Nutritional Disorders in Sitka Spruce in the Republic of Ireland

M. L. CAREY[1]

THE main nutritional problems that are encountered in growing Sitka spruce (*Picea sitchensis* Bong. Carr.) are associated with the three major nutrients, nitrogen, phosphorus and potassium. In general the species can be successfully established on a range of site types, from the oligotrophic peats of the West (blanket bogs) and Midlands (raised bogs) to the podsolised soils derived from Old Red Sandstone in the south of the country, providing phosphorous is applied at planting. The present recommendation (O Carroll, 1975), is to broadcast 500 kg/ha of rock phosphate, supplying 72.5 kg of P/ha, on land which, prior to afforestation, was unenclosed and was never used for intensive agriculture. On land which had been used in the past for agricultural cropping, but which had deteriorated somewhat in fertility due to being abandoned for a number of decades or to some other cause, the recommended rate of application is reduced to 250 kg of rock phosphate per hectare (36 kg P/ha). Such sites frequently carry a vegetation dominated by *Ulex* or *Pteridium.* On areas where agricultural cropping has been abandoned only in recent years, phosphate application is not considered necessary. A further series of experiments has recently been established across a wide range of sites in order to refine these prescriptions.

Although good growth of Sitka spruce can persist even on the more impoverished sites, such as the oligotrophic peats and the Old Red Sandstone podsols, it often falls off markedly, ultimately reaching a checked condition after 6-7 years. In most situations the reason for this decleration in growth can be attributed to the low level of available nitrogen in the soil resulting from such factors as high acidity, low biological activity or, in the case of the mineral soils, an almost complete lack of organic matter. The problem appears to be accentuated in some situations by the presence of *Calluna vulgaris* which may decrease the availability of whatever nitrogen is present (Handley 1954). Although in some instances a second application of phosphate has had the effect of reviving such crops and taking them out of the checked condition, this treatment was effective only in situations where the original quantity of phosphate applied was less than the present recommended rates.

1. Research Branch, Forest and Wildlife Service, Dublin.

The problems of nitrogen nutrition of Sitka spruce on oligotrophic peat are in many respects similar to those in Northern Ireland but perhaps not quite as acute. The lower elevation of the western bogs and the higher input of cations in precipitation, relative to more inland areas in Northern Ireland, ultimately results in a tendency towards less acidity and a greater "flushing effect" in the peat, reflected perhaps in the widespread occurrence of *Schoenus nigricans*. This species is normally associated with fen conditions. Whatever the reasons, in practice the forester may succeed more often in growing Sitka spruce satisfactorily relative to his counterpart in more northern, and climatically colder areas.

Before leaving the problems of nitrogen nutrition on oligotrophic peat, it is worthwhile to refer briefly to a plantation of Sitka spruce established in 1970 on what was formerly a raised bog near Ballinasloe in east County Galway. This bog, which varies in depth from 2-5 metres was drained, fertilised, rotovated and sown with a grass clover sward by the Irish Sugar Company in the late nineteen fifties (see *Irish Forestry* 19 (2) 1962, p. 175). During the 1960s grass was harvested from the area and it was also used for sheep grazing. In 1970 the bog was abandoned for agricultural usage, acquired by the Forest and Wildlife Service and planted with Sitka spruce, following double mouldboard Cuthbertson ploughing. Although the crop suffered severe damage from autumn frost in September 1973 it has recovered remarkably and now has a top height of 3.7 metres and a projected yield class of $24m^3$/ha/annum. Although one can be criticised for estimating production after 7 growing seasons, a smaller strip of the same bog which was planted with Sitka spruce in 1962 has a similar yield class now after 14 years. The performance of this plantation to date, and its present healthy condition, (N concentration of 1976 needles, 2.3% D.M.), clearly illustrates that the problem of nitrogen deficiency on oligotrophic peat can be solved and that high production rates are attainable. Although the inputs necessary to achieve these may appear prohibitive they must be weighed against the fact that the projected yield is 4-$8m^3$/ha/annum above that obtainable for Lodgepole pine (*Pinus contorta* Dougl.) on oligotrophic peat.

