RESEARCH FOR PRACTICAL ARBORICULTURE

Proceedings of the Forestry Commission/Arboricultural Association seminar at

Preston February 1980

Research

for

Practical Arboriculture

Proceedings of a Seminar held in February 1980
at the Lancashire College of Agriculture at Preston
and arranged by the Forestry Commission and the
Arboricultural Association

CONTENTS

INTRODUCTION

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To make the results of research available to those who use them often presents a problem in communication. It is especially important to bridge this gap when the research concerned has a strongly practical objective. So it is with the technical seminar whose results are published in the present volume. Recent research projects carried out on behalf of the Department of the Environment by the Forestry Commission and the Institute of Terrestrial Ecology are now drawing to the close of their contract periods and it is especially appropriate at the present time to review the progress of this research in relation to its practical applications. Other work worthy of note is also being undertaken by the Forestry Commission, as well as independent arboricultural research taking place in certain universities. Before assessing in more detail the present seminar, it is useful to review the history and general background.

In 1967 the Association of British Tree Surgeons and Arboriculturists organised a three-day course on tree surgery at Merrist Wood Agricultural College. This course stimulated great interest and, as a result, the Association which later, through amalgamation, became the Arboricultural Association, has held an Annual Conference. In 1972 the Conference concentrated on current research in arboriculture and ended with a discussion about unsolved problems. The Conference unanimously passed a motion calling for the establishment of an Arboricultural Research Working Party. Professor F.T. Last, Director of the Natural Environmental Research Council Unit of Tree Biology, agreed to chair the working party.

The terms of reference adopted by the working party were:

'To identify and evaluate problems associated with the cultivation and management of trees as individuals, or in small groups, and to make recommendations on research and other needs to resolve these problems'.

The working party reported in 1974 making specific recommendations for research. The Department of the Environment welcomed the report and instituted a 5-year programme of research into:

i) Tree production and establishment
ii) Protection problems including practical aspects of control
iii) Tree selection

with provision for the establishment of an information and advisory service. Subsequently a further contract was let to provide for research into the establishment of trees on deep mined colliery spoil.

During the deliberations of the working party it became clear that much research was in progress and that considerable information and expert knowledge existed but that much of this was not readily accessible to the practitioner. The need for improved communication, which I confidently believe that this Seminar has done much to help, may be judged by the fact that - on account of restrictions imposed by space and other facilities - those who wished to attend the Seminar exceeded by some 50 per cent those whom it was actually possible to accommodate.

As has been said, the primary objective of the seminar was to encourage communication with the industry by reporting the progress of the research funded by the Department of the Environment and by highlighting areas of related work undertaken with support from other sources. A review of the achievements of this research must also assess the relevance of the results and extend the work of the original working party by highlighting the most important future needs and directions in which extensions of the present research, which are certainly necessary, should take.

The Seminar took place in five sessions. The first session considered problems in the management of mature trees, particularly their protection against decay and the need to ensure adequate nutrition. Early detection of decay, so that treatment can be given in good time, is an important objective. As far as nutrition is concerned the needs for fertiliser application to cause healthy tree growth are not clearly understood as there is a deficiency in basic knowledge.

The second session turned to problems presented by the young tree, particularly the need for good quality and well-treated seed and for care in handling and moving plants from nurseries to where they are to be used. Special treatment of seed before sowing has proved valuable in obtaining reliable germination. Chemical defoliation has been shown to be effective in permitting a longer planting period. Research in tree production has been restricted to seed treatment and plant handling because the nursery trade and the Arboriculture Research Working Party considered that other related subjects fell under the aegis of the Agricultural Research Council.

The third session reviewed problems of planting on 'man-made' sites which, indeed,include the majority of amenity planting sites and which may, in general, present especial difficulties because they are usually unnatural and have been disturbed by man. Motorway and trunk road verges have received considerable attention during the research contracted by the Department of the Environment. Other problems arise in the planting of regraded spoil heaps or excavations created by mineral extraction. These include the composition of the herbaceous cover prior to tree planting and in this leguminous plants may play an important role in the enrichment of the soil. Other factors such as the selection and provenance of trees in relation to such needs as tolerance of heavy metal concentrations may also be important.

The fourth session reviewed research on clonal selection of trees for man-made sites undertaken at the Unit of Tree Biology, Edinburgh, under the direction of Professor F.T. Last. Such selection can lead to better establishment and growth on the difficult sites discussed in the third session. The fourth session also contained a contribution by D.A. Burdekin on the clonal susceptibility of London planes to anthracnose.

The fifth and final session 'And So On From Here' dealt with the future of arboricultural research and was chaired by T.T.W. Peregrine of the Department of the Environment.

As I implied earlier, the report of this seminar represents more an interim review rather than a record of completed research. Particularly when dealing with the problems of trees, time can be an important dimension in experiments and sometimes adequacy of time is essential to change tentative and uncertain results into firm conclusions. The seminar during its progress demonstrated this repeatedly and clearly, as well as indicating the new directions of research needed in the future.

As has been already mentioned, the popularity of this seminar was such that some 70-80 potential delegates were unable to attend. The publication of the Papers, therefore, is a valuable element in helping to solve the communications problem, which was one of the main reasons for the present seminar. I very much hope that the important contributions in this volume will help still further in making available the results of arboricultural research to those who put them to practical use.

AMENITY TREE MANAGEMENT

Chairman **R. Finch**
Roy Finch Tree Care Specialists, Malvern

THE DETECTION OF DECAY AND ITS TREATMENT

by

P.C. Mercer
Forestry Commission

SUMMARY

Possible techniques for detecting decay in trees are reviewed and particular reference is made to experience gained in research projects using the Shigometer.

Treatment of established decay in trees and preventative measures are also assessed.

INTRODUCTION

Decay is one of the most intractable problems anyone associated with trees has to deal with. Frequently the first a tree owner knows of decay in his tree is when it has been blown over or a large branch broken in a wind. It would be of great assistance to arboriculturists to know if a tree contains decay before it is in a sufficiently advanced stage to seriously weaken the structure.

CURRENT PRACTICE

The most commonly used instruments for detecting decay in trees are the Pressler borer and the auger known as the 'French Walking Stick'. Both remove pieces of wood for observation; those from the borer in the form of a core and those from the auger in the form of chips or shavings. The borer has several advantages over the auger. The core is in one piece permitting study of the tree rings and measurement of growth rates. In addition stain and incipient decay can also be identified. It is generally a much more satisfactory instrument than the auger whose only advantage is that it is longer and can be useful for investigating roots, but interpretation of the shavings produced is very difficult.

Both instruments have one big disadvantage - they make comparatively large holes which may or may not become infected with decay organisms (Polge and Thiercelin 1970; Laflamme, 1979).

For many years workers have been examining non-destructive methods of assessing the interiors of trees, using ultrasonics (McDonald and Bulgrin, 1969), resonance (Shaw, 1974), gamma rays (Beaton *et al.* 1972; Lachance, 1977) and X-rays (Kühn and Handl, 1973; Habermehl and Ridder, 1978). Apart from the weight and complexity of the apparatus the main disadvantages of these methods have been interpretation of results. At best the methods only worked in hollow trees and rarely could diagnosis be attempted on the site because traces or photographs had to be produced and examined in the laboratory.

It appears unlikely that the diagnosis of decay in trees using these techniques will improve dramatically in the near future.

The Shigometer

About six years ago an alternative line of investigation was initiated (Shigo and Shigo, 1974; Shigo *et al*, 1977) which, although not completely non-destructive, is almost so. A 3mm diameter hole is bored into the test tree and a twisted wire probe with bared ends inserted. A pulsed electric current is passed through the wood and the electrical resistance measured between the probe ends. The device, known as the Shigometer, depends on the observation that decayed wood and incipiently decayed wood generally have a lower electrical resistance than sound wood, while a hollow has an infinite resistance. After boring a series of small holes into a tree this instrument may be used to build up a perspective of the tree's internal condition (Mercer, 1979a). The instrument has been tested over three years on a range of species at the Forest Research Station, Alice Holt Lodge, Farnham and the results have been reasonably consistent. There are however some problems to bear in mind.

a) The drill bits and probes have a maximum length of 30 cm, permitting assessment of a 60 cm maximum diameter.

b) For the Shigometer to give readings of electrical resistance bearing a relatiosnhip to the state of decay the wood must be reasonably moist. Dry decay can give as high values as sound wood. It has been found that syringing water into drill holes and then removing excess water after a minute or so, allowed subsequent satisfactory detection of dry decay. However, dry decay does not appear to be common in the butt of trees.

c) Sometimes pruning wounds acquire a hard surface which appears sound but overlies an area of decay (case-hardening). Shigometer readings of case-hardened wood may be considerably higher than sound wood, even after syringing water into the drill holes. If such a situation is suspected the probes should penetrate beyond the case-hardened area.

d) As observed above, small holes are made in the tree by the drill bits but they are sufficiently small to callus over in under 9 months. Once the wound has occluded, decay-causing organisms either cease functioning or function at a greatly reduced level, so there is practically no danger of major decay resulting from a Shigometer drill hole.

e) Several battery-powered drills have been tested but were discarded as the batteries had inadequate storage capacity. A more satisfactory method is to use a 110 volt generator powering an appropriate drill. Recently a very satisfactory drill was tested which runs off a car battery (Versadrill, L.V. Motors Ltd., Welwyn Garden City).

Generally, although not so simple to use as a Pressler borer, the Shigometer has proved a satisfactory instrument in tests over three years, but like a chainsaw, instruction and experience in its use are needed to get the best out of the instrument.

The Shigometer is not a 'tool' to be used on every tree. It should be regarded more as a means of confirming the presence of decay suggested by externally visible symptoms. For example, presence of fruit bodies, thin crowns, poor callusing of wounds, would indicate a need for a closer examination of the tree. These points are detailed by Burdekin (page 17) and Young (1976).

Treatment of decay

Once decay has been detected can anything be done to effect eradication? Unfortunately, with present knowledge, very little can be done or recommended. The recommendation in British Standard 3998: 1966 (Anon 1966) to clean out cavities is still practised, water is occasionally drained off with a pipe drilled into the trunk, and the wood is cut back to beyond the decay. The remaining wood surface is then treated with a fungicide before the cavity is either left open or filled using materials such as concrete, saw-dust and bitumen or expanded polystyrene. However, it is very likely that this method has little value for the tree, as by gouging back wood, drilling holes in the trunk, and using fungicides which are often phytotoxic, defence barriers created by the tree around the cavity are breached (Shigo and Marx, 1977), and the end result is reactivated decay and a larger cavity than was present to start with. It would seem, therefore, that loose material only should be removed, and filling with expanded foam to provide a surface for the callus to grow over would be reasonable, but much research work remains to be done.

Much more work has been done on preventative techniques than on the treatment of established decay in trees. Research has largely been concentrated on placing some sort of sealing and/or fungicidal compound over the surface of a wound to protect it from fungal attack (Mercer, 1979b).

The most commonly used material is a bitumastic emulsion, but decay has frequently been found behind the bitumen surfaces. In a recent small survey carried out by the author using beech trees *(Fagus sylvatica)* the incidence of decay fungi was four times greater in wounds treated with bitumen than in untreated wounds. Although the survey was too small to be statistically significant it does suggest that the traditional form of treatment is largely ineffective. Do better treatments exist? To cope with the large number of products available, preliminary screening tests for phytotoxicity and fungitoxicity were carried out (Mercer, 1979c). The most promising materials were subsequently tested in the field. The general message from the results to-date seems to be that although some of the products, e.g. thiophenate methyl (Topsin), bitumastic and latex paints are quite good at stimulating or encouraging callus growth, none of them seems to be very good at preventing growth of micro-organisms, at least in the long term.

Another possibility is biological control. A piece of decayed wood does not usually contain just one decay fungus. A whole mass of competing fungi and bacteria may be present. Would it be possible to use a non-decay fungus or bacterium to prevent colonisation of the wound by a decay fungus? There are several hundred potential candidates and these were tested in the laboratory for antagonistic properties, both on agar and on strips of beech wood. Four were thought suitable for field-testing and were inoculated into trunk wounds of beech. A sample was removed 10 months later and examined for the presence of micro-organisms. The best micro-organism was *Trichoderma viride* which was recovered from over 90 per cent of wounds into which it had been inoculated, and in over 75 per cent of the wounds it was the only fungus present. Clearly there is some potential for biological control but longer term assessments need to be made.

It may also be possible to combine biological and chemical control, e.g. by using a chemical which favours a non-decay fungus but inhibits a decay fungus. At present it seems that the best treatment for pruning wounds is to paint the cambium with a sealant, but leave the centre of the wound unpainted or give only a very light coating for aesthetic purposes.

CONCLUSIONS

Many wounds on trees could be avoided if more thought was given to the requirements of the tree in the first place - avoidance of excessive lopping of branches by not placing large forest trees in unsuitable urban type surroundings. However, until all trees are planted perfectly and properly maintained, the need for treatments to try to combat the worst of man's excesses will remain. Further research is needed before recommendations for treatment of wounds can be made and as a result the need to detect decay will remain. To date the Shigometer appears the most appropriate instrument.

ACKNOWLEDGEMENTS

The assistance of Mrs S.A. Kirk is gratefully acknowledged. Thanks are also due to the many firms who have supplied wound chemicals, and to tree-surgeons and local authorities for their help and co-operation. The paper is based on work carried out under a Department of the Environment arboricultural contract with the Forestry Commission.

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DISCUSSION

P.A. Hemsley - If research indicates treatment of the cambium is beneficial what should be done to prevent decay entering the wood?

P.C. Mercer - Sealant treatment appears to prevent drying of the cambium and if the paint includes a growth stimulant so much the better. To prevent decay would require a very strong and persistent fungicide. The only product with any claim in this direction is Santar.

P.G. Biddle - Have biological control treatments been tested in field trials?

P.C. Mercer - Only on trunk wounds in which the vessel ends had been exposed by drilling to imitate pruning wounds more exactly. Results after 10 months were quite encouraging.

P. Kenyon - Is it worthwhile painting wounds on street trees pruned on a 2-year cycle?

P.C. Mercer - Not really, but the public expect to see wounds painted and must be educated away from the practice. Even in a routine cutting cycle medium-sized and large wounds would probably benefit from callus stimulation resulting from painting.

