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22. WITHIN-SPECIES VARIANTS OF TREES FOR PLANTING DERELICT LAND

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Approximately 36,000 ha of the UK are classified as derelict, of which *c* 11,000 ha are attributed to the dumping of coal waste (Tandy, 1975). Natural colonization of this waste is usually a lengthy process, taking up to 80 years, with woodland ultimately developing on stable areas. To hasten this process, methods of reclamation have been developed, involving the addition of organic and artificial fertilisers, limestone, and occasionally top soil prior to sowing grasses and/or planting trees. Although these procedures are usually costly, success cannot be guaranteed. For the future, it would seem advisable to adapt these methods, taking greater note of the processes of natural colonization and reducing the reliance on ameliorants. Attempts are being made to obtain within-species variants of different species of trees that are adapted to conditions on derelict land and investigations of mycorrhizal associations of trees on these sites are in progress. For the future, the inclusion of leguminous plants such as broom and lupins is worth considering because of the ability of these plants to fix nitrogen.

1. Nature of substrate

Colliery waste is variable material and hence problems of reclamation vary from site to site. It is composed of varying proportions of mudstones, shales, siltstones, sandstones, seat earths (fireclays) and limestone characteristic of the geological strata associated with the different coal seams. In addition to reflecting the proportions of these different constituents, the physical and chemical nature of coal slag reflects the degree of weathering and the extent of burning.

The limited growth of plants on coal spoil can be attributed to at least 13 factors, but the relative importance of each of them varies from site to site and depends on whether or not the land has been regraded (Table 32). Nutrient deficiencies, extreme pH and compaction seem to be the most important factors limiting growth on regraded sites. Coal waste usually contains little or no nitrogen or phosphorus available for plant growth and acid shales are calcium-deficient. Iron pyrites is present in many wastes and can be the cause, when oxidised, of extremely acid conditions allowing the release of toxic amounts of aluminium and manganese. Acidity tends to increase as a result of weathering (Doubleday, 1971); surface materials, immediately after regrading, are typically neutral, tending to become acid in succeeding years. In Lancashire, pHs ranging from 2.2 to 7.9 have been recorded (Vyle, 1971). Compaction, caused by heavy earth-moving machinery, which can exert pressures of 49 kg cm^{-2}, has sometimes been so severe that penetrometer readings for regraded spoil have been the same as those for tarmacadam roads (Richardson, 1975).

TABLE 32 Some factors limiting plant growth on coal spoil

1. Physical factors
   - 1.1 instability and erosion
   - 1.2 unfavourable water regime
   - 1.3 absence of fine material
   - 1.4 compaction
   - 1.5 exposure
   - 1.6 spontaneous combustion
   - 1.7 extreme surface temperature
2. Nutritional factors
   - 2.1 nutrient deficiency
3. Toxicities
   - 3.1 extreme pH (range 2-10)
   - 3.2 extreme salinity
   - 3.3 presence of toxic metals
4. Biological factors
   - 4.1 absence of soil microbes and fauna
   - 4.2 lack of humus

2. Amelioration

In the short-term, raw colliery waste can often be ameliorated to give "instant" green fields. In these circumstances, the costs of amelioration and grassing can account for 30% of the £2,470-24,700 spent on reclaiming each hectare (1978 prices from the Scottish Development Agency). Large amounts (756 kg ha^{-1}) of nitrogen and phosphate-rich fertilisers are necessary plus limestone to counteract acidity—1% FeS_2 (pyrites) necessitating the application of 40 tonnes of limestone per hectare to neutralise the acidity of the top 15 cm layer of waste. It is usual to 'rip' the surface to minimise compaction before these amendments are applied. However, despite these procedures, it is still necessary to consider aftercare because of continuing acidity and the rapid leaching of nitrogen and the binding, in the absence of organic matter, of phosphate and potassium in inaccessible forms.

3. Plant selection

To make site amelioration more cost effective, and in the hope of minimizing the extent of aftercare, attempts are being made to refine the selection of trees grown on unameliorated coal spoils. Traditionally, plants are selected on the basis of their yields, disease resistance and ease of propagation, to mention but a few of the criteria. However, for planting spoil, often in exposed conditions, other criteria are likely to be of greater significance, remembering that trees that perform well on natural soils are unlikely to be those that tolerate spoil—they have not been subject to the selection pressures exerted by this unnatural substrate.