After oligotrophic peat the biggest nutritional problem affecting the growth of Sitka spruce arises on soils derived from Old Red Sandstone. This formation dominates the geology of the south an south west of the country and soils derived from it account for about 25% (75,000 ha), of the present forest area. In general, soils derived from Old Red Sandstone that are acquired for afforestation, are very impoverished. They are strongly podsolised and compacted, very acid in reaction (pH 3.5-4.0), and extremely low in available nitrogen and phosphorus. Due to the low levels of organic matter, the result very often of scrawing activities by man over the years for fuel, the total reserves of nitrogen are also generally extremely low.

In practice the problem of compaction is dealt with by tine ploughing or ripping to a depth of 60-90 cm. This has the effect of shattering the indurated layer and the iron pan, where present and generally loosens up the soil profile, thereby improving aeration and drainage. Phosphorus deficiency is remedied by broadcasting ground rock phosphate at a rate of 500 kg/ha. These operations, that is cultivation and the addition of phosphate, ensure the successful establishment of the crop but within a short number of years growth falls off, as on the oligotrophic peats, due to a lack of available nitrogen. Although it would appear to be a relatively easy solution to apply fertiliser nitrogen and restore tree growth to a satisfactory level, the cost of such an operation is high and, because of the porous sandy nature of the soils, the response would very likely be even more short term than on oligotrophic peat. In practice it has been found that the addition of fertiliser nitrogen in the year of establishment may result in high plant mortality.

The alternative to applying fertiliser nitrogen on these soils and for that matter on oligotrophic peat, is to grow leguminous plants, such as clover and broom, in association with the trees in order to improve soil nitrogen status. This nitrogen may then be passed on to and utilized by the trees. An experiment, which was designed to test this hypothesis, was laid down by O'Carroll (1972) at Cappoquin forest on a peaty podsolised gley soil derived from Old Red Sandstone in 1961. The treatments, which are given in detail by Dillon *et al.* (1977) included different combinations of liming, complete ploughing, basic slag and potash magnesia. The legume species tested included a mixture of broom (*Cytisus scoparius*), and the tree lupin (*Lupinus arboreus*). Although the lupins grew well in the early years and bore large root nodules, they were all dead by 1966 and their place was taken by the broom which continued to grow vigorously. By 1970 the trees in the experiment, which had shown promising results in the early years, had reached a checked condition irrespective of treatment. In 1971 the whole area was treated with 625 kg/ha of rock phosphate and 250 kg/ha of sulphate of potash. This had the effect of increasing tree leader growth very significantly in the legume plots only (Table 1). Because of the fact that Sitka spruce does not respond to potassium application on Old Red Sandstone derived soils, it is assumed that the response in growth was due to the phosphate application. Furthermore, the reason why the growth response was obtained in the legume plots only is because of the fact that the other factor limiting growth on this site, nitrogen, was in adequate supply in these plots. The trees in the plots without legumes did not respond to phosphate application because they

Table 1: The effect of legumes on the growth of P/61 Sitka spruce. Cappoquin Forest.

	Leader Growth (cm)	
	1973	1974
No legumes	20	27
Legumes	41	69
L.S.D. (5%)	5	

were still limited by nitrogen deficiency. The overall conclusion to this experiment so far is, therefore, that Sitka spruce can be grown satisfactorily on Old Red Sandstone soils, providing adequate phosphorus is applied and a continual supply of nitrogen is available.

The common furze or whin, *Ulex gallii,* a naturally occurring species, also has the capacity to fix atmospheric nitrogen. Invariably where phosphorus has been applied and *Ulex* is present on Old Red Sandstone soils, the growth of Sitka spruce is vigorous. This is presumably due to the increased nitrogen supply resulting from the presence of the Ulex. It is not known yet to what extent the species can, in fact, fix atmospheric nitrogen or indeed if it is achieving its maximum potential in this respect on these soils. If the experience of the agriculturalist with clover is anything to go by then a lot remains to be learned. At the experimental level *Ulex*, broom and white clover are now being tested further as sources of nitrogen for not only Sitka spruce, but also the even more demanding species, Douglas-fir (*Pseudotsuga menziesii*), on these soils.