J. Kopinga - In Holland sealants are considered valuable to exclude Coral spot *(Nectria cinnabarina)*.

P.C. Mercer - The extent of this disease in Britain is not known but mercuric oxide is known to be valuable as a control measure.

DECAY - SOME MANAGEMENT CONSIDERATIONS

by

D.A. Burdekin

Forestry Commission

SUMMARY

Every tree owner is under a duty to inspect his trees to assess their safety and he may be judged negligent and liable for damages if a decayed tree falls and causes injury or damage. A number of the principles which need to be considered in the organization of tree inspections are discussed, with particular reference to decay. A series of examples of visible indicators of decay are described.

INTRODUCTION

It is desirable to identify unsafe trees before they cause injury to people or damage to property. As decay is probably the commonest source of structural weakness in trees, recognition of decay symptoms and early implementation of remedial measures should reduce the risks. Indeed it would be even more desirable to prevent the entry of decay into trees. The latest information available on treatments to prevent decay and techniques for detection of decay within a tree have been reviewed by Mercer (page 12).

In this paper consideration is given to measures local authorities and other tree owners should take to identify the externally visible signs of decay and reduce the risks associated with decayed and potentially dangerous trees.

It should always be borne in mind that where a tree shows external evidence of decay, the owner may be liable, in law, for any damage caused should that tree break or fall. Further, in a joint dircular from the Department of the Environment (No. 90/73) and the Welsh Office (No. 154/73) the Secretaries of State advise that:

> 'an authority or any person responsible for the safety of a tree is under a duty to have it inspected by a competent person at reasonably frequent intervals so that any indication of disease or possible disease present at the time of inspection can be noted and acted upon'.

The approach to inspections will differ according to the size of the tree population and its location. For example, the larger local authorities may have a million trees or more under their care whereas the average householder may only have a specimen tree. Some trees may be situated in the open countryside whereas others may be in urban locations close to busy roads.

GENERAL TREE SURVEYS

Recognition of decayed trees should be part of an overall examination of trees in a particular area. The standard text books on arboriculture give examples of record cards (perhaps suited to computer analysis) indicating how a system for such surveys can be organized. There are many urban situations where records of location, tree species, size, condition, amenity value, etc. would be useful but these records are rarely maintained. In large rural areas such detailed records are not a practicable proposition. If a tree population is to be properly managed, however, it must be inspected periodically and records must be kept. The most important records for established and mature trees relate to the condition of the tree. Is it safe? Does it require pruning or other tree surgery to make it safe? - these are probably the most important questions. Although these two questions may be inter-related insofar as pruning may be necessary to remove decayed wood, pruning itself is outside the scope of this paper.

INSPECTIONS FOR DECAY

It should always be borne in mind that owners have a responsibility to inspect all their trees. When large numbers of trees are to be inspected it is vital to make optimum use of the resources available to carry out the work. Priorities must be decided, based upon age and condition of trees and the degree of risk to people and property. Decayed trees growing close to buildings or places where people are frequently present pose the greatest threat. Some of the most dangerous situations are listed in Table 1 (page 19).

It is perhaps worth commenting on the last item in the table, i.e. sites where trees have previously fallen. Where a tree has shed a branch or has been uprooted, there is some likelihood that neighbouring trees may also be vulnerable. Windthrow or breakage may be a particular problem of the site and if decay is present, more than one tree is likely to be infected. These sites are particularly important and should be included in all tree surveys.

Whether small or large numbers of trees have to be inspected, each tree must be appraised from all sides for tell-tale signs of decay. Arboricultural Leaflet No.1 *External Signs of Decay in Trees* (Young, 1977) should be referred to for detailed guidance. Decayed trees are best detected by an experienced arboriculturist who should carry out a close inspection at ground level and with binoculars. If necessary, the arboriculturist may climb the tree to inspect weaknesses in the crown. Table 2 (page 19) summarises the following comments.

INDIVIDUAL TREE INSPECTIONS

There are a number of circumstances where individual trees or groups of trees merit special attention, for example, new building developments may be carefully designed to take advantage of existing mature trees. Any trees to be retained in these situations must be carefully examined to ensure that there are no external signs of decay and that the trees have an anticipated safe life of several years. Other trees which may warrant close examination include valuable amenity trees, especially those subject to a Tree Preservation Order or in Conservation Areas. If there are any doubts about the safety of such trees a specialist arboriculturist should be called upon to make a detailed investigation.

DIRECT EVIDENCE OF DECAY

The most obvious sign of decay in a tree is the presence of a fungal fruit body on the stem or roots. It is important for arboriculturists to be able to recognise the fruit bodies of those fungi which are commonly found associated with decay. The recently published Arboricultural Leaflet No.5 *Common Decay Fungi on Broadleaved Trees* (Burdekin, 1979) is an illustrated booklet which provides valuable information on this subject. Many fungi produce fruit bodies in the autumn and the period September/October is therefore the optimum time for tree inspections. The presence of fruit bodies on a tree indicates that the tree is likely to be seriously decayed, at least locally, and the tree should certainly be subject to detailed inspection. Unless there is good evidence that the decay has not rendered the tree unsafe, then decayed boughs must be removed or, if necessary, the tree should be felled.

Decay organisms often enter trees through pruning wounds or through natural fractures and fungal fruit bodies may develop on the wounds. The presence of extensive decay may be obvious because the wood is soft and spongy or a small cavity may have developed. However, there have been a number of occasions when

Table 1.

Situations Where Falling Trees or Branches Cause Severe Damage Most Frequently

Roadsides	-	Trunk roads
		'A' Class roads
		Busy minor roads (including busy short-cuts)
		Roundabouts
		Cross roads and junctions
		Blind corners
Buildings	-	Any tree within falling distance
Open Areas	-	School playgrounds
		Car parks
		Cemeteries
		Recreation areas (including caravan, camping, picnic sites, etc.)

Sites where trees have previously fallen.

Table 2.

Summary of External Signs of Decay

Position on tree	*Indirect evidence*	*Direct evidence*
Overall crown	Discolouration	
	Reduced leaf size	
Branches	Abrupt bends in boughs	Fungal fruit bodies present.
	Acute 'V' shaped crotches	
	Splitting of long horizontal branches.	Presence of cavities
	Presence of cankerous outgrowth.	
Trunk	Presence of cankerous outgrowths.	Presence of fungal fruit bodies.
		Presence of cavities
Root area	Soil displacement at ground level.	Presence of fungal fruit bodies.

a pruning wound has been found with a skin of seasoned undecayed wood, a centimetre or more in thickness, covering an extensively decayed region below. This can be detected by tapping the surface and listening for a hollow sound or by breaking the skin with a mallet and chisel.

Sometimes the surface of a pruning wound is not clearly visible and this applies especially to pollarded trees and those which are pruned back regularly to a permanent framework. This is, of course, a common practice with many street trees. Decay does develop in such trees and if extensive regrowth occurs, the weight of the branches may render them more likely to fall and cause serious damage. Consideration should be given to a crown inspection of at least a sample of such trees.

Decay may also enter a tree through its root system. There are several fungi which can cause extensive decay of roots and render trees liable to windthrow. Unless a detailed root excavation is undertaken the detection of root rots depends to a large extent on the presence of fungal fruit bodies. Most fruit bodies of root decay fungi grow out from the tree bases and larger roots and this is a useful feature which helps the inspector to distinguish dangerous decay fungi from other more harmless species which may grow beneath trees. However, every keen arboriculturist should be able to recognise fruit bodies of the more important root rots including Honey fungus *(Armillaria mellea)*, *Meripilus giganteus, Ustulina deusta, Ganoderma resinaceum* and *Inonotus dryadeus*.

In addition to pruning wound decays and root rots, decay may develop following mechanical damage to the stem. Trees growing very close to roads or in car parks are particularly vulnerable. In extreme cases large cavities may develop at the base of the tree and these require very careful examination.

Cankerous outgrowths can be indicative of the presence of decay. Such outgrowths may be caused by fungi or bacteria which do not themselves cause decay but damage the stem so that decay organisms can enter.

INDIRECT EVIDENCE OF DECAY

There are a number of features of roots, stem or crown which may be indicative of the presence of decay.

A general deterioration of the crown can occur following extensive death and decay of roots. Symptoms may include abnormally small leaves, premature defoliation and dieback. However, it is important to recognise that these symptoms can have a number of other causes. Confirmation of root decay can be obtained only by recognition of fruit bodies or by excavation for the presence of decayed roots. Further evidence of root decay can sometimes be seen by the presence of displaced soil or turf around the base of the tree, caused by movement of the tree and its roots in high winds.

If a main stem or bough divides to form an acutely-angled V-shaped crotch, there is always a danger that decay may enter and that the stems may subsequently split apart. Cavities may develop in such crotches and these commonly fill with water. The cavity may not be visible from the ground but discoloured seepage tracks below can suggest its presence.

Another branch characteristic which may indicate the presence of decay is the right-angled or abrupt bend. Such bends frequently develop where a forked limb has in the past lost one of its members through death or breakage, thus allowing the entry of decay fungi. Some sign of the lost member normally remains on the outside of such bends either as a remnant stub or as a circular growth of callus tissue. Where such bends are present, particularly on branches overhanging roads or buildings, they should be removed.

Long, horizontal branches sometimes develop longitudinal splits prior to breakage. These splits may be present for a number of years and therefore give an opportunity for decay to enter and develop. The passage of time also allows the development of callus tissue either side of the split and this is a useful indicator for the tree inspector.

CONCLUSIONS

In conclusion, it must be emphasized that every tree owner may be judged guilty of negligence if a tree or bough showing external evidence of decay falls and causes damage. Local authorities in particular have been advised by government ministers to inspect their trees for the presence of disease. A system of recording the condition of trees should be devised therefore to satisfy this requirement. The frequency of inspection will depend on a number of considerations and it will probably also be necessary to pay particular attention to inspections of trees in situations where there is the greatest risk of damage. A number of visual indicators of the presence of decay have been described and these should prove valuable to all those involved in tree inspections.

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DISCUSSION

P.G. Biddle - It is important for an owner to inspect all trees as courts do not differentiate between risks when considering common law cases.

D.A. Burdekin - That is quite correct.

A. King - Beech trees infected with root disease have shown increased growth compared with five years ago. New fibrous root formation has occurred below the decay.

D.A. Burdekin - This is relatively uncommon - more frequently a beech with root disease shows declining annual ring growth.

J. Good - Are all hollow trees dangerous?

D.A. Burdekin - It depends on a number of factors including the extent of decay, the size of the crown and tree species.

E. Larratt - If a mature beech is surviving on decayed roots and the crown looks healthy, must the tree be felled on sole evidence of a fruit body?

D.A. Burdekin - More information would be required, e.g. identification of the fungus,to decide on the likely significance of the decay. If *Meripilus giganteus* is present it is very unlikely that the tree will be safe.

Miss Short - Should trees be inspected by climbing into the crown?

D.A. Burdekin - If a potential weak point is present which cannot be clearly observed in any other way. For example, pollarded trees should be inspected for the presence of decay in pruning wounds.

NUTRIENTS AND THE TREE

by

H. Insley
Forestry Commission

SUMMARY

Foliar analysis has been used to examine nutrient concentrations in a range of broadleaved amenity trees. In *Tilia* x *europaea* no significant variation was found in foliar nutrient concentration with height or aspect on the crown, provided the samples were collected from the true crown and consisted of fully expanded, clean, undamaged leaves which had been fully exposed to the light. The foliar nutrient concentration of such leaves gave a good indication of a tree's nutrient status.

Broadleaved trees showing healthy growth were found to have nutrient concentrations (expressed as percentage oven dry weight) as follows:- N 2.0+, P 0.2+, K 1.0+, Ca 1.5+ and Mg 0.2+, for leaves collected in July or August.

INTRODUCTION

Arboriculturists frequently feed trees which are showing signs of decline. Pretreatment diagnosis, if done, may include taking an increment boring to examine the tree's growth over the previous 4 or 5 years. If this shows evidence of decreasing growth, which together with the outward appearance of the tree indicates a lack of vigour, then fertiliser is applied. Usually this is done by boring holes in the ground beneath the tree crown with a powered auger at 0.6 m spacing, 5 to 10 cm deep and backfilling with a mixture of fertiliser and peat (Matthews, pers. corresp.). Although this is becoming an increasingly widespread practice in arboriculture, the need for, and response to, such treatment is not well researched.

Against this background a research programme has been started with the following objectives:

a) To determine the nutrient status of amenity trees established on a variety of sites, to try to identify concentrations associated with normal healthy growth.

b) To find out whether or not established amenity trees require nutrient addition and, if so, to produce a series of recommendations for fertilizer application.

METHODS

The first stage has been to measure concentrations of nutrients in selected broadleaved species, and find out how these vary. This has been done using foliar analysis, which is an established technique for the diagnosis of nutritional status in coniferous plantations (Everard, 1973).

Collection of information has been in two ways. Firstly, data have been collected on nutrient concentrations in a wide range of amenity broadleaves. Each year since 1975, foliar samples have been collected from 4 or 5 species growing in both town and country throughout England and Wales. As so many species are used in arboriculture the programme has been arranged so that after 5 years, information will have been obtained for at least one representative of each main family used for amenity.

Collection of samples has followed the accepted practice for broadleaved trees (Guha and Mitchell, 1965). The samples consisted of fully expanded, undamaged leaves taken from a branch exposed to full light on the south side of the tree, at about half the height of the crown. In addition, sampling has been restricted to July and August when foliar nutrient concentrations are relatively constant.

Common lime *(Tilia* x *europaea)* was chosen for a more extensive investigation of the variation in foliar nutrients through the season, between seasons and within the crown. Knowledge of this variation should allow more accurate interpretation of nutrient concentrations found in other trees provided that time and position of sampling are known.

Approximately 600 cm^2 of leaf were collected for each sample. These were oven dried at $100^{o}C$ overnight before the petioles and large veins were removed. The leaf blades were then ground up and stored in glass tubes until required for analysis.

Before analysis the samples were redried at $100^{o}C$ for 1 hour. A subsample of 100 mg of the ground leaf was then weighed into a test tube and dissolved in 1 ml of concentrated sulphuric acid. 0.8 ml hydrogen peroxide was added to the solution in two stages, each of 0.4 ml to control the reaction, before heating at 330°C for 30 mins. The solution was then allowed to cool for 10 mins before a further 0.2 ml of hydrogen perioxide was added and the solution reheated at 330°C for 10 mins before being made up to 15 ml with deionised water. After thorough shaking to mix the solution, subsamples were taken for analysis. Nitrogen concentration was measured by the colorimetric method (alkaline phenol) using an autoanalyser; P, K, Ca and Mg were assessed by plasma emission spectroscopy.