Bradshaw (1952), and subsequently others, working with grasses, have found that plants collected from metalliferous mine sites could tolerate larger concentrations of particular metals than 'normal' populations. Specifically, they have been able to identify populations of *Agrostis* spp, *Festuca* spp, *Anthoxanthum odoratum,* and *Holcus lanatus.* Mine spoil populations of grasses are tolerant of the metals that are present in normally toxic concentrations in wastes on which they grow; they are not tolerant of other metals. When 2 metals; (eg Pb, Zn) occur together in toxic concentrations, dual tolerances can be found. Jowett (1959) found that a lead-tolerant population of *Agrostis tenuis* was able to grow in substrates with amounts of calcium and phosphate which would have been inadequate for most populations—a suggestion of multiple tolerances. Salt tolerance has been found in *Senecio vulgaris* growing in roadside verges 'salted' during winter (Briggs, 1978); acid tolerance has been found in barley (Stolen & Andersen, 1978).

Tolerances that have been demonstrated so far have been confined to a few chemical factors, but plants growing on coal waste are subject to a multiplicity of adverse factors, chemical, physical and biological (Table 32), and, because some specimens of a variety of trees including species of *Betula, Sambucus, Salix* and *Quercus* seem able to establish themselves 'naturally' on some coal spoils, it seems likely that they may possess multiple tolerance unless one factor is of overriding importance. Two species of birch, *Betula pendula* and *B. pubescens,* and two of alder, *Alnus glutinosa* and *A. incana,* are being investigated; birch, because it is a primary coloniser, and alder, because nitrogen is fixed in its root nodules. *Alnus* spp have been used successfully in the reclamation of mining spoils in Denmark, Germany, Great Britain, Holland and the United States (Plate 14).

Working on the principle that trees growing successfully on coal waste may have tolerance, cuttings were taken from (i) natural colonizers and (ii) the better survivors of man-made plantings. Samples of soil taken from near their roots were analysed. During the last 2 years stocks of vegetatively propagated plants have been accumulated and are now being used in a series of glasshouse and field trials with commercially available nursery-stocks as the standards for comparisons—the 'controls'. During propagation, the roots of *Betula* spp are inoculated with soil containing inocula of mycorrhizal fungi; roots of *Alnus* spp are inoculated with a suspension of macerated root nodules. The field trials are being done on a variety of coal spoils with pH ranging from 5-7, growth being assessed with and without added fertilisers. So far, drought has been a problem, particularly on coarser wastes. In these conditions, some of the selected alder clones seem to be growing better than the controls (unselected nursery stock), their better performance possibly, and surprisingly in this genus, being related to drought tolerance.

On looking at fungal sporophores occurring on spoil heaps, it seems that improvements might be obtained if mycorrhizal inocula were taken from the heaps themselves where *Paxillus involutus* and *Scleroderma* spp, which are known to form mycorrhizas with many tree species, commonly occur (see Marx, 1975). These fungi contrast with species of *Hebeloma* and *Laccaria* which develop as a result of inoculation with nursery soil. Are *Paxillus involutus* and *Scleroderma* spp, or some isolates of them, inherently suited to conditions in industrial spoil?

4. Discussion

In doing this type of work, there is an 'unconscious' selection of rapid-growing 'easy-to-root' clones (as stocks of these build up more rapidly), a trait possibly running counter to the selection of tolerance; grasses adapted to small concentrations of nutrients are also slow-growing (Jowett, 1959; Gemmell, 1977). However, there is some evidence of tolerance in some *Alnus* clones and an impression that this tolerance may be largely related to their abilities to withstand drought. Early experiments have, however, served to emphasize the need to work on a broad front. Marx (1975) demonstrated that inoculation with effective mycorrhiza enhanced the establishment of some trees on strip-mined coal waste in Kentucky. Paralleling the search for tolerant trees, attempts are being made to ensure that mycorrhiza established during propagation will withstand conditions in coal spoil and tolerant strains of mycorrhizal fungi are being sought.

The use of nitrogen-fixing plants is an attractive alternative to the provision of fertiliser. *Alnus* spp are already being studied, both in their own right and as nurse plants for other species of trees.

However, the use of herbaceous nitrogen-fixers could also provide useful continuing nitrogen supplements minimizing the onset of growth checks attributable to nitrogen deficiencies. Doubtless, the readily available stocks of legumes could, for this purpose, be improved by selection, because it should be remembered that many grow badly on acid mine waste, possibly as a result of manganese toxicity and phosphate deficiencies (DoE Contract Report DGR1 B71, 1978). However, natural populations of gorse and broom seem to have no difficulty in establishing themselves, at least on some types of spoil.

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