Finally, before leaving the problem of nitrogen nutrition on Old Red Sandstone soils, reference must be made to the possibility of using nurse tree species such as alder (*Alnus*), birch (*Betula*), larch (*Larix*) or pine (*Pinus*) in order to improve the environment for Sitka spruce. Although *Alnus incana* has been tested experimentally, and is known to have nitrogen fixing properties, it has so far failed to improve the growth of the spruce and if anything tends to decrease it due to its own vigorous nature. It is intended to test another species of alder, *A. crispa,* for its potential in this regard. This is a pioneer species in Alaska where it is usually succeeded by Sitka spruce naturally. The only other species which has been tested and has actually produced positive effects on the growth of Sitka spruce is Japanese larch (*Larix leptolepis*), although it is not known to fix nitrogen (O'Carroll, N., Forest and Wildlife Service, Bray, Co. Wicklow, personal communication). Although the Sitka spruce/ Japanese larch mixture is not put forward as a solution to the nitrogen problem on Old Red Sandstone forest soils it does provide the forest manager with an alternative to Lodgepole pine in these situations.

The other areas that have presented nutritional problems in the early stages of the rotation for Sitka spruce are the eutrophic or fen-type peats, which are mainly confined to Midland areas. Here the main soil factor limiting growth is potassium and neither nitrogen nor phosphorus application are necessary. In fact it has been found on a number of these sites that phosphorus application decreases growth significantly (Table 2), for reasons which are so far unclear. Induced zinc deficiency has been suggested as a possibility. The eutrophic peats, which have a pH in the region of 4.5-5.0, are extremely low in available potassium. Their susceptibility to drying out during the growing season, occurrence in areas with a low content of potassium in the rainfall (O'Carroll and McCarthy, 1973), and relatively high calcium levels, probably accentuate the problem. Excellent responses in growth are obtained when potassium is applied, the recommended rate of application being 250 kg/ha of muriate of potash supplying 125 kg of potassium (O'Carroll, 1975).

Table 2: The effect of Sulphate of Potash (K) and Ground Rock Phosphate (P) on the leader growth (cm) of Sitka spruce, in the fourth growing season on eutrophic (fen) peat.

	0 kg P/ha	87 kg P/ha
0 kg K/ha	14	14
100 kg K/ha	24	22
200 kg K/ha	27	35
300 kg K/ha	34	28
S.E. 2.9.		

There are few nutritional problems associated with the establishment and early growth of Sitka spruce on the other major forest soils, where the levels of available nutrients appear adequate for tree growth. On the gley soils in the north west (Cavan/Leitrim) there are some indications, after three years growth, that Sitka spruce may respond to both phosphorus and potassium application. However, the effects are small and may be short term. Dillon (1968) found that a high yielding 15 year-old crop of Sitka spruce growing on a heavy gley soil did not respond to either nitrogen, phosphorus or potassium application.

The possibility of increasing production through fertiliser application in semi-mature or polestage forest crops can be a highly attractive economic proposition because the return from the money invested comes much sooner compared with an investment made at the establishment stage. Because of the fact that a large area of the

Sitka spruce present in the country was established over the period 1930-1950, before the use of fertilisers as establishment became standard practice, it was thought in the early nineteen seventies that such crops might show a large response to fertiliser application. This was despite the fact that the land acquired in those years was probably of a somewhat higher quality than that acquired more recently. The problem was to find out what areas would respond best to fertiliser application and, secondly, what nutrient and quantity of that nutrient was best applied. No relevant soil maps were available to serve as a basis for laying down the experiments representatively. Accordingly O'Carroll (Forest and Wildlife Service, Bray, Co. Wicklow, personal communication) decided to establish a series of 26 experiments at random across the yield class range of the species for all stands greater than 4 ha in extent planted between 1925 and 1940. Although the processing of the results from this series of experiments is incomplete, there are some very encouraging and somewhat unusual trends in the data so far.

