Fertiliser application to conifer plantations on oligotrophic peat sites

Michael Carey[1]

- *Lack of drainage and nutrient deficiencies, primarily phosphorus and nitrogen, are the main factors limiting tree growth on oligotrophic peat sites.*
- *Rock phosphate has proved to be the best source of phosphorus and urea is the preferred choice for applying nitrogen. Broadcast application is preferable in terms of tree growth to spot application.*
- *Duration of response to fertiliser application depends greatly on the composition of the soil to which the fertiliser is being applied, the rate of application and the fertiliser source being used.*
- *Ploughing or mounding at the time of establishment can provide adequate drainage for tree growth.*
- *There is concern about the potential impacts on the aquatic environment of applying fertiliser to plantations growing on oligotrophic peat sites. The environmental guidelines produced over the last decade are aimed at ensuring there are no negative impacts.*
- *The freshwater pearl mussel is of high conservation importance due to the marked decline in populations over the past century due to over-exploitation and a deterioration in water quality. Clean gravel and sand are essential for a healthy population. Its presence in rivers or streams is an indication of water of the highest quality.*
- *A control buffer strip around rivers some 30 m wide, in addition to management at catchment level, is recommended as a means of reducing the risk of nutrient runoff.*

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Forest fertilisation is an operational tool that was developed in the 20th century with the establishment of man-made forests on difficult site types. Although forest growth is not generally limited by soil nutrient supply on a worldwide basis, the application of inorganic fertilisers has been commonly used and continues to be used to correct nutrient deficiencies and enhance tree growth in man-made forests. This has been particularly so in areas where the soils are impoverished and there is heavy reliance on plantations for wood fibre (Miller 1988, Binkley et al. 1995). The most common problems relate to phosphorus and nitrogen and to a lesser extent potassium deficiency.

Within Britain and Ireland the expansion of afforestation from the 1950s onwards to impoverished mineral and in particular peat soils resulted in a surge of interest in research aimed at the correction of the associated nutrient deficiencies. Such soils are strongly acid and contain low levels of available nutrients.

Substantial areas of plantations of pure Sitka spruce and mixtures of Sitka spruce and lodgepole pine have been planted by the private sector in counties Galway and Mayo over the last 20 years, particularly since about 1990. Many of these were established on poor acid oligotrophic peat soils that contain low levels of available nutrients.

Research carried out on oligotrophic[2] peat sites has indicated that lack of drainage and nutrient deficiencies, primarily phosphorus and nitrogen, are the main factors limiting tree growth.

Research has indicated that successful tree growth can be obtained on many oligotrophic peat sites, in situations where exposure is not a limiting factor, provided sites were drained properly, fertiliser phosphorus was broadcast applied evenly and planting was confined to the two common species - Sitka spruce and lodgepole pine - or a mixture of both.

The research also indicated, however, that where Sitka spruce was planted on such sites, fertiliser nitrogen inputs would very likely be required to sustain an acceptable growth pattern, although there was some uncertainty over the number of applications that might be required. The exception to this was localised flushed

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[2] *The term oligotrophic is derived from Greek, oligos meaning few, and trophikos meaning nourishment.*

Poorly drained area within a typical checked plantation in an area in Galway.

or somewhat enriched areas of peat where spruce grew satisfactorily without added nitrogen.

The performance of spruce in general was in contrast with the less demanding lodgepole pine, a species that appeared to grow satisfactorily, without any inputs of fertiliser nitrogen, provided it received an application of phosphorus at planting.

Application of fertiliser

Much emphasis has been placed on finding the best source of nutrients or fertiliser to apply, the optimum rate and the method of application. Rock phosphate proved to be the best source of phosphorus and urea became the preferred choice for applying nitrogen. The research indicated that broadcast application was preferable in terms of tree growth to spot application that had been the preferred practice initially (OCarroll 1972). OCarroll (1972) suggested that although potassium (K) deficiency had not become a serious problem on western peats it might do so in the future arising from increased growth rates following P application.

