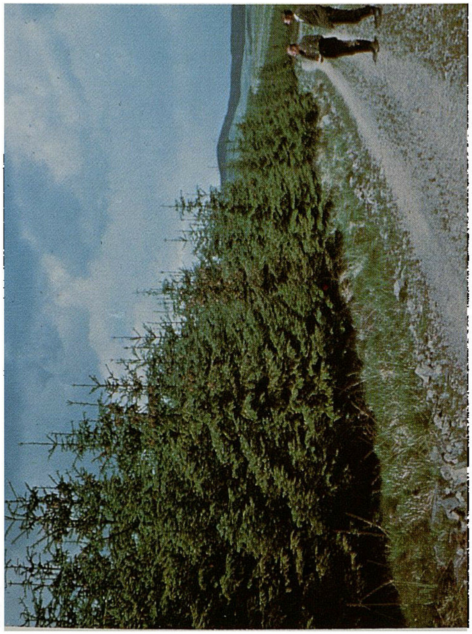

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Table 1

Deficient and Optimum Foliar Nutrient Concentrations for Stands of 0·3-3·5 m Mean Height, as per cent Oven-dry Weight

Species	*Mean needle weight associated with poor growth, mg*	*Nitrogen*		*Phosphorus*		*Potassium*		*Magnesium*	
		Def	*Opt*	*Def*	*Opt*	*Def*	*Opt*	*Def*	*Opt*
Sitka spruce Norway spruce	(<3·5) (<1·5)	<1·2	>1·5	<0·14	>0·18	<0·5	>0·7	(<0·03	>0·07)
Lodgepole pine Scots pine	<10·0	<1·1	>1·4	<0·12	>0·14	<0·3	>0·5	(<0·03	>0·05)
Corsican pine	<20·0	<1·2	>1·5	<0·12	>0·16	(<0·3	>0·5)	(<0·03	>0·05)
Douglas fir	(<2·0	(<1·2	>1·5)	(<0·18	>0·22)	(<0·6	>0·8)	(<0·04	>0·06)
Western hemlock	(<1·2)*	(<1·2	>1·5)	(<0·25	>0·30)	(<0·6	>0·8)	-	-
Japanese larch Hybrid larch	(<3·0)	(<1·8	>2·5)	(<0·18	>0·25)	(<0·5	>0·8)	-	-

*Notes: Values in brackets are tentative. *This species has a very variable needle size.*

The values presented apply to foliage collected from the uppermost whorl of branches from trees less than about 5m top height (mean height 3·5m), and it appears they may provide only a rough guide to the nutritional state of older stands. There may also be different thresholds for different seed origins within a species range, particularly in Lodgepole pine. However, more information is required before differentiating between seed origins.

Trees are usually sampled during October, and needles from one shoot from each of five to ten trees constitute a sample. Everard (1973) describes the sampling procedure in greater detail. The concentration in individual trees can vary between years by up to 15 per cent due to differences in sunshine, temperature and rainfall. In particular, heavy rainfall can leach potassium from needles and the concentration may be reduced by about 10 per cent, so that weather just prior to sampling can over-ride or modify seasonal effects.

Critical concentrations for copper are still uncertain, particularly for Sitka spruce. Analyses of samples taken in autumn from untreated stands in Britain have not shown consistent differences between trees with symptoms of copper deficiency and those without. Analyses from experiments however have been more rewarding (see Table 2) and it may also

PLATE 8. (Opposite). Potassium and nitrogen deficiency in pines.

TOP

Left N-deficient Lodgepole pine.

Right N-deficient Scots pine.

BOTTOM

Left K-deficient Lodgepole pine.

Right K-deficient Scots pine.


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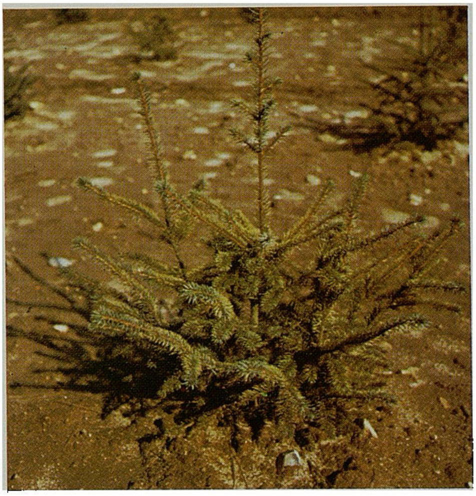

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PLATE 9. Magnesium deficiency symptoms. Nutrient concentrations as per cent oven dry weight.