RESULTS

Tables 1 and 2 illustrate the type of information being gathered by the widespread sampling of 4 or 5 species during July and August each year.

Table 1.

Mean foliar nutrient concentrations (% o.d. weight) of four rosaceous species sampled in July/August 1977

Species	*Sample size*	*N*	*P*	*K*	*Ca*	*Mg*
Crataegus prunifolia	55	1.82	0.16	0.84	1.93	0.20
Malus spp.	89	2.12	0.18	1.23	1.84	0.33
Sorbus aria	100	2.23	0.19	1.14	2.18	0.29
S. aucuparia	101	2.17	0.21	1.16	2.24	0.30

The nutrient concentrations found in broadleaved trees are invariably higher than those in conifers used for forestry. For Sitka spruce *(Picea sitchensis)* growing well, Everard *(ibid)* cites N. P and K concentrations (all expressed as % oven dry weight) of 1.5+, 0.18+ and 0.7+. In the present study most broadleaved species have shown higher mean concentrations, particularly of N and K. The rosaceous plants sampled in 1977 showed an overall mean of 2.01% N and 1.09% K.

Table 2.

Foliar N concentrations (% o.d. weight) of three *Tilia* species sampled in July and August 1975

		N			
Species	*Sample size*	*Min.*	*Max.*	*Mean*	*S.D.*
T. x *europaea*	233	1.68	4.26	2.92	0.36
T. platyphyllos	97	2.27	4.56	3.03	0.41
T. cordata	61	2.06	3.98	3.09	0.39

VARIATION THROUGH THE SEASON

Variation in foliar nutrients through the season was monitored over two growing seasons (1977/78) using an avenue of 30 common limes at Avington, Hampshire, with samples being taken while the trees were in full leaf. The trees were sampled at 3 positions on the crown, the bottom, middle and top of the south aspect. For N, P and K the pattern was of a high nutrient concentration in May, immediately after completion of leaf expansion, with a steady decline until the leaves were shed at the end of October. The only period during which the nutrient decline slowed and concentrations became relatively constant was during July and August. In contrast, the total concentration of Ca in leaves increased throughout the season from approximately 1.5 per cent in May to 4.4 per cent in October. Mg concentrations showed no pattern of change and fluctuated between 3 per cent and 4 per cent throughout the season.

The height on the crown from which the sample was collected was found to make little difference to the nutrient concentration. Figure 1 illustrates within season variation of N for samples taken at 3 heights on the crown of the Avington trees.

BETWEEN SEASON VARIATION

Although between season variation could be compared between two seasons for the Avington trees, this source of variation was also examined over four years in 24 limes scattered around the Farnham area of Surrey. Leaf samples were collected during August each year from 1975 to 1978 ('78 data not yet available) using the standardised collection procedures. Correlation analyses were carried out to determine whether foliar nutrient concentrations were related over the years 1975 to 1977 inclusive. A summary of the significant coefficients is given in Table 3.

Table 3.

Significant coefficients for correlation analysis of N P K, Ca and Mg in 24 *Tilia* x *europaea* over the three years 1975-1977

	Correlation between data for		
Nutrient	*75-76*	*76-77*	*75-77*
N	-	0.431*	-
P	0.466*	-	-
K	0.801***	0.756***	0.899***
Ca	0.844***	0.933***	0.759***
Mg	0.840***	0.799***	0.837***

*Significance levels given in Table 4

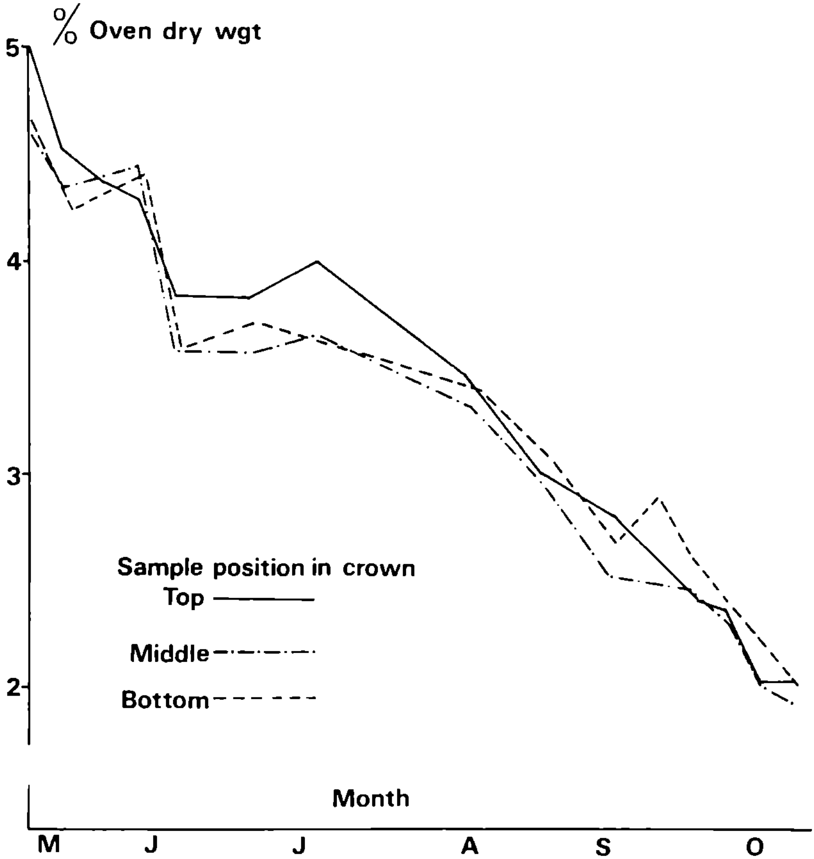

Figure 1. Variation in foliar N through the season (1977) at three levels in the crown of 30 Common limes at Avington, Hants.

The results of these analyses show a consistently high correlation between years for the concentrations of nutrients K, Ca and Mg, but for N and P there were no consistent or very definite relationships.

VARIATION WITHIN THE CROWN

Leaf samples collected from four common limes at Shortfield Green, Surrey, over the four years from 1975 to 1978, were taken from basal epicormic shoots and the bottom, middle and top of the crown. In the analysis of the results of this sampling the basal shoots have been treated separately from the true crown samples. The results for 1977 are summarised in Table 4.

Table 4.

Foliar Nutrient Variation with Height in four *Tilia* x *europaea*, 1977

	N	*P*	*K*	*Ca*	*Mg*
<u>Basal shoots vs True Crown</u>					
Basal	3.05	0.390	1.947	1.45	0.286
Crown	2.79	0.268	0.698	1.28	0.219
S.E. of the difference	0.042	0.012	0.050	0.064	0.0087
Experimental contrast	***	***	***	*	***
<u>Within True Crown</u>					
Bottom	2.80	0.267	0.700	1.37	0.224
Middle	2.77	0.249	0.680	1.29	0.223
Top	2.79	0.287	0.712	1.20	0.210
Standard error	0.036	0.010	0.043	0.055	0.0083
Experimental contrast	-	*	-	-	-

<u>Contrast scale</u>

* - significant at 5% level
** - " " 1% "
*** - " " 0.1% "

The results demonstrate that concentrations of all five nutrients in the basal shoots are very much higher than in the crown, so basal shoots should be avoided for estimating tree nutrient status. Within the true crown there was little change with height and only with P was the 5% level of significance reached for difference between the samples.

Samples were also taken from the four cardinal aspects on the Shortfield Green trees. As with variation with height, the results for the three seasons

1975 to 1977, for which the data have been analysed, were consistent. Taking 1977 as an example of the results, there was no significant variation in nutrient concentration with aspect in the true crown. In basal shoots the results were less consistent. In 1977 the concentration of N was greater for east and west than for north and south aspects. Basal samples from the southern aspect contained significantly less P and K than samples from the other aspects. Analysis of the basal shoots in the previous two years showed differing results so that these differences were rather spurious.

DISCUSSION

It can be concluded from the results obtained so far that samples should be collected during July and August. Provided shade leaves and basal shoots are avoided, it doesn't matter where on the crown the leaves for analysis are collected.

Although one case of Mg and K deficiency in Silver pendent lime *(Tilia petiolaris)* (Anon, 1979) has been recorded during the present work, it has been found that N is the only nutrient which may be in short supply. This is probably because most established amenity trees are situated on fairly fertile lowland soils, while in town soils there is rarely any shortage of P and K in the quantities required for healthy growth by broadleaved trees.

Present indications are that there is less variation in nutrient concentrations in the foliage between species than between deficient and healthy trees. Concentrations for healthy broadleaved trees appear to be of the following order (expressed as percentage oven dry weight).

N	P	K	Ca	Mg
2.0+	0.2+	1.0+	1.5+	0.2+

for samples collected during late July and August using fully exposed, fully expanded, clean, undamaged leaves.

ACKNOWLEDGEMENTS

This work could not have been done without the help and co-operation of many people. W.E. Matthews has taken an interest in this project since its conception and has helped in various ways. Col. J.B. Hickson of Avington Hall, Hampshire, has allowed us to carry out intensive sampling from his avenue of lime trees over two years. Within the Forestry Commission, I wish to thank the following foresters who have helped with the collection of foliar samples: K.F. Baker, I.H. Blackmore, D.A. Cousins, T.J. Davis, D. Elgy, J.B.H. Gardiner, C.W. Shanks, A.W. Westall; Mrs S.A. Wright, who has carried out the nutrient analyses, and R.C. Boswell who has been responsible for the statistical analyses.

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DISCUSSION

H. Williams - To what level must the foliar nutrients fall to be considered deficient?

H. Insley - Levels 50 per cent below the mean figure would indicate an unhealthy tree but consideration must not be given to a single nutrient - all the nutrients should be in a balanced proportion.

TREE NUTRITION IN THE UNITED STATES

by

Thomas H.R. Hall
Oxford University Parks

SUMMARY

This paper reviews the practices adopted for the introduction of nutrients as a palliative into amenity trees in the United States.

INTRODUCTION

Neely and Himelick (1971) recommended three methods of applying fertilizers to amenity trees:

i) surface application of mineral salts,

ii) placement of mineral salts in pre-drilled soil holes, and

iii) soil injection of nutrient solutions.

More recently stem injection has been shown to be effective.

SURFACE APPLICATION OF MINERAL SALTS

Mechanical spreaders, especially the hand-held types which can be used in small suburban gardens, are the most economical and practical means of applying fertilisers to the soil surface. For a mature tree, irrespective of species, it is assumed that the tree covers an area of 1,000 square feet. It is recommended that 6 lbs nitrogen, 3 lbs phosphate and 6 lbs potash should be applied to this area every 3-5 years depending on soil type.

PLACEMENT OF MINERAL SALTS IN PRE-DRILLED SOIL HOLES

Where fertilizers are placed in pre-drilled holes it is assumed that the feeding roots are in the upper two feet of soil within the canopy. Within this area, but not less than 2.5 ft from the stem, holes are augered or punched to two feet deep on a two foot grid. An NPK 10:10:10 fertilizer is applied to the holes at the rate of two level tablespoons sulphate of ammonia, one level tablespoon super-phosphate and one level tablespoon of muriate of potash per hole. However, the disadvantages of this system are the high labour requirement and mechanical root injury which may occur during hole drilling or as a result of too much fertilizer in too few holes.

SOIL INJECTION OF NUTRIENT SOLUTIONS

Fertilizer solutions are injected into the soil to a depth of 18 inches on a 2½ foot grid within the tree canopy at a pressure of 150-200 lbs/square inch. Each injection point receives 1.2 US gallons (1 imperial gallon) of a solution with a 30:10:7 NPK analysis (Funk, 1974). The equipment needed for soil injection is expensive and the facility is normally only available from contractors.

STEM INJECTION SYSTEMS

Surface application of fertilizers as a solid or solution can only be adopted where the tree stands in a permeable surface which extends beyond the canopy. For street trees and other similar situations nutrients may be applied by stem injection systems using a solution or solid fertilizer. Kielbaso and Ottman (1976) and Smith and Mitchell (1977) report the successful correction of manganese deficiency in maple *(Acer* spp.*)* while Neely (1973) controlled lime-induced chlorosis in Pin oak *(Quercus palustris)* by implanting capsules of mineral salts.

Two commercial injection systems are available in the United States. Both systems, Mauget and Medicap, require injections to be made every 4-6 inches around the circumference of a tree and as close to ground level as possible. The two systems are compared in Table 1 (page 33).

Workers with experience of stem injection for controlling Dutch elm disease *(Ceratocystis ulmi)* reported severe internal injury of trees as a result of many years of injection (Shigo and Campana 1977). It was concluded that injection systems should use as small and shallow a hole as possible to minimise serious problems within the tree. Neely *(ibid)* claims that fertilizer injection wounds callused within one year. However, Shigo *et al*. (1977) report wood discolouration but very little cambial die-back associated with the wounds when the Mauget system was used to inject Red maple *(Acer rubrum)*, White oak *(Quercus alba)* and Shag bark hickory *(Carya ovata)*.

CONCLUSION

The injection systems, adopted for control of Dutch elm disease, had limited success and this could prejudice opinion against investigation and adoption of a promising technique for applying nutrients to urban trees in Britain.

Table 1.

Specification of the Mauget and Medicap Nutrient Injection Systems

Requirements	*Injection System*	
	Mauget	*Medicap*
Size of hole	3/16" diameter x 2⅛" deep	⅛" diameter
Amount of fertilizer applied per hole	1.7 oz	1.75 oz
Form of fertilizer	Solution	Solid
Macro elements		
N	0.7% (ammonium sulphate and potassium nitrate)	12%
P	1.0% (ammonium di-phosphate)	4%
K	0.9% (muriate of potash)	4%
Trace elements	Chelated Edta	
	Cu 1%	Fe: Mn: Zn 4% each
	Fe 0.4%	
	Mn 0.1%	
	Zn 0.4%	
Pressure of system	8-10 lbs/in^2	0
Comments	Fertilizers absorbed in a few minutes - capsule and feeder tube then removed	Capsules remain in the tree. The system is not suitable for trees less than 2" diameter

The nutrient composition of both systems may be amended for specific problems

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BETTER VALUE TREES

Chairman M.E. Edwards
Director, Roses & Shrubs Ltd. Wolverhampton

who began and ended the session with these cautionary tales -

<u>The Lowest Tender</u>

They burned them one night
Close beside the planting site
There their heads and stems so slender
All that was left of the lowest tender.