Young plantations respond positively to fertiliser at planting due to the nutrient deficiencies inherent in the site. The primary nutrient limiting growth is phosphorus and is usually corrected in the short-term by application of rock phosphate. Because the initial fertiliser application is often not sufficient to result in the trees reaching canopy closure, (due to uptake of significant amounts of the fertiliser by the competing vegetation, soil fixation and some loss through runoff from the site), additional responses in tree growth usually result from a second application - in some instances a third application - of the limiting nutrient.

The duration of the response to fertiliser applications has been a key issue in forest fertilisation generally across the world. Duration of response depends greatly on the composition of the particular soil to which the fertiliser is being applied, the rate of application and the fertiliser source being used. Phosphorus tends to more persistent than nitrogen because the rates normally applied often exceed those present in the above ground biomass of forest stands and their impacts on the levels of ‘available phosphorus’ tend to be more long term. This contrasts with nitrogen where the response curve is usually more transitory and typically peaks 2-4 years after application followed by a decline to growth rates of unfertilised stands after 5-10 years (Ballard 1984, Miller 1988).

Stands in check

Although the provision of adequate drainage and the application of fertiliser P results in the successful establishment and a significant improvement in the plantations on the site types concerned, and greatly enhances their timber production potential, deceleration in tree growth frequently sets in some 5-10 years after establishment due to a combination of P and N deficiency, the latter sometimes accentuated by the presence of competing heather vegetation. Needle growth and size are reduced, leader growth decreased significantly and, in extreme situations, the trees develop a condition commonly referred to as ‘check’.

Typically checked crops have the following features:

- Uneven growth. Typically trees can vary in height from less than 1 metre to 4-6 metres depending on age and on the amount of fertiliser applied received initially. The uneven growth is a function of the manner in which the fertiliser was initially spread. Short stunted needles are common.
- Yellowish foliage- depending partly on time of year.
- Leader growths of 1-5 cm.
- Strong heather competition where drainage is reasonable. The most widely accepted explanation for the difficulties presented by heather is that its root exudates adversely affect the development of mycorrhizal roots on the trees thereby interfering with N uptake. However, heather, and other ground vegetation, has also been shown to compete actively for fertiliser nutrients before canopy closure and to accumulate significant amounts of applied fertiliser relative to the trees needs.

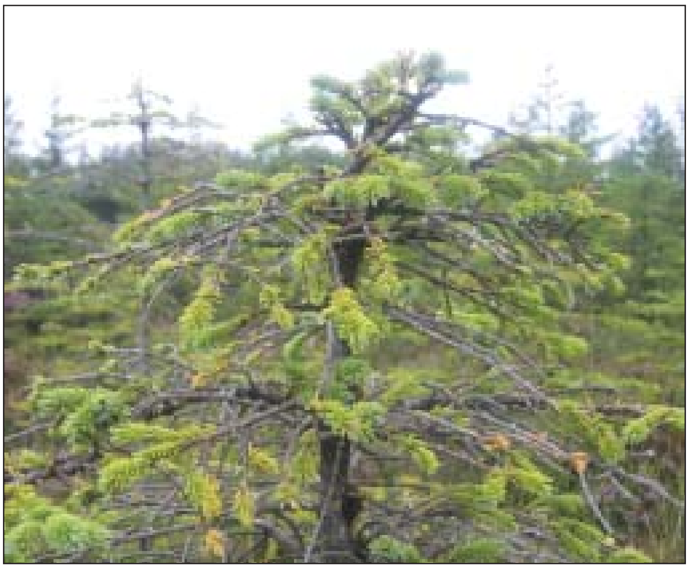
Where the crop is not in check but showing evidence of ill health the following features are common:

- Declining leader growth over the last 3-4 years.
- Yellowing of the foliage.
- Reduction in leader and needle length

Many owners of checked or partially checked plantations planted since 1990 continue to draw premiums for areas that have essentially stopped growing or are growing at a rate far below their potential. In the absence of a private forest inventory it is impossible to determine the area of plantations affected by check. When the income stream from premium payments ends at age 20 owners are likely to become increasingly concerned about the potential productivity of their plantations. Although many of the sites have an inherently low production potential (YC 10-12), this will not be achieved unless nutrient deficiencies are corrected. An inventory of the plantations needs to be carried out as a matter of urgency in order to determine the scale of the problem and to enable workable solutions to be developed.