		N	P	K	Mg
Left	Sitka spruce	1·74	0·30	1·03	0·019
Right	Corsican pine	1·37	0·13	0·65	0·019

be that trees must be sampled when they are under stress for copper, i.e. when the shoots are elongating at their maximum rate.

Table 2

Copper concentrations in October-sampled foliage of young Douglas fir and Sitka spruce with N or Cu fertiliser, as ppm dry matter. Trees with N alone showed symptoms of copper deficiency.

	N	Cu
Douglas fir	1·1	1·5
Sitka spruce	1·5	2·4

RECOGNITION IN THE FOREST

The best time of year to observe deficiency symptoms is during the autumn and early winter when height growth is complete, foliar nutrient concentrations and colours have stabilized, and cold winds have not scorched the needles. Useful observations can however be made at any time of year, and in spruces potassium deficiency is particularly noticeable in early summer when the new shoots are fully extended. The normal autumnal yellowing of the old needles of pines prior to these being shed should not be confused with nutrient deficiency symptoms, although early shedding

PLATE 10. (Opposite). Copper deficiency symptoms in Sitka spruce.

TOP

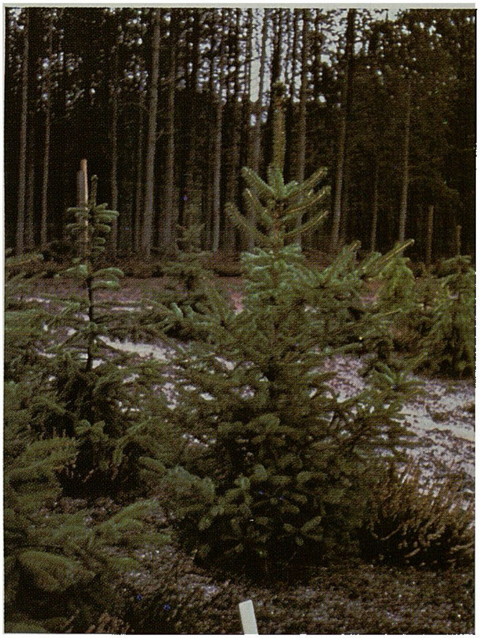
Left Healthy (PKCu added)

Right Mild deficiency (NPK added)

BOTTOM

Left Extreme deficiency (annual NPK)

Right Leader deformation in fast grown tree (P added)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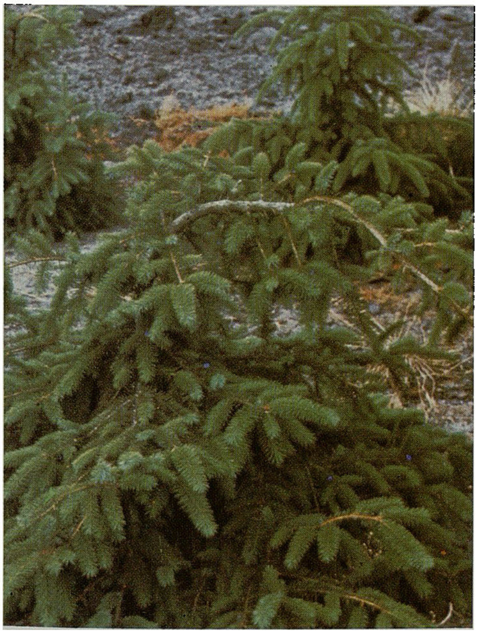
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Table 3

Likelihood of Nutrient Deficiency by Site Types and Early Growth Stages

		Nitrogen			*Phosphorus*			*Potassium*		
Site Type	*Growth Stage*	*probable*	*possible*	*unlikely*	*probable*	*possible*	*unlikely*	*probable*	*possible*	*unlikely*
Brown earth	Establishment		S	P		S	P			SP
	Thicket			SP		S	P			SP
Podsol and ironpan soil	Establishment	S	P			SP			S	P
	Thicket		SP			SP				SP
Surface water gley and flushed peats	Establishment			SP		SP			S	P
	Thicket			SP		S	P			SP
Peaty gley	Establishment		SP		S	P			SP	
	Thicket	S	P		S	P			SP	
Molinia peat	Establishment			SP	SP				SP	
	Thicket		S	P	S	P		S	P	
Unflushed peat	Establishment	S	P		SP			SP		
	Thicket	S		P	SP			SP		

Note: S = Anticipated deficiency in spruce   P = Anticipated deficiency in pine of needles can be a symptom of nutrient disorder.