<u>The Lowest Tender Revisited</u>

That's the lowest tender he cried!
And in the spring they died.
But they died before this spring,
They died before he put them in.
Sow your seeds as advised by Rowe
And watch your trees just how they grow.
And if you move but a few
Then do it as advised by Hugh.

THE BEST FROM SEED

by

D.C.F. Rowe
Forestry Commission

SUMMARY

Germination problems of seeds of a number of broadleaved tree species are surveyed with particular reference to interactions between dormancy controls, presowing seed treatments, and subsequent germination.

The results of various experiments carried out by the Forestry Commission Seed Branch are presented to demonstrate the value of presowing seed treatments producing reliable germination. Seed pretreatment conditions are described.

It is suggested that some nurserymen have not appreciated that reliable broadleaved seedling production is possible, and have been dissuaded from attempting pretreatments on the basis of misleading past experience.

INTRODUCTION

The paucity of recently published information, with the exception of McMillan-Browse (1979), is forcing nurserymen to rely mainly on out-dated, contradictory and unreliable recommendations from abroad, with the result that seeds are often being sown on an entirely hit-or-miss and uneconomical basis. Although the cost of seed is relatively small, considerable time and money is being wasted on preparing and maintaining seed beds for seeds in a condition unsuitable for germination.

Forestry Commission Bulletin 43, *Nursery Practice* (Aldhous, 1972) contains information about propagation of conifers from seed, but the information on broadleaved seedling production is very sketchy. It is based on limited experience because broadleaved tree seed research in the Forestry Commission had been restricted to species important to the forest industry. An increasing commitment by the Forestry Commission to amenity and environmental planting, including contract planting on motorways for the Department of Transport and a desire to improve the reliability of seedling production of ornamental species in trade nurseries, has prompted a review of the situation.

This paper presents the results of recent Forestry Commission research which demonstrates the effects of presowing seed treatments in producing reliable germination of broadleaved tree seeds. Also, procedures are recommended to propagators which will improve their seedling production rate.

SEED TESTING

By knowing the quality of a seed lot in advance of sowing, a nurseryman can adjust his sowing density to achieve optimum stocking density in the seed bed. If the seeds are home-collected or bought in without a test certificate, then even a simple cutting test to assess the number of full seeds should be adequate to provide a rough guide to the proportion of potentially viable seeds. More precise results can be obtained by submitting a seed sample to the Principal Seeds Officer at Alice Holt Lodge, Wrecclesham, Farnham, Surrey, who will, for a modest fee, perform a reduced 'quick information' seed test on the sample to provide an estimate of the number of viable seeds per kilogram.

Seed Dormancy

Unfortunately, very few of the viable seeds in a seed lot will be capable of germinating at the time of sowing, because most temperate broadleaved tree species produce seeds with some degree of dormancy. This means that seeds fail to respond when subjected to conditions of moisture, temperature and light, normally considered conducive to germination. Dormancy is imposed by a number of factors working either alone or, more often, in combination with one another, and may be classified into three main groups (Nikolaeva, 1967):

1. Exogenous or external dormancy imposed by factors in the outer seed covers These factors are often removed by a moist warm period.

   a. Physical inhibition - seed coats are impermeable to water, e.g. False acacia *(Robinia pseudoacacia)*.

   b. Chemical inhibition - seed coats contain an inhibitor, e.g. Korean ash *(Fraxinus rhyncophylla)*.

   c. Mechanical inhibition - outer seed coats provide a mechanical barrier to embryo growth, e.g. Oleaster *(Eleagnus angustifolia)*.

2. Endogenous or internal dormancy

   a. Morphological dormancy imposed by under development of the embryo. This condition usually occurs in combination with other factors.

b. Physiological dormancy imposed by factors in the embryo or in the inner seed covers, e.g. Box elder *(Acer negundo)* and *Nothofagus obliqua*.

3. Combined dormancy. Spindle tree *(Euonymus europaeus)* seed contain a morphologically immature and chemically inhibited embryo surrounded by an endosperm barrier which restricts gaseous exchange.

In nature, delayed and irregular germination is beneficial because it staggers the times of seedling emergence thereby increasing the chance of some surviving. However, during nursery propagation, irregular germination can be a serious problem to nurserymen because it leads to irregular stocking of different ages and sizes of seedlings, and can tie up seed bed space for an excessive length of time causing plant production costs to rise accordingly. Ideally, nurserymen should aim for a uniform crop of seedlings in the first year, but this goal cannot be achieved with most broadleaved tree seeds unless they receive a presowing treatment to break the dormancy.

SEED PRETREATMENTS

The variety of dormancy combinations means every species of seed must be given individual treatment to break dormancy. Seeds of most British native broadleaved tree species require either a period of warm, moist conditions followed by a prechilling treatment, e.g. hawthorn *(Crataegus monogyna)*, or just a prolonged, moist, prechilling treatment, e.g. beech *(Fagus sylvatica)*. The warm conditions facilitate inhibitor leaching, embryo maturation and stone breakdown while many, as yet ill-understood, physiological changes occur during the cold phase.

Most successful pretreatments are based, therefore, on the conditions experienced by seeds in nature. Attempts have been made to circumvent development of natural dormancy by collecting seeds early. Vincent (1970) suggested early collection of Lime *(Tilia* spp.*)* and hornbeam *(Carpinus betulus)* seeds and McMillan-Browse (1979) advocated collecting Field maple *(Acer campestre)* samaras before they dry out. Not only is this practice detrimental but, in the case of Field maple seeds, it is also unnecessary. Figure 1 shows that maximum germination of untreated Field maple seed occurs before the seeds are ripe but also before the embryos have reached final dry weight.

Early collection and sowing produces more seedlings but they are markedly inferior compared with seedlings which develop from mature embryos. It is better, therefore, to leave Field maple seeds on the tree and allow them to develop and dry naturally to a moisture content of about 10 per cent. If

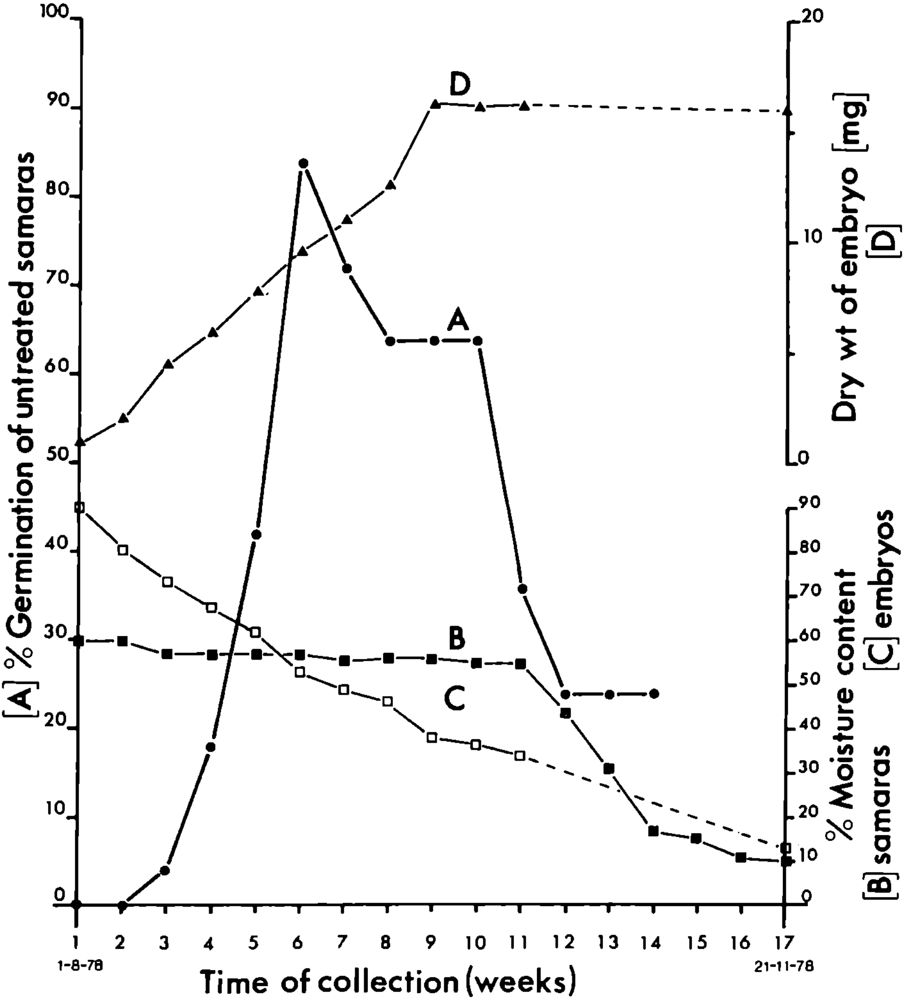

Figure 1. The development of dormancy in *Acer campestre* seeds is unrelated to the moisture content of the samaras or embryos. Maximum germination occurs at a time before the embryos have reached full physical maturity.

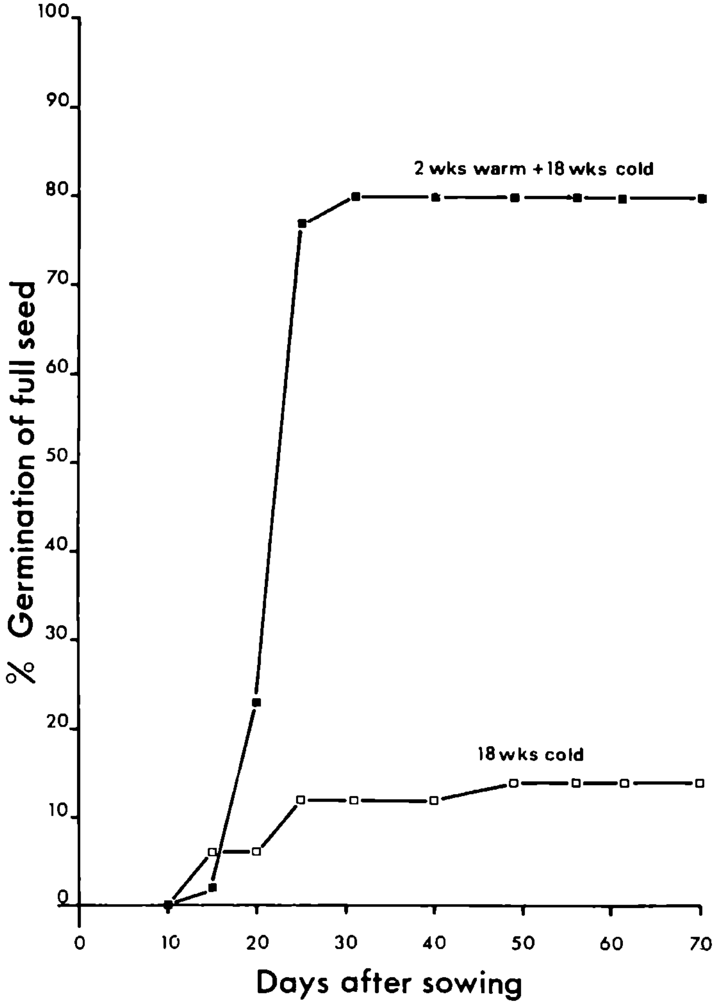

Figure 2. The nursery germination of *Prunus spinosa* seeds after pretreatment showing the benefit of a warm period prior to the cold.

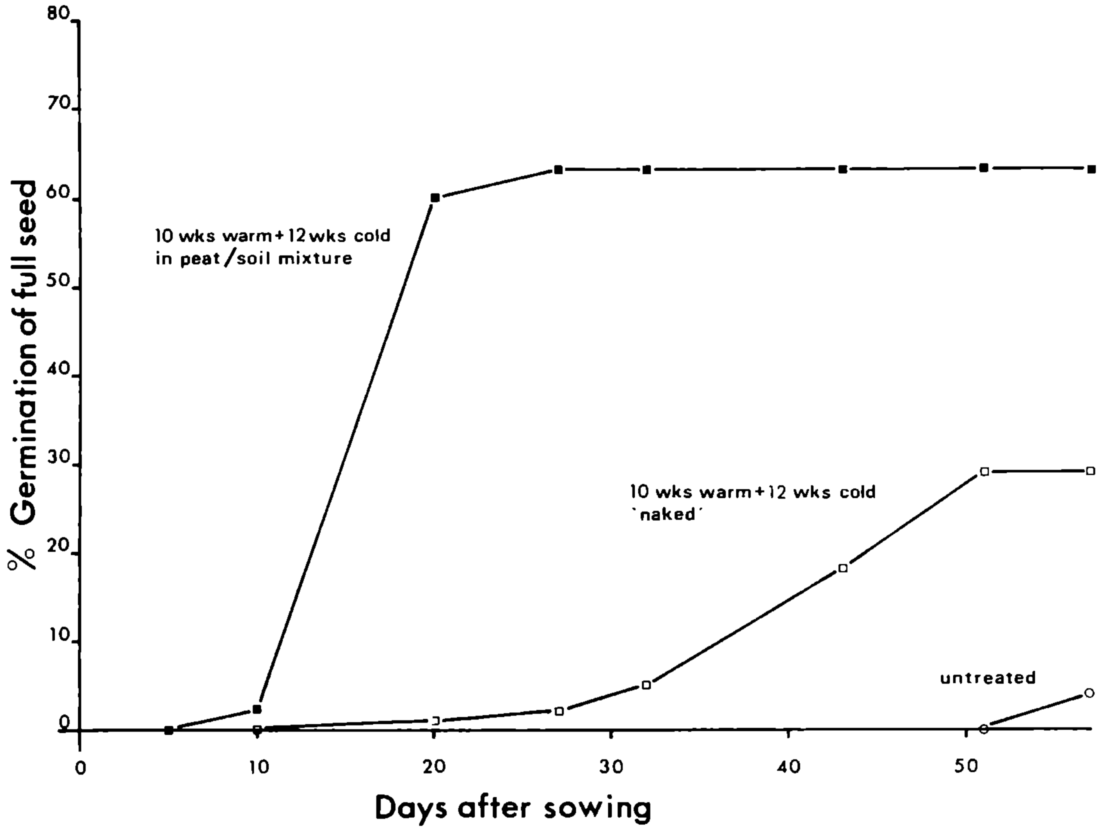

Figure 3. The nursery germination of *Sambucus racemosa* seeds demonstrating the benefit of using a water retaining medium during pretreatment.

exposing Swedish whitebeam seed to four weeks warm pretreatment prior to the cold period, prechitting, and hence pregermination should be reduced to zero. All seed lots of *Sorbus aria, S. aucuparia* and *S. intermedia,* tested in this way have reacted similarly; total germination may be reduced slightly but the crop appears over a shorter period, is more uniform and seedling quality is increased. This pretreatment is very useful therefore for *Sorbus* seeds which have been dried. However, if *Sorbus* fruits can be home-collected then the best practice to follow is to macerate the fruits immediately and separate the pulp from the seeds in water, because germination from uncleaned seeds is sporadic and unsatisfactory. Ensure the seed coats of cleaned seeds remain moist and then sow the seeds as soon as possible (September/October). Fresh *Sorbus* seeds are not deeply dormant so total germination will occur the following spring. Although this practice has only been tested for the seeds of *Sorbus* species, Bean (1929) stated that seeds of all *Malus, Pyrus* and *Sorbus* species will germinate most quickly when fresh.