Mixtures

Much interest has centred over the years on the use of mixtures of tree species in alleviating the problems associated with check on impoverished soils and there have been many observations of enhanced growth of Sitka spruce when grown in the vicinity of pines and to a lesser extent birch. Besides addressing the relatively local issue of growth check in spruce plantations in Britain and Ireland, there has also been increasing interest in mixed species forestry plantations on a world-wide scale over the last 10-15 years in response to a demand for ecologically and environmentally more sustainable forests (Hekhuis 1999). Although there are reservations in Ireland about the success



Checked Sitka spruce on oligotrophic peat in Mayo. Age 11 years. Note the short stunted needles, yellow colour and lack of leader growth.

of mixtures on oligotrophic peats (Horgan et al. 2003), it is apparent from work conducted in Scotland that, when properly designed and maintained from a nutritional point of view, their use eliminates the problem of check and the need to apply fertiliser nitrogen. However, the system will only succeed if the phosphorus nutrition of the spruce is maintained. This means in practice that more than one application of phosphorus, and very likely three applications will be necessary in order for the system to operative effectively.

Drainage

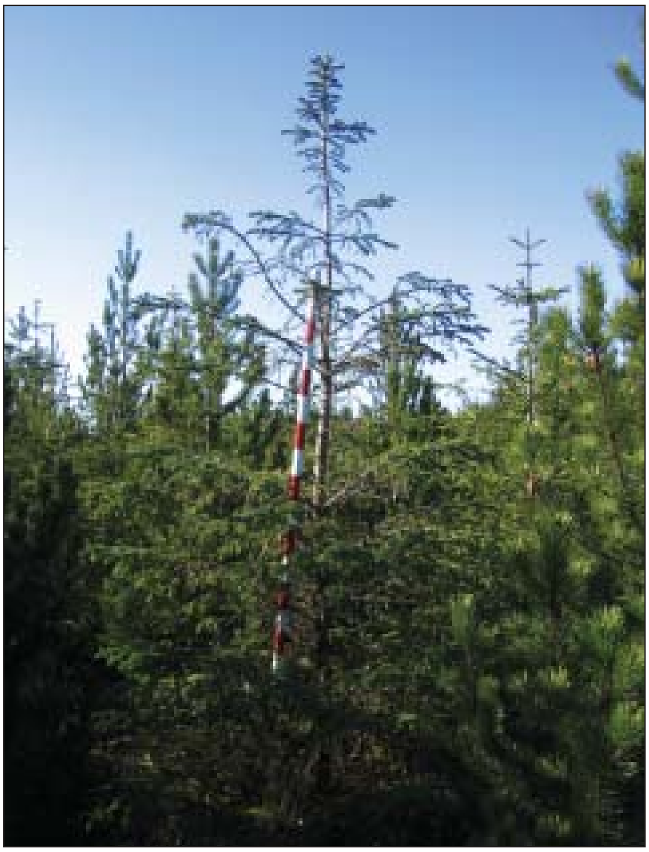
Blanket peat sites are by their nature poorly drained, and this is exacerbated by high rainfall. However, most forestry developments on such sites have generally been either been ploughed or (more recently) mounded at the time of establishment, both aimed at the provision of adequate drainage for tree growth. In general such systems are effective although mechanical mounding can give rise to difficulties due to the impermeable nature of the peat and the distance between mound drains.

Poorly drained sites are usually associated with areas with flat or concave topography and associated problems relating to outfall. Where the initial ploughing is shallow, and/or the site extremely wet, sometimes manifested in an almost quaking bog situation, the original drains are often filled up with sphagnum and other moss species. The watertable is usually close to or within 5-10 cm of the surface in such situations and is a serious constraint for tree growth. The wetness of such sites will also seriously restrict the response of the trees to fertiliser application.