STAND MANAGEMENT AND SITE TYPES

The forest manager's ideal stands develop at a steady rate throughout their life, without either checks or spurts of rapid growth. Not only is this important for productivity, as mentioned in the introduction, but wood grown at a steady rate may be more valuable than wood with annual rings of widely varying width. It follows that remedial treatments should, as far as possible, be timed so as to maintain steady growth. Unfortunately a stand that shows deficiency symptoms will not have been growing at its optimum rate for two or three years previously nor is it usual for the rate to recover in the year following fertilising; and though decreasing height growth can be a useful sign (for growth may decline before deficiency symptoms are obvious), by the time this is seen some production will already have been lost.

Thus although foliar analysis and visual symptoms can be used to identify nutrient deficiencies, it is still difficult to achieve the most efficient use of fertilisers. Here local experience and a knowledge of species performance by site types are valuable, for the manager can be on the look-out for deficiencies before growth is seriously affected. Table 3 indicates the likely occurrence of individual deficiencies on different site types, which should help in anticipating the need for fertilisers.

CONCLUSIONS

Combined with foliar analysis and site-type appreciation, deficiency symptoms form a practical basis for prescribing fertiliser treatment. However, until local experience is gained, they should not be used on their own for making decisions on top-dressing. It should also be remembered that fertiliser treatment may not cure a nutrient deficiency; and even if it does, it may not pay.

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SUMMARY

Symptoms of nitrogen, phosphorus and potassium deficiency in forest stands up to 5m tall are described and illustrated for Sitka spruce, Scots pine and Lodgepole pine. Less complete coverage is given for Norway spruce, Corsican pine, Douglas fir, Western hemlock and larches, as well as for the rare deficiencies of magnesium and copper. Concentrations of nutrients in the foliage associated with deficiency are given for the different species, and the site types where deficiencies in spruce and pine are most likely are tabulated.

Deficiency symptoms, used in conjunction with foliar analysis and site-types, form a practical basis for prescribing fertiliser treatments; they should not, however, be used on their own without considerable local experience.

RESUME

Ce guide décrit et illustre les symptômes de carences en azote, phosphore et potassium, dans des peuplements jusqu'à 5m de haut, pour le Sitka, le Pin sylvestre et le Contorta. Il est moins détaillé pour l'Epicéa commun, le Laricio de Corse, le Douglas, *Tsuga heterophylla* et les Mélèzes, de même que pour les carences plus rares en magnésium et en cuivre. Les teneurs foliaires associées aux carences sont indiquées pour les différentes essences. Un tableau donne les types de stations où des carences sont le plus probables chez Epicéa et Pin.

Les symptômes de carences, en relation avec les analyses foliaires et les types de stations, constituent une base pratique pour prescrire des applications d'engrais. Cette base est toutefois insuffisante à elle seule et doit être renforcée par une sérieuse expérience locale.

ZUSAMMENFASSUNG

In der vorliegenden Arbeit werden Stickstoff-, Phosphat- und Kalimangelerscheinungen in bis zu 5m hohen Sitkafichten- und Kiefernbeständen (Scots pine und Lodgepole pine) beschrieben und in Abbildungen gezeigt. Die entsprechenden Angaben für Fichte (Norway spruce), Korsische Kiefer, Douglasie, Tsuga (Western hemlock) und Lärche sind nicht so erschöpfend dargestellt. Gleiches gilt für die seltener vorkommenden Magnesium-und Kupfermangelsymptome.

Die in Korrelation mit dem jeweiligen Mangel in Verbindung stehenden Nährstoffkonzentrationen in den Nadeln werden für die verschiedenen Baumarten ebenso angegeben wie die Standorttypen, wo die Mängel bei Fichte und Kiefer am wahrscheinlichsten sind.

Mangelsymptome in Verbindung mit Nadelanalysen und der Beurteilung der Standorttypen sind eine praktische Grundlage für vorzunehmende Düngemitteleinsätze. Dessenungeachtet sollten diese aber nicht ohne Kenntnis der örtlichen Gegebenheiten und Erfahrungen erfolgen.

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