During pretreatment seeds are very susceptible to desiccation, especially when a warm period is required. Seeds of alder *(Alnus* spp.*)*, Birch *(Betula* spp.*)* and *Nothofagus* spp. can be pretreated very successfully in a 'naked' condition but they require prechilling for four to six weeks only. Seeds requiring longer prechilling periods, or a warm pretreatment of any duration, benefit if they are mixed with two to four times their own volume of moistened water-retaining medium (an imbibing medium). Fine, sharp sand is adequate but a peaty soil compost is better. By mixing the seeds in this way, pretreatment times are reduced and final germination figures are increased. Figure 3 illustrates the beneficial effect of an imbibing medium on seeds of Red-berried elder *(Sambucus racemosa)*.

PRETREATMENT WITH GIBBERELLINS

Unfortunately the pretreatment methods discussed so far can be extremely lengthy processes. Researchers have investigated the possibilities of using growth stimulants, notably gibberellins, to induce rapid seed germination.

Experimental evidence suggests gibberellins occur naturally in seeds and play a regulatory role in seed germination of many woody species (Arias *et al.* 1976; Kentzer, 1966; Michalski, 1968; Ross and Bradbeer, 1968; and Webb *et al.* 1973). Furthermore, germination of many broadleaved tree seeds is shown to be stimulated by application of various gibberellins to the intact seeds (Bonner, 1976; Bradbeer and Pinfield, 1967; Burns, 1967; Farmer and Hall, 1971). However, the technique has seldom been proven a viable alternative to prechilling for nursery sown seeds.

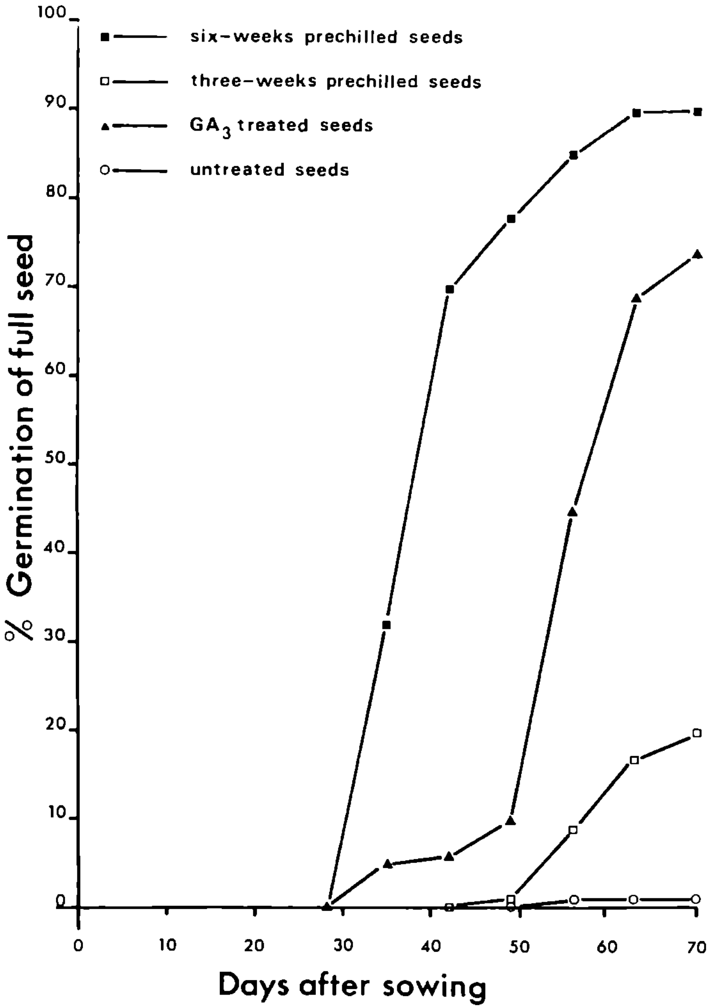

Figure 4. Effects of various seed pretreatments on the nursery germination of *Nothofagus obliqua* seeds.

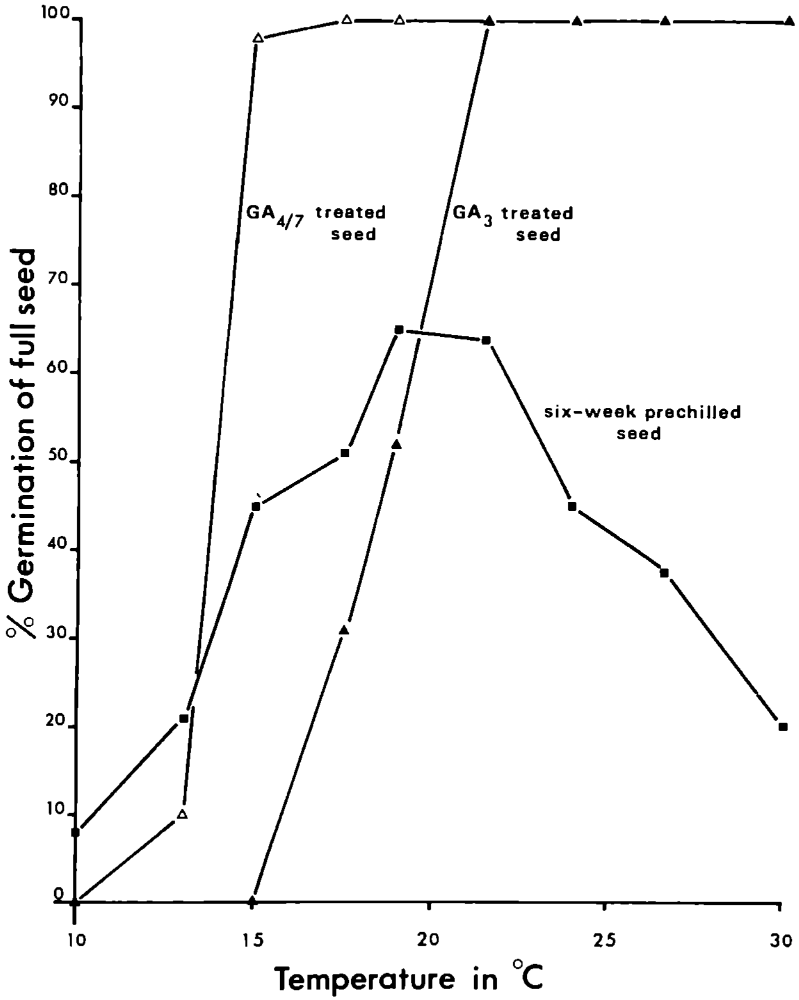

Figure 5. Effects of GA_3, $GA_{4/7}$, and a six weeks 'naked' prechilling treatment on the germination of *Nothofagus obliqua* over a range of constant temperatures.

Gordon (1977) showed that a 24-hr soak in concentrations of gibberellic acid (GA_3) between 50 and 200 mg/l produced 100 percent germination of viable seeds of both *Nothofagus obliqua* and *N. procera* within 14 days under laboratory conditions. Subsequent investigation (Rowe and Gordon, 1980) demonstrated that nursery germination of GA_3-treated seeds was unreliable. (Figure 4).

In terms of total germination induced, GA_3-treatment was inferior to a six-weeks prechilling treatment. However, Rowe and Gordon (1980) also demonstrated that a 24-hr soak in 50 mg/l $GA_{4/7}$ (a mixture of gibberellins A_4 and A_7) was only slightly inferior to a six weeks prechilling treatment for seeds of *N. procera* and superior for seeds of *N. obliqua*. $GA_{4/7}$ treatment is recommended, therefore, as a rapid and reliable alternative to prechilling treatment for nursery sown *Nothofagus* spp. seed. Figure 5 (?) demonstrates the differential effectiveness of GA_3 and $GA_{4/7}$ over a range of constant temperatures. $GA_{4/7}$ is able to induce almost total germination of *N. obliqua* seeds at constant temperatures down to 15°C, but GA_3 is only fully effective at temperatures above 21°C.

CONCLUSION

At present many nurserymen are paying scant attention to propagation of broad-leaved trees from seed because it is thought to be unreliable. Prescriptions for time-consuming methods of warm and cold presowing seed treatments cannot guarantee total germination but they do offer techniques which should be used more widely.

Although use of gibberellins has advantages, particularly the speed of seed treatment allowing flexibility of sowing time, many tree species produce seeds with deeply dormant embryos. Such embryos are unaffected by gibberellins or the seed coverings cannot be penetrated by the chemical. As a result gibberellin seed-soaks are unlikely to become a common pretreatment except for the treatment of *Nothofagus* spp. seeds and other species with similarly shallowly dormant seeds.

By selecting an appropriate presowing seed treatment nurserymen should be able to achieve reliable seedling production of many broadleaved trees.

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DISCUSSION

Dr Good - Firstly, what is the optimum concentration of $GA_{4/7}$ and secondly, do pretreated seed give better plants than untreated seed.

D. Rowe - 50 p.p.m. Plants developing from untreated seeds which germinate in the first spring are often poor and they seldom catch up with earlier germinations of pretreated seed.

B. Humphrey - Addition of imbibing medium in stratification and pretreatments is unattractive to the nurseryman because of problems of sowing or separation.

D. Rowe - Additives used by the Forestry Commission are peat or soil which may cause some difficulty but better results may justify extra work. Also imbibing medium appears to reduce rot in the radicle which can occur when some seeds are prechilled naked.

MOVING PLANTS SAFELY

by

H. Insley
Forestry Commission

SUMMARY

Assessments in 1978 and 1979 of trees delivered to motorway foresters have shown that 10 per cent and 3.5 per cent of trees respectively had lost more than 50 per cent of their moisture content between lifting in nurseries and delivery to planting sites. Experiments with broadleaved seedlings have demonstrated the effects of moisture loss on survival and height growth.

Chemical defoliants in multiple and single doses are being investigated in an attempt to induce leaf fall without causing damage, thus allowing nurserymen to lift trees earlier in the autumn. This would permit nurserymen to programme lifting operations with greater confidence and purchasers to spread the load of planting over a longer period.

EFFECTS OF MOISTURE LOSS ON NURSERY STOCK

When lifted, even dormant plants can suffer damage. Between the nursery bed and planting site nursery-grown trees suffer damage principally through root loss during lifting, drying out with consequent death of roots, and heating up as a result of poor packaging and handling. Forestry Commission research has been concentrated upon the problems of moisture loss, its effects on survival and growth, and means of minimising the problem.

Sampling of deliveries made to Forestry Commission motorway foresters by the trade in the 1978 and 1979 planting seasons demonstrated that drying out occurs even under the strict handling requirements specified by the Department of Transport (Insley, 1980). In the 1978 season, 10 per cent of the plants sampled had lost more than half the water they contained at lifting. The figure for the 1979 season was 3.5 per cent.

Effect of drying out on plant survival

It has been found that root loss through drying can kill seedlings (Insley, 1980). Figure 1 (p. 50) shows that the reduction in survival of seedlings of three species - *Nothofagus obliqua,* Sessile oak *(Quercus petraea)* and Norway maple *(Acer platanoides)* is related to the fall in moisture content between lifting and planting.

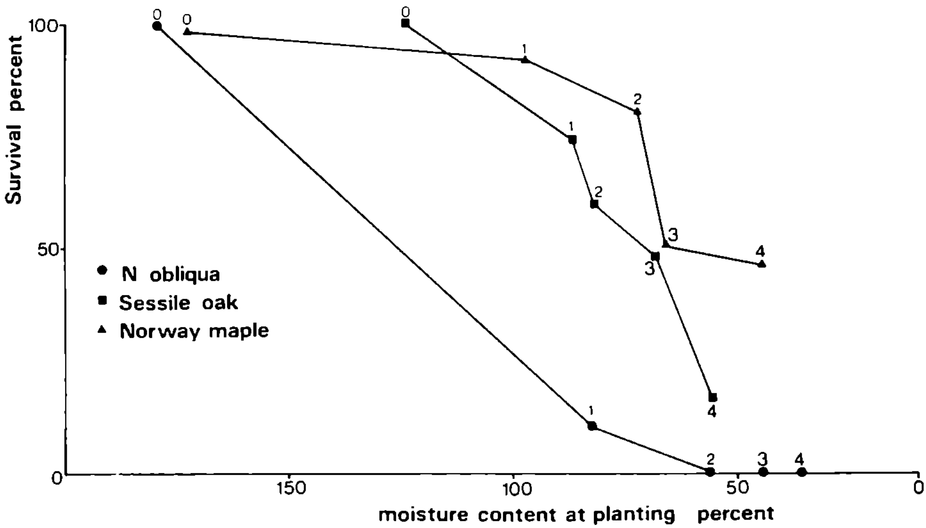

Figure 1. Reduction in survival of three species with fall in moisture content.

Different species varied widely in the rate at which they dried out during exposure and in their susceptibility to damage as a result of exposure. Species with finely structured root systems like birch *(Betula* spp.*)* and *Nothofagus* proved very susceptible to damage by drying, while species with coarser root systems like maple *(Acer* spp.*)* and lime *(Tilia* spp.*)* were fairly resilient and survived well even after four days drying.

Root structure and its relationship to drying out is being investigated further. Table 1 highlights the difference between a White birch *(Betula pubescens)* root system and that of Narrow-leaved ash *(Fraxinus angustifolia)*.