Potential water quality influences

The main concern in relation to the fertiliser application to plantations growing on oligotrophic peats is the potential impacts of such operations on the aquatic environment. In response to this, environmental guidelines produced over the last decade are aimed at ensuring there are no negative impacts, i.e. the Code of Best Forest Practice - Ireland (2000), The Forestry Schemes Manual (2003), The Forestry and Water Quality Guidelines (2000) and the Guidelines on Aerial Fertilisation (2002).

Although earlier studies showed that significant runoff of nutrients could occur after forest fertilisation, the introduction of guidelines on good forest practice has reduced such risks very significantly. It should be possible



▲ A mixtures experiment with Masset lodgepole pine (age 15). Note the deceleration in height increment of the Sitka spruce due to phosphorus deficiency. Sections on height rod= 10 cm.

to address nutritional needs without compromising ecological values. Compliance with guidelines on environmental protection and good planning are seen as the key elements to resolving the issues.

Sensitivity of water catchments, rivers and streams to nutrient enrichment and to siltation is now a major issue in land-use generally. Sensitivity to a certain impact means that a natural system is liable to be negatively impacted or altered as a result of a particular intervention, the consequences of which may have serious cost implications in terms of ecological restoration. Besides drinking water supplies, concerns relate to fisheries and the presence of the freshwater pearl mussel (FPM) in some streams and rivers, each of which can be adversely affected by nutrient enrichment and /or siltation.

As peatland systems are oligotrophic, they naturally have very low nutrient status and so they have little capacity to buffer against inputs of nutrients (phosphorus and nitrogen). Because their baseline levels are so low, even a small increase can mean their phosphorus or nitrogen levels increase by orders of magnitude, meaning a higher potential impact for their freshwater life in the particular catchment.

The Environmental Protection Agency (EPA) national monitoring programme has demonstrated that Irish waters are becoming increasingly eutrophic over time. Catchments dominated by peats soils are viewed as sensitive to eutrophication because the peat has a low capacity to bind or fix phosphorus and because the buffering capacity of the water in the system is so poor. Systems with a very acidic geology are acid-sensitive. Because of this they are considered to be very acid systems. Therefore, they have little capacity to buffer against anything that further acidifies the system or results in further reduction in pH of the water.

There is little evidence of significant runoff of fertiliser nutrients following application - provided there is compliance with the guidelines on application methods. As a result there is increasing concern among foresters that fertiliser application could be restricted in areas unnecessarily and without justification. In most instances, buffer zones are seen as effective means for protecting water from impacts/inputs. Some concern has been expressed, however, about the effectiveness of buffer zones, given that sensitivity frequently applies to the whole catchments and in particular in relation to areas considered sensitive for the freshwater pearl mussel (FPM). The definition of catchment area and the extent of the areas requiring fertiliser inputs are criteria that need to be considered in any intervention process.

The FPM is of high conservation importance due to the marked decline in European and Irish populations over the past century due mainly to over fishing of the mussel (Aileen O'Sullivan- personal communication) and a deterioration in water quality. As a result it is a protected species under European and Irish law (Fuller, 2003, Moorkans, 2004). The water quality requirements of the FPM are higher that those of salmonids and the organism is highly sensitive to any input of silt or nutrients into the water bodies in which it lives. Its presence in rivers or streams is an indication therefore of water of the highest quality. The nature of the substrate of the riverbed is also very important for the FPM. Clean gravel and sand are essential for a healthy population. According to the NPWS, the critical level for MRP (water soluble molybdate reactive phosphorus) for the freshwater pearl mussel is 5 µg/l (Philip O'Dea, personal communication). Moorkens (2004) points out that FPM population levels decline where the gaps between the river gravel become clogged with silt and the flow of water in the interstices is restricted. River-bed silt arises from both organic and inorganic sources. The organic sources include peat particles and the inorganic include fine detritus from the breakdown of algae, which in turn arise as a result of excess phosphorus and nitrogen in the sensitive catchments. A control buffer strip around rivers some 30 m wide, in addition to management at catchment level, is recommended as a means of reducing the risk of nutrient runoff.