The reason why fertiliser application increases growth in certain polestage crops, and not in others, raises a number of important questions. First of all, are those crops that are responding positively doing so because of the fact that their basic soil nutrient reserves are exhausted, or, is it because large quantities of nutrients previously taken up, are being immobilised within the forest floor in the litter layers? Measurements in typical Sitka spruce polestage crops have shown that the litter layers may contain up to 1000 kg of nitrogen, 50 kg of phosphorus and 150 kg of potassium (Carey, 1977). The litterfall in comparable crops arverages about 4500 kg DM/ha/annum and contains approximately 68 kg of nitrogen, 6 kg of phosphorus and 14 kg of potassium. The interesting feature with regard to these figures for litterfall, when considered in conjunction with the input from precipitation, is that they coincide reasonably well with the estimated annual uptake of N, P and K in a 33 year polestage crop of Sitka spruce at Glenmalure forest in Co. Wicklow (Carey, 1977). Do these data suggest therefore, that if the reserve of nutrients in the soil is adequate in the early stages of the rotation, Sitka spruce will ultimately satisfy its own nutritional requirements through recycling? The answer to this question depends on the rate with which the litter in the forest floor decomposes and releases its nutrients. In the relatively mild climatic conditions which we experience in Ireland this is probably influenced by stand density as much as by any other factors. Work carried out by Wright (1957) on Norway spruce in Britain is interesting in this regard. He showed that the heavier the grade of thinning the greater was the decomposition of the litter on the forest floor.

Because of the steep rise in fertiliser prices and the limited nature of soil nutrient resources, it is essential that a better understanding be achieved of the nutrient cycle in man-made forest crops and of the degree to which it can be influenced by various silvicultural operations. If Wright's figures are anything to go by, then clearly there is considerable scope for manipulating the accumulation of litter and its rate of decomposition by thinning operations alone. This has also been found by Miller *et al* (1975) working with Douglas fir in America. However, the hypothesis needs testing under tightly controlled circumstances for Sitka spruce growing under Irish conditions and the best management system for these crops must also take into account other factors such as harvesting policy and the price of the end product in addition to the cost of fertiliser materials themselves.

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Discussion following the papers of D. A. Dickson and M. L. Carey

CHAIRMAN: **N. O'Carroll**

Mr. Kilbride asked Dr. Dickson how long a dressing of 7.5 tonnes/ha of lime would influence the pH of the peat. **Dr. Dickson** said that the effects of lime were very marked 13 years after application; he considered that one or perhaps two applications over a rotation would be enough.

Mr. Duane thought that the method of deep ploughing recommended by Dr. Dickson could lead to considerable problems of access in later years. **Dr. Dickson** agreed with this, but said that if nitrogen were to become available to the trees deep ploughing is necessary. **Mr. Carey** added that evidence from Glenamoy indicated that where tunnel ploughing had been carried out, tree rooting was much deeper than with conventional methods, the trees remained healthy and access was not a real problem.

Mr. Brosnan wondered why Dr. Dickson had not recommended heather control as a method for stimulating Sitka spruce growth on peat. In reply, it was stated that killing heather, like applying urea, can improve growth but the main nutritional problems arise after canopy closure when all ground vegetation is dead.

In discussing the relative merits of Sitka spruce and Lodgepole pine on oligotrophic peats, **Mr. Condon** asked whether, as had been suggested, there was firm evidence that pine could be successfully grown on these sites. **Mr. Carey** replied that the oldest coastal pine was planted in 1952 at Cloosh Valley. The crops seemed to be growing successfully but tended to have rather undesirable form. **Dr. Gallagher** considered that pine could be grown well on low elevation peats but at higher elevations there might be more problems as these sites are windier and form might suffer more. One of the supposed advantages of Lodgepole pine is its ability to root more deeply than Sitka spruce, but **Dr. Farrell** stated that in recent work at Glenamoy he had been unable to detect any difference in the rooting depth of the 2 species, though it is difficult to measure this with any great degree of accuracy.

Dr. Gallagher said that if, due to instability, reduced rotations were necessary, the effect of this on net discounted revenue favoured Lodgepole pine. He added that Mr. Carey's observation on the effect of stocking density on the rate of litter decomposition was a field which needed more research.

Mr. Carey had indicated that the growth of Sitka spruce on some soils could be improved if it were planted in mixture with other species and **Mr. Maher** suggested that mixtures of pine and spruce would be valuable pioneer crops on peat. Several speakers thought that such mixtures would be very difficult to manage however. **Mr. Bulfin** suggested that on some soils Sitka spruce/larch mixtures might be better. They would be easier to manage and had the advantage of allowing more light to reach the forest floor.