Table 1.

Proportions (as % of total root o.d. weight) of root systems of seedlings of two broadleaved species in each of four diameter size classes

Species	*Root diameter classes (mm)* 0.1	0.1-0.3	0.3.0.6	0.6+
Betula pendula	20.6	10.9	14.6	53.9
Fraxinus angustifolia	-	18.2	8.4	73.4

Birch, which is very susceptible to drying out, has a large proportion of its roots in the diameter class of less than 0.1 mm while ash, which is much less susceptible, has no roots in that class, its finest roots falling into the 0.1 to 0.3 mm diameter category.

Effect of drying on growth

Although in the more extreme cases of roots drying out plants can be killed between lifting from the nursery and replanting on site, it is more important that non-fatal levels of drying reduce shoot growth on trees after replanting. This is probably a physiological response to desiccation of roots since other workers have demonstrated reductions in the gas exchange of plants following root damage. Rabensteiner and Tranquillini (1970) found that gas exchange did not return to normal until the root : shoot balance had been restored.

In the United States, Mullin (1971) showed that growth in the season after planting out is related to exposure. Such relationships have also been found in the present work.

Figure 2 (p. 52) shows the variation in response in terms of height growth during the season after root exposure of two species. Small-leaved lime *(Tilia cordata)* seedlings, which have a fairly coarse root system, grew about 5 cm in height after planting out and there was little variation even after four days root exposure. However, Silver birch *(Betula pendula)* seedlings exposed over the same period showed a rapidly diminishing height increment with increase in exposure period.

This work demonstrates the harm caused by desiccation. Since plants will start to dry as soon as they are lifted, except under very damp conditions, the time that plants are out of the ground must be minimised or precautions taken to prevent moisture loss. Sealing trees in polythene is one method that has been examined. There can be problems with the use of polythene but guidelines for its

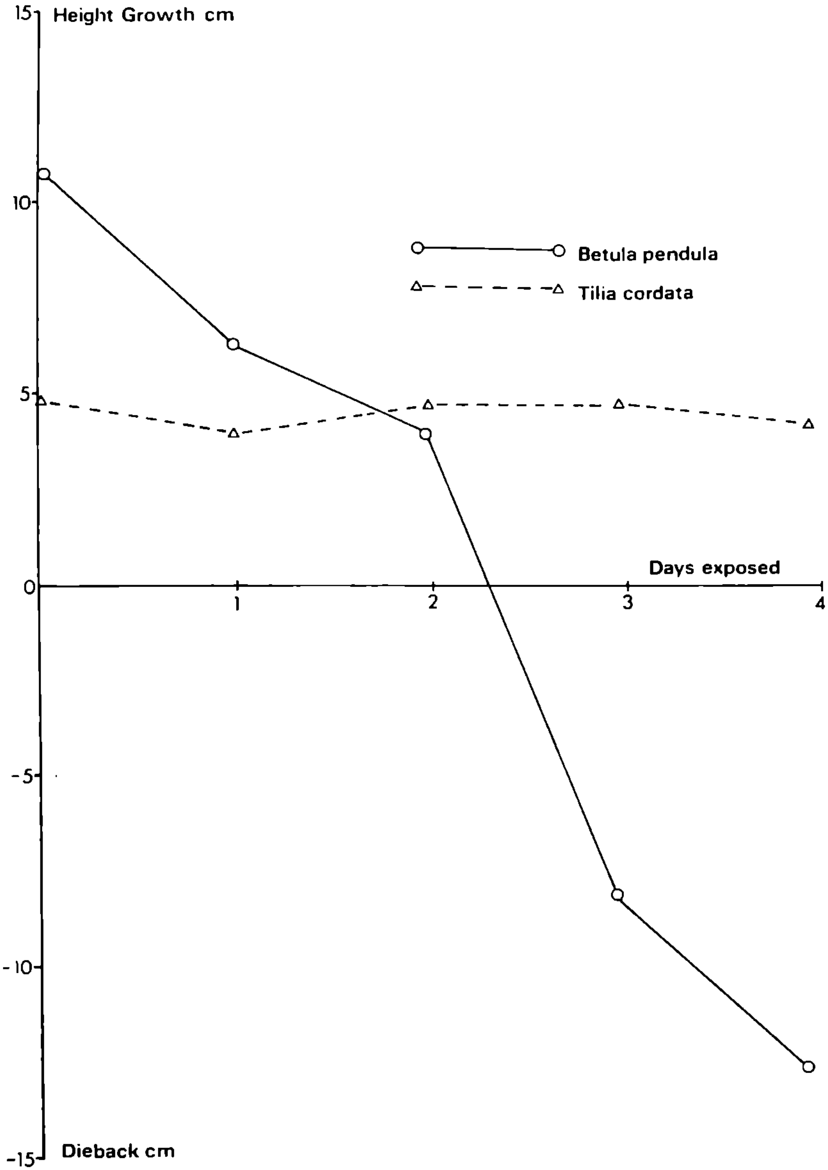

Figure 2. Height increment during the first growing season of seedlings planted after initial exposure to drying periods of 0-4 days.

safe use for the movement of nursery stock have been laid down (Aldhous, 1972).

An experiment carried out with White birch seedlings examined the loss of moisture when either roots or shoots were sealed in polythene compared with unprotected trees. This demonstrated that moisture was lost most rapidly from completely unprotected seedlings, and that those with roots exposed lost water more quickly than those with roots covered (Insley, 1979). That more moisture is lost through roots than shoots is not unexpected, and this provides nurserymen with a compromise to complete wrapping, which is to simply protect the roots.

CHEMICAL DEFOLIATION

The nursery trade is regularly pressured by customers for autumn delivery of trees and shrubs. At the same time customers expect plants to arrive on site in good condition, with the roots fresh and moist, the shoots dormant,and, in the case of deciduous plants, leafless. However, very few deciduous tree species are completely leafless before the end of November. Because dormancy is partly determined by the weather, lifting of field-grown trees is probably the most difficult operation for a nurseryman to programme. The use of chemical defoliation can extend the lifting season and enable nurserymen to supply a tree which is leafless and dormant.

Chemical defoliants

The range of chemicals which have been tried as defoliants by previous workers is very large. In recent work the most frequently used have been potassium iodide (KI), ethephon (2 chloro-ethyl phosphonic acid) and D.E.F. (S,S,S-tributyl phosphorotrithioate). Defoliation of hardy nursery stock is not itself very difficult. However, it requires careful timing and correct rates of chemical to defoliate plants without causing damage which shows either immediately or the following season in the form of dieback.

Dieback and growth reduction after defoliation

Consideration of the efficacy of a chemical defoliant must include assessment of any possible plant damage as well as the chemical's ability to induce leaf abscission. A distinction must also be made between damage caused to plants during defoliation as a result of genuine phytotoxicity and simple physiological damage resulting from the act of defoliation.

Damage resulting from too early an application of defoliant can take the form of shoot dieback, reduced shoot growth in the following growing season or both.

Therefore it is only when the plant has accumulated sufficient reserves for leaf expansion and early growth the following season, that defoliation can be safely carried out.

The period when deciduous nursery stock can be defoliated usefully is between the time when defoliation no longer triggers refoliation and natural leaf fall. This can be as long as seven weeks. However, within this period there is a point after which defoliation does not affect the subsequent growth of trees, and it is only after this point in time that it becomes safe to defoliate.

The difficulty with using defoliants is that the period of reserve accumulation (maturation) required before defoliation can be carried out safely varies between species, cultivars, localities and seasons. The effect of chemicals is also variable. For example, ethephon is more effective when the ethylene, which is the active ingredient, is released slowly at low temperatures, than at higher temperatures when it may be given off quickly.

Trials with defoliants

The current work commenced in October 1977 with a trial of a commercially produced defoliant, Ethrel R (ethephon and hydriodic acid) on six broadleaved species growing in Hillier Nurseries at Ampfield and Romsey, Hampshire. Response varied considerably between species and it has subsequently been found that this is so whatever the defoliant used. Hawthorn *(Crataegus monogyna)*, Common alder *(Alnus glutinosa)* and Norway maple showed no response, while *Nothofagus obliqua*, London plane *(Platanus* x *hispanica)* and Turkey oak *(Quercus cerris)* sprayed with 2 per cent and 4 per cent solutions, showed significant loss of leaves compared with controls sprayed with water and wetting agent only (Insley and Gardiner, 1978).

The following season a larger screening trial was carried out using RH 2915 (A Rohm and Haas herbicide containing oxyfluorfen as the active ingredient, Ethrel R, D.E.F., potassium iodide and ammonium sulphate). In each case the chemicals were tested both with and without a pretreatment, applied seven days before defoliant application with a 0.5 per cent solution of solubised ethephon (Turner and Loader, 1974). The species used were Silver birch, Grey alder *(Alnus incana)*, Hornbeam *(Carpinus betulus)* and London plane. These were chosen for variation in the ease with which they could be defoliated; hornbeam being very easy and plane, with its waxy pubescent leaf covering, very difficult. In all cases (except Grey alder with 0.8 per cent potassium iodide) ethephon pre-treatment enhanced the defoliant action of the chemical used.

The purpose of ethephon pretreatment was to act as a growth retardant. However, it is more likely that the ethylene released by the ethephon acted in combination with the defoliant chemical to produce a more effective abscission. (Insley and Boswell, 1980).

After 14 days the greatest defoliation had been achieved by spraying a 0.8 per cent solution of potassium iodide whether or not a pretreatment of ethephon was used. Very little was lost by reducing the strength of the solution to 0.4 per cent. RH 2915 at 4 kg per ha with a pretreatment of ethephon appeared to be the next best defoliant, although without ethephon it was fairly ineffective. The control treatment of water + wetting agent (Teepol) or control + ethephon always produced least defoliation,demonstrating that all the chemicals tested were effective to varying degrees as defoliants.

Because of the relatively high cost of Ethrel R and ethephon, further trials were carried out during 1979 using potasium iodide alone, applied at both low and medium volume. This trial has shown that, provided the concentration of potassium iodide is high enough, either low or medium volume applications will induce effective defoliation compared with control plots.

Table 2.

Defoliation of Silver birch at 15 days after low volume (50 litres/ha) spraying with potassium iodide in water.

Solution (per cent)	*kg/ha*	*Leaves lost (per cent)*
1.5	1.34	67
3.0	2.67	75
6.0	5.34	78
Control (water only)		36

These trials have shown that potassium iodide or, for more difficult species, a pretreatment of ethephon one week before spraying with potassium iodide, will successfully induce leaf drop. Multiple applications or mixtures of defoliants seem to work better than a single dose of one chemical. The only problem remaining is how to determine when to apply the chemical without damaging the plants. Unfortunately there is no easy practical method of identifying the completion of 'maturation'. Because of this the best solution for nurserymen is probably not to try to gain the whole period between completion of 'maturation' and natural leaf fall, but to time defoliant application late enough to be safely past this stage while still gaining two to three weeks advance in abscission. In the south of England this probably means application in the third or fourth week of October in all but the latest of seasons. Further work will be carried out to produce a prescription for rapid effective defoliant with a low phytotoxicity for as wide a range of amenity tree species as possible.

ACKNOWLEDGEMENTS

We are indebted to A.P. Dunball and R. Cure of the Department of Transport who allowed us to take samples from deliveries of trees being made to motorway foresters in 1978 and 1979; to B.E. Humphrey and J. Woodhead, Hillier Nurseries (Winchester) Ltd for making available the nursery stock on which the defoliant trials have been carried out. Within the Forestry Commission the following research foresters have been actively responsible for the work described in this paper:- I.H. Blackmore, T.J. Davis, J.B.H. Gardiner, P.D. Howard, C.W. Shanks, A.W. Westall, J.E.J. White, and the late D.H. Jackson. The work reported in this paper has been carried out under Department of the Environment Contract No.483/7.

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DISCUSSION

E. Larratt - What is the value of anti-transpirants as an aid to reduce desiccation?

H. Insley - There has been no research in the current series of experiments but the protective film is thought to be too short-lived to produce adequate reduction in moisture loss. Previous Forestry Commission work to test the use of anti-transpirants to improve survival did not show those materials tested to be effective.

B. Humphrey - Does soaking dried or partially desiccated roots or plants have any remedial effect?

H. Insley - No detailed work to date, but investigation of correcting drying is the next logical step in the programme.

PLANTING ON MAN-MADE SITES

Chairman W.T. Preston
Landscape Officer, London Borough of Ealing

SURFACE WORKINGS AND TREES

by
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Forestry Commission

SUMMARY

Restoration for forestry requires careful planning in which foresters must be involved. Restored spoils of all textures are almost always compacted. Thirty-metre wide ridges with slopes of 1:10 to 1:15 both shed water and allow it to move in the spoil. The ridge should slope length-ways and drains may be needed in the gullies on heavier spoils. The compaction can be relieved by cultivation across the ridges with a 300 h.p. tracked tractor and triple tines, preferably mounted on a parallelogram linkage. Tining should be to 70-80 cm over porous materials, but only to 50 cm on heavy textured spoils. Wings on the tines improve the efficiency of cultivation. Where there is insufficient material to raise the restored ground above the water-table, carefully sited lakes may improve appearance, raise the level of the remaining land surface and form useful habitats for wildlife.

Where there is no organic matter or top soil, alders or *Robinia* should form 50 per cent of the crop, with pines, larch and birch as the other species. Commercial crops at low elevations will commonly be pine. Where spoil is moderately fertile, larch, sycamore and maple may be used. Climax species such as oak, beech, hemlock and spruce should be avoided.

INTRODUCTION

There are extensive mineral workings in Britain; estimates for 1974 for England are shown in Tables 1 and 2. (Anon 1975).

Table 1 (which does not include inherited dereliction) shows that holes are three times more common than heaps; that the heaps are mainly spoil from coal mining; and that nearly half the holes derive from sand and gravel workings. This paper is devoted entirely to problems in the restoration of surface workings, and most Forestry Commission experience has been on sites worked for sand and gravel, open-cast coal and ironstone.

Table 1.