Legislative framework

There is much legislation in place in respect of water quality and the potential threat posed by various land use practices. The European Communities Water Policy Regulations (2003, S.I. No.722) is the legal instrument that translates the requirements of Directive 2000/60/EC - The Water Framework Directive - establishing a framework for community action in the field of water quality. In Ireland, the EPA and Local Authorities are identified as competent authorities for implementation of the legislation.

Eutrophication is a serious environmental pollution problem in Ireland. A strategy document entitled "*Managing Ireland's Rivers and Lakes- A Catchment Based Strategy Against Eutrophication*" (DOE 1997) sets out Ireland's policy and pollution reduction programme in respect of diffuse source pollution caused by phosphorus. Because of the crucial threat posed by phosphorus in the eutrophication process, The Minister for the Environment, Heritage and Local Government has prescribed environmental quality standards for phosphorus in rivers and lakes. These standards were given a statutory basis in 1997 and the associated regulations specify a chemical and biological standard for water quality that must be maintained or achieved by 2007.

The Department of Environment, Heritage and Local Government has established a Water Framework Directive (WFD) Co-ordination Group to coordinate and promote at national level implementation of the Water Directive. This group is supported by a number of advisory/technical working groups in specialist topics with representatives from a number of government departments and agencies including COFORD, Coillte and the Forest Service. In addition to this group the National Technical Co-ordination

Group (NTCG) has been established to provide guidance on the Water Framework Directive in Ireland and to ensure coherence to its implementation.

Water quality standards

Arising from ongoing concern over the quality of water generally there is much discussion about water quality standards. The EPA (2001) sets out the parameters of water quality and the interim statutory standards for rivers and lakes to aim for by 2007. In relation to phosphorus, the standard for rivers is set at values of 15-30 µg/l (ppm) as molybdate reactive phosphate (MRP) depending on existing biological quality rating in unpolluted situations, 50 µg/l in moderately polluted and 70 µg/l for polluted rivers. For ultra-oligotrophic clearwater lakes a target average total P of <5 µg P/l is set and 5-10 µg P/l for oligotrophic lakes. For 'other lakes' a target of <10 µg/l for total P is set for oligotrophic and 10-35 for mesotrophic situations. These figures are reflected in the Forestry and Water Guidelines (2001) produced by the Forest Service. The current debate centres on a threshold P concentration for rivers, separating satisfactory and unsatisfactory waters, set at a medium of 30 µg/l for MRP concentration and a Total P concentration of 20 µg P/l for lakes. According to the NPWS, the critical level for MRP for the Freshwater Pearl Mussel is 5 µg/l.

The application of fertilisers to forestry plantations in general, particularly areas with sensitive waters, is a cause of significant concern among fisheries and conservation interests. The use of aerial application to address nutritional needs is a cause of even greater concern and the Aerial Fertiliser Application Guidelines (2002) represent a response to address such concerns.

Although the results from many of the initial studies on nutrient runoff were a cause of some concern it has become apparent in recent years that the losses that occur from application of fertilisers, when there is good compliance with operational procedures and guidelines, appears to be relatively small and does not present serious treats to the trophic status of the associated streams and lakes. Heavy rainfall events and storms influence both runoff and its nutrients concentrations very significantly. Such impacts must be considered carefully in any studies on the effects of fertiliser application on nutrient runoff. Any decision to apply fertiliser should be preceded by analysis of representative foliage samples from the affected areas and a review of their fertiliser history. Although many stakeholders continue to have concerns about the risk of eutrophication following aerial application of fertiliser phosphorus in particular, there are strong indications that when operations are well planned, and guidelines are adhered to, the risk is greatly reduced. Modern application methods have sophisticated systems for tracking and guidance but their success depends on the extent to which operators are capable and/or willing to ensure compliance with both technological needs and guidelines. An indication of likely weather events during the days following application would also be useful.

Fertiliser spreaders based on modified harvesting forwarders may also offer possibilities for application on some sites and reduce the risk of runoff even further.

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