Mineral workings in England 1974
000' ha (DOE 1975)

Mineral	*Area currently affected*			*Area not yet affected*	*Total area*	*Counties mainly concerned*
	Spoil heaps (1)	*Excavations + pits (2)*	*Total (1+2) (3)*	*(4)*	*(3+4)*	
Sand and gravel	1.2	17.0	18.2	15.2	33.4	Beds, Berks, Bucks, Cambs, Cumbria, Derby, Dorset Durham, Essex, Glos, Hants, Herts, Kent, Lands, Leics, Lincs, Norfolk, N. Yorks, Notts, Oxford, Staff, Suffolk, Surrey, Warwick, W. Sussex, Gt. London.
Clay and shale	0.8	4.6	5.4	6.5	11.9	Beds, Cambs, Derby, Devon, Kent, Leics, Staffs, Manchester, W. Yorks.
Coal	7.2	1.7	8.9	2.2	11.1	Derby, Durham, Leics, Northumberland, Notts, Staffs, S + W. Yorks.
Limestone	0.5	5.0	5.5	5.2	10.7	Cumbria, Devon, Derby, Dorset, Durham, Staffs, Somerset, S + W. Yorks.
Ironstone	-	1.2	1.2	4.9	6.1	Leics, Northants, Oxford.
China clay	0.8	1.0	1.8	3.2	5.0	Cornwall and Devon.
Silica moulding sand	0.1	1.9	2.0	1.9	3.9	Beds, Cheshire, Kent.
Chalk	0.1	2.1	2.1	1.6	3.7	Essex and Kent.
Igneous rock	0.4	0.9	1.3	1.4	2.7	Devon, Cornwall, Salop.
Sandstone	0.3	0.8	1.1	1.1	2.2	Cumbria, Warwick, W. Yorks.
Gypsum/anhydrite, slate, vein materials and others	0.9	0.6	1.5	2.2	3.7	Avon, Beds, Cornwall, Cumbria, Notts, N. Yorks, Surrey.
Total	12.3	36.8	49.1	45.3	94.4	

Table 2.

Mineral workings, England 1974
Areas with permission, 000' ha (DOE 1975)

	Land currently affected	*Land not yet affected*	*Total*
Covered by restoration conditions	36.2	37.3	73.5
Not covered by restoration conditions	12.9	8.0	20.9
	49.1	45.3	94.4

Table 2 shows that a surprising proportion of sites with permission for work are not covered by restoration conditions, which means it may not be possible to make the operator of the working restore it to a state regarded as satisfactory by the forester. It is very important with any new site to agree the principles and scheme of restoration before work starts, so that suitable land forms, as described below, can be built into the plan. Because a tougher line backed by planning law is now taken by local authorities it has become easier to insist on adequate standards of restoration.

Much ground worked for minerals will be restored to agriculture, but because of loss or degradation of top soil this can be difficult. Forest crops, in many respects less demanding than agricultural crops, are an alternative land use. Furthermore, when Country Parks are envisaged, or when some screening or break in the skyline is required, trees may be planted primarily for their appearance, which widens the choice of species considerably. Large water-filled workings may be used for recreation (sailing, fishing) but the area which can be used in this way is usually limited.

TRADITIONAL RESTORATION OF SURFACE WORKINGS

Up to 20 years ago most restoration followed drag-line working, with little further modification of the resultant steep hill-and-dale topography. This type of ground was easy to plant, and trees on the slopes and tops grew well, though the hollows were often water-logged or full of boulders. The forester also found that managing plantations on such steep slopes could be difficult and extraction of timber now presents problems.

Present techniques

Most mineral extraction is now done with box-scrapers and hydraulic shovels or back-acters; in recent years the drag-line has been restricted in use to ironstone working and some of the larger open-cast coal sites. Restoration will also be done by dumper and box-scraper, finished off by dozer blade. This engineering approach often results in very level sites, with a slope no greater than 1:100 or 1:200, which allows flow of water in well-graded drains but not through the soil. However, the laying down of a large number of relatively thin layers, each traversed by heavy machines, results in serious compaction and poor aeration, leading to water-logging, poor rooting and difficult planting conditions. In these conditions tree planting is badly done - a point fully appreciated only by those who have tried to plant such sites! Compaction of this degree is found even on sandy-textured materials. On sites where minerals have been worked for a long time, or which have been allowed to go derelict, the original topsoil has often been lost (or sold off), or else stored for long periods in dumps with resultant deterioration of structure and loss of nitrogen.

The first investigation to relieve this compaction used cultivation with plain tines. However, unless the tining penetrated through to uncompacted or porous materials, the result was a somewhat greater depth of water-logged material; indeed, it was suggested that conditions were worse rather than better!

Topography

Reasoning suggested that a greater slope was needed on the ground, so that the water could flow sideways <u>through</u> the loosened spoil to a drain. A gradient of between 1:10 and 1:15 was chosen as combining acceptable appearance with adequate water movement, whilst still providing reasonable stability without the need to sow grass or grass-clover swards to control erosion.

Such gradients can be produced either by doming the whole site, or by making a series of ridges each of which drains laterally from its crest to the intervening furrow. Ridges have the advantages of being less intrusive in the landscape, requiring less spoil than a dome, and the maximum distance to a drainage channel is only half the ridge width.

The current view is that ridges should be between 20 and 40 metres across, the size being dictated by the machinery used for the work. Thirty-metre ridges suit a Caterpillar D8 or equivalent, 20 m ones should suit smaller machines. The ridges should slope gently along their length, at about 1:100 or 1:200, so that water in the gullies between will flow off site, without causing erosion. The scheme must be planned, <u>before</u> extraction starts, taking account of the volume of materials on site, the water table, the land forms desired, the slopes and the distances to water courses.

If there is insufficient material on site to give between 0.7 and 1 metre of freeboard above the water-table, then more must be imported. Alternatively, lakes and ponds can be constructed which not only form features in the landscape but also help to raise the restored land surface above the water-table. This has been done at Bramshill Forest, Hampshire, where the lakes contain islands for water fowl to nest on.

Silting, both in ponds and outflows, is likely until the ridges have settled, and must be taken into account in designing silt traps or a series of ponds.

Compaction and cultivation

In 1976, a three-tine assembly mounted on a 300 h.p. Caterpillar D8 tractor was used to cultivate areas newly restored and also to cultivate between lines of slow-growing trees. This was successful, but it was found on unplanted ground that two passes of the plain tines (which were set at 1.2 m spacing) were needed to give full loosening of the profile. An experiment testing three intensities of cultivation was established and the results for the first four years are shown in Table 3.

Table 3.

Cultivation intensity on reclaimed gravel workings
Bramshill Forest, Hants. March 1976.

	Spaced shallow cultivation	*Spaced deep cultivation*	*Complete deep cultivation*
	A. Deaths up to June 1977, per cent		
Corsican pine	14	3	2 ns
Bishop pine	25	10	11 ns
	B. Heights after 3 yrs, cm		
Corsican pine	21a	37c	37c
Bishop pine	37a	54c	60c
	C. Heights after 4 yrs, cm		
Corsican pine	32a	71c	71c
Bishop pine	66a	97b	111bc

Letters denote significant differences in treatment means as follows:

a : b	5%
a : c	1%
ns	not significant at 5%

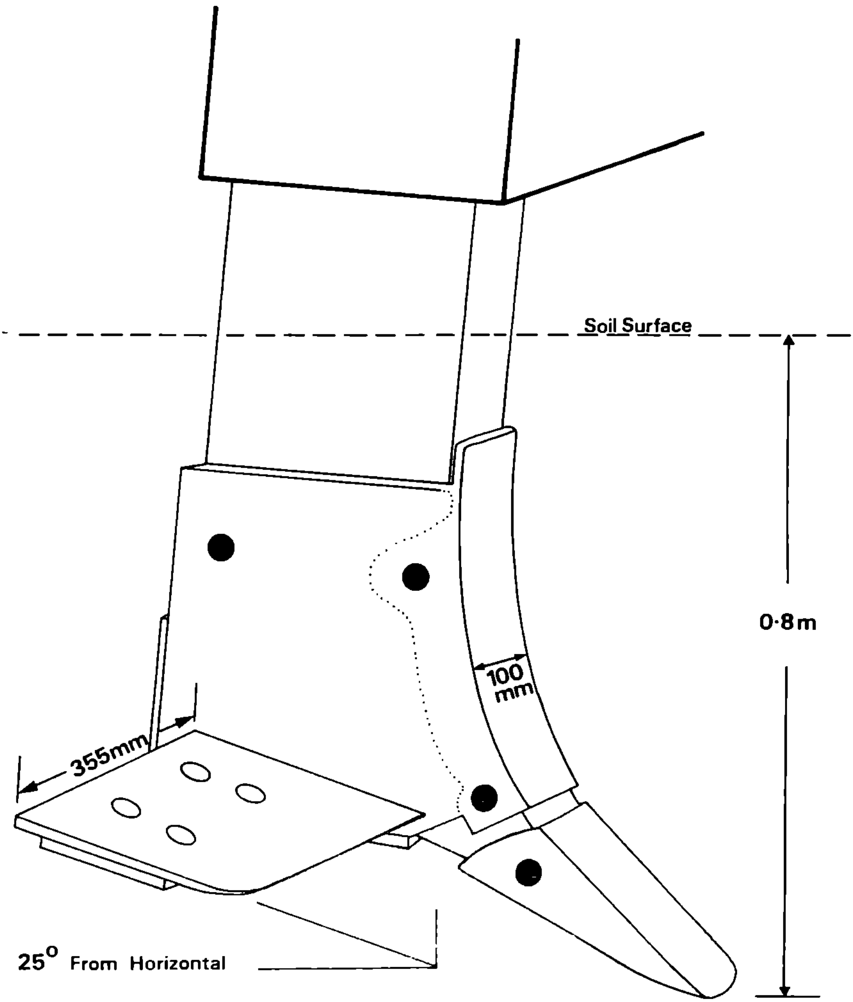

Figure 1. Current design of winged tine. The 25° angle was found to be the best compromise for the factors of resistance, disturbance, and wear on the underside of the plate.

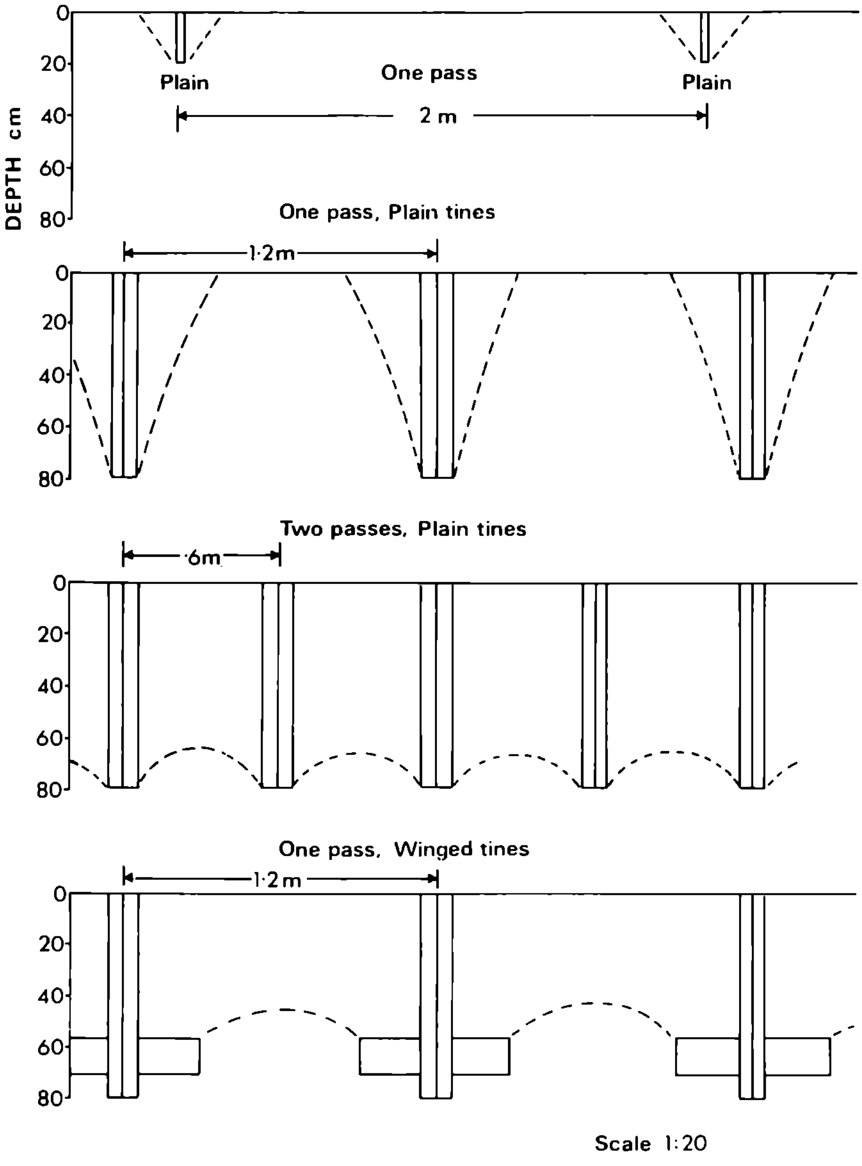

Figure 2. Disturbance with increasing intensity of cultivation.

The need to use two passes of the plain tines was clearly a disadvantage. Following discussions with Mr Gordon Spoor, National Agricultural Engineering College, Silsoe, Bedfordshire, who had been experimenting with winged tines for cultivation of agricultural soils, a scaled-up version of his system was produced for use on surface workings restored for forestry (Fourt 1979). The design of the tool is shown in Figure 1 and the effects produced by it and the three intensities of plain tining used in the experiment are shown in Figure 2.

On some sites it has been found difficult to pull three winged tines with a D8, even with its 300 h.p. Two winged tines in the outer positions with a plain tine in the middle was adopted, as the best compromise. This arrangement, together with the mounting system, is shown in Plate 1. A 400 h.p. tractor - D9 or equivalent - would certainly pull three winged tines, but these machines are less common. Moreover, they need a police escort on the road while the wide tracks are too big to go through forest gates.

Plate 1. Outer winged tines with a plain centre tine, mounted in a tool bar on a hydraulic parallelogram linkage. (A10002)

A system of ridges, cross-ripped with winged tines, has recently been tried on a 90 hectare opencast coal scheme in the Forest of Dean. Originally the site was a particularly wet and sticky area of forest with only moderate tree growth. The restoration scheme was designed before extraction was started and included two lakes. Borings were examined to see if there were strata at depth, suitable for soil forming; some were located, the material set on one side and put back at the top of the restored column of material. Any topsoil worth saving was put back as the final layer. The ridges were made with box-scrapers and bulldozers, and then ripped across with a D8, with either winged or plain tines. After some initial resistance the operators accepted the system, which involved little extra work and gave very satisfactory results.

Ridge designs for two different site types are shown in Figures 3 and 4 below.

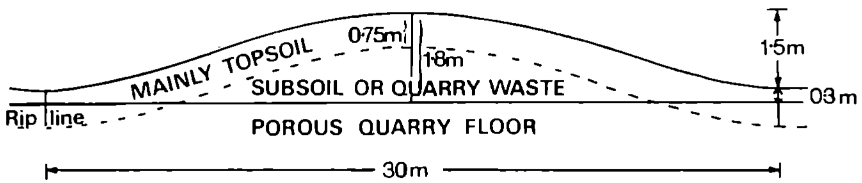

Figure 3. Land form for restoration over porous sands. Ridges ripped across by Caterpillar D8 with multi-shank ripper, tool points at 75 cm. Vertical scale 2 times horizontal.

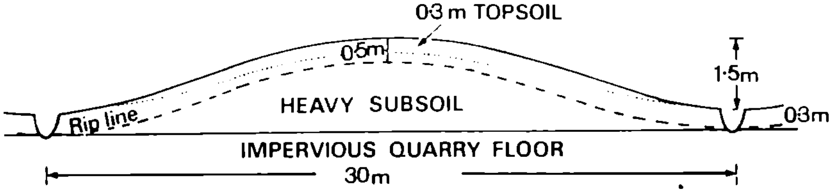

Figure 4. Land form for restoration over impervious materials. Ridges ripped across by Caterpillar D8 with multi-shank ripper, tool points at 50 cm. Drain put in by side-acting digger. Vertical scale 2 times horizontal.

Time of cultivation

Soil conditions at the time of cultivation are critical. It is no use cultivating when the soil is plastic because machines will have difficulty traversing the ground and cultivation will not work properly. This means that cultivation (and restoration) operations should be restricted to the period from May to September, though advantage may be taken of dry periods in spring or late autumn. It may be necessary to stop operations altogether during wet spells in summer.

Mounted and trailed tines

If contractors do not have the mounted parallelogram system for tines they may wish to use trailed tines. However, the mounted system of tines is better than trailed tines because:

a) it ensures good control of depth,

b) the outer tines follow without fail in the tracks of the vehicle, ensuring that any compaction caused by the vehicle itself is immediately removed (thus machines with a single, central tine are undesirable),

c) the whole assemblage is very manoeuverable, and

d) the operator can lift the tines clear and start again if buried objects too big to move (tree stumps, boulders, baulks of timber, large-diameter hawsers) are encountered.

Access to the ridges must be provided from a hard-surfaced ride or road, to allow further restoration operations and provide good access for machines later on.

Soil water supply

People sometimes assert that slopes of 1:10 followed by deep tining will result in loss of soil water by shedding and draining, so increasing the incidence of drought. This cannot be so, provided the material is loosened enough to allow water to percolate to the full depth of cultivation (ideally 70-80 cm). Any water not firmly held by the soil is by definition harmful; in other words, if it will drain away, it is not wanted. Where restored soils overlie clays or other impermeable materials it is especially important to move this excess water away as rapidly as possible. Seventy centimetres of rootable material will supply adequate water storage for young tree crops, especially if the ground is free of other vegetation.

Nutrition

Experience on a wide variety of site types has shown that, with the raw materials used in restoration, trees are not normally limited for growth by shortages of phosphorus, potassium or magnesium, at least in the early years. Nitrogen deficiency however is common, because most of the material used in restoration lacks organic matter especially where there is no topsoil. Nitrogen deficiency can be dealt with either by regular additions of a proprietary fertiliser, or by using trees and other plants which fix their own nitrogen. (It must be emphasised that inorganic nitrogen will be wasted unless compaction has been dealt with first). Alders *(Alnus* spp.*)* of several species are suitable and *Robinia pseudoacacia* has also been used. There are no other obvious species of forest tree which fix their own nitrogen, but a number of shrubs and herbs are worth considering. Examples are: broom *(Cytisus scoparius* and *C. alba)*, Perennial lupin *(Lupinus arboreus)*, Everlasting pea *(Lathyrus sylvestris* and *L. latifolius)*, oleaster *(Elaeagnus angustifolium)*, medick *(Medicago lupulinus)*, and Sweet and other clovers *(Melilotus* and *Trifolium* species). The ideal would be a vigorous perennial herb, which would return some of the nitrogen fixed from the atmosphere when it died down each year, but which would not compete with the trees.

SURFACE WORKINGS FILLED WITH RUBBISH

Owners of large holes in the ground, derived from mineral workings, are often pressed to accept rubbish as a fill. Alternative ways of disposing of rubbish are expensive and existing open tips are often eye-sores and may be health hazards. The pressure to put rubbish into holes in the ground is therefore increasing. In towns such filled sites may be used for playing fields or green spaces, and in the country they are usually returned to farming. However, in some places playing fields are not needed and the ground may be too poor for farming, so trees are planted either as production forest or for amenity. Unfortunately little research has been done on the best way to finish off such rubbish-filled holes for good tree growth. The following should be regarded as basic principles, outlining a system commonly used.

Types of rubbish

Household rubbish is probably the commonest type, with some additional waste from light industry (metals and plastics). Toxic wastes from heavy industry are quite another matter, needing special treatment, and are not dealt with in this paper. The main feature of today's rubbish is the large amount of paper and plastic and the low proportion of ash, compared with rubbish from even 20 years ago. Water may percolate rather slowly through layers of paper and plastic, so that anaerobic decomposition sets in. Whether this is important depends very much on the geology of the pit.

Types of pits

Although, as will be mentioned below, all rubbish tips should end up with the same final treatment, more care is needed in impervious materials (e.g. clay) than in porous materials (e.g. sand, gravel, chalk). Water that moves into a pit on porous materials can also move out, so that any decomposition products become diluted and disperse. In contrast, water cannot move out of a pit in impervious material so that it inevitably becomes anaerobic. If an impermeable seal is needed to keep water out, it can be argued that materials able to produce unpleasant decomposition products should not be put in at all.

Design and topography

As with other forms of restoration, it is essential to agree the design before operations start (though frequently the decision to tip rubbish is made after extraction is under way). Each day's tipping must be covered to avoid the nuisance of rubbish blowing about, smells and flies. Thus appreciable quantities of clean fill are needed and these must come either from waste on the site (usually readily available on sand and gravel sites) or else brought in from outside.

As in any restoration, a slope is needed on the finished ground. This not only helps rooting but serves to keep water out of the pit. The 1:10 to 1:15 slopes proposed for normal restoration seem suitable and also ensure that if, in spite of efforts to compact the site properly, some local subsidence does occur, the tendency to form pools of stagnant water will be reduced. All the near-level sites examined tended to accumulate water in large pools after rain and if trees had been planted a high proportion were found to be dead.

Long, low ridges are generally preferable to a single dome covering the whole site, because the former usually fit better into the landscape. However, there may be sites where a big dome, to form an eventual wooded hill, would be acceptable.

Methods of working

The following system is in general use and was observed in a worked-out sand and gravel pit in Ringwood Forest on the Hampshire-Dorset border. Parallel banks, which may be several hundred metres long, about 1½ m in height, had been constructed of sand-pit waste and spaced about 30 m apart. Rubbish was then tipped at one end between these, against the quarry face, continuously compacted and covered with sand-pit waste moved in by front-end loader. It was finished off as a gently sloping, 30 m wide ridge, about ½ m taller in the centre than at the edges. The design, which can be repeated across the floor of the quarry, is shown in Figure 5.

Compacting each layer of rubbish reduces the rate of decomposition, economises on space, reduces subsidence and ensures that the cover is economically used. Compacting the cover itself compacts the rubbish beneath still more and allows another layer to be spread on top. The process can continue until the design height is reached. At this stage each ridge should be covered with a final layer of sand-pit waste, clean fill or other suitable material, and finished off with any topsoil saved from the original surface. The slopes should be slightly greater than during construction, so as to give the 1:10 to 1:15 slope advocated for normal restoration. The ridges should also slope gently along their lengths as previously described, so as to reduce the quantity of water percolating in between the ridges and enable it to be led off the site into a settling pond before directing it into some suitable water course. The topmost layer of cover must be at least 1 metre thick above the last layer of rubbish and it should be deep tined across the ridges during a dry period in late summer as the final operation before planting. One metre of final cover should give at least 100 mm of available water and probably the 150 mm which should be adequate for tree growth in the first few years. In due course trees should root through into the rubbish and further increase their moisture supply.

GRASSING

In forests the bare appearance of restored landscapes does not matter, but near towns there may be considerable pressure to grass down areas before trees are planted. There is no doubt that in some places an instant greenness is not only pleasing but shows the general public (and the politicians) that something is being done. However, there is also no doubt that many grass and grass-clover swards are extremely competitive for water and nutrients and that tree growth suffers. It follows that if a grass sward is used its composition must be chosen with care and herbicides or mulches employed to control strips or patches of vegetation until the trees are well established.

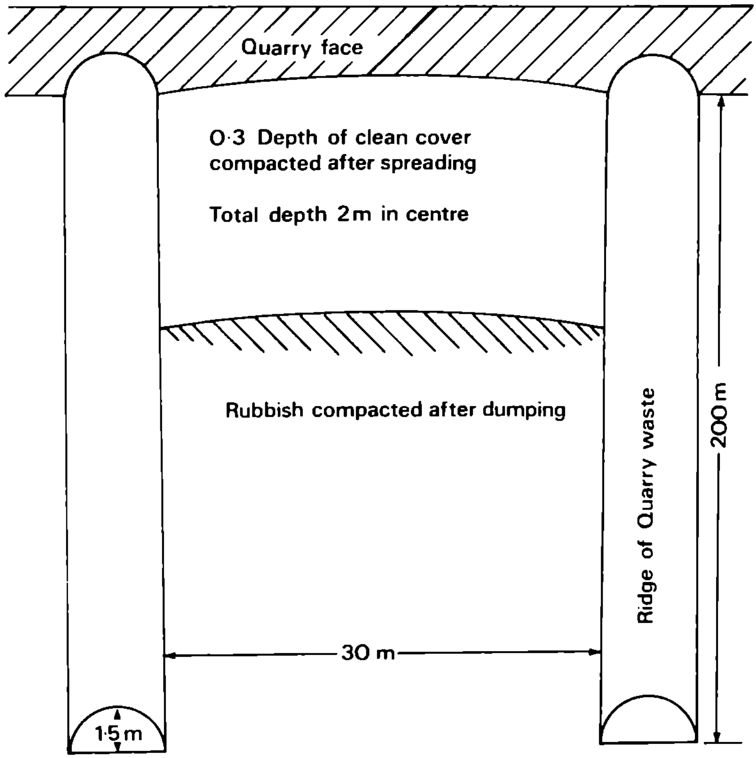

Figure 5. Pattern of filling a gravel quarry with household rubbish.

Grass or grass-legume swards also help to stabilize the restored surface, especially on the erodible shales of reshaped deep-mined spoil and any slopes steeper than 1:10. However, the penalties of using a sward must be appreciated. Grassing and sward competition are discussed by Insley (page) and Jobling (page 83).

SPECIES

If adequate topsoil or organic-rich material, capable of supplying and storing soil nitrogen is present, lowland sites can grow good Corsican pine *(Pinus nigra* var *maritima)* and other pines and larches *(Larix* spp.*)*. If the general fertility is high, some broadleaves such as birch *(Betula pendula)* and sycamore *(Acer pseudoplatanus)* can be added. If there is no topsoil or organic matter, then nitrogen-fixing species of tree, such as alder *(Alnus* spp.*)* and *Robinia pseudoacacia* should form at least 50 per cent of the cover, the rest being Corsican pine, larch, birch and sycamore - all pioneer species. Productivity will be low until soil profiles have developed.

Experiments on building up the soil nitrogen supply with bush or herb legumes, planted between the rows of pine, larch and birch, are under way. Trees are nevertheless unlikely to grow at normal rates until the organic nitrogen has accumulated over at least 10 years.

A high lime content affects the choice of species, Lodgepole *(Pinus contorta)* and Scots *(P. sylvestris)* being especially sensitive. Slow soil development operates against all climax species, such as beech *(Fagus sylvatica)*, oak *(Quercus* spp.), hornbeam *(Carpinus betulus)* and among the conifers Douglas fir *(Pseudotsuga menziesii)*, Western hemlock *(Tsuga heterophylla)*, spruces *(Picea* spp.*)*, and Silver firs *(Abies* spp.*)*. Most of these species are also sensitive to soil compaction. Pioneer species, including sycamore and Norway maple *(Acer platanoides)* on medium and heavy textured calcarious materials, or species which fix their own nitrogen are preferable. Poplars *(Populus* spp.*)* and willows *(Salix* spp.*)* have been successful on the heavier textured, more fertile spoils.

ACKNOWLEDGEMENTS

We should like to take this opportunity of thanking the following for help during the developments and investigations described above: Blacknest Engineering Company Ltd., English China Clays (Quarries) Ltd., Hall Aggregates (Thames Valley) Ltd., Northern Strip Mines Ltd., and the Opencast Executive of the National Coal

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REWORKED SPOIL AND TREES

by

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SUMMARY

Serious and widespread land reclamation problems are being tackled by local authorities to remove industrial eyesores left by the coal industry. Tips of colliery spoil, which are regraded prior to their revegetation, pose particular difficulties. These and the research being undertaken to improve tree survival and vigour on reclaimed spoil, together with some tentative results, are briefly reviewed.

BACKGROUND

In 1954 coal was being mined in Britain at more than 1,000 collieries. Now the number of pits in production is nearer 250. The closure of such a large number of worked-out or uneconomic mines during the past 25 years has increased the area of derelict land in Britain and created serious reclamation problems in all the coal fields.

Of some 12,000 ha of land covered in colliery spoil in Britain, 9,000 ha are in England of which 4,000 ha are in the north of England.

Colliery spoil heaps composed of wastes from underground have a widespread visual impact on the environment. This is not surprising since the smaller heaps may contain from one to four million tonnes of spoil, and the larger ones more than 10 million tonnes. The largest heap in Britain contains 18 million tonnes of spoil. On average each heap covers rather more than 5 ha of land. The larger heaps extend to 150 ha.

There are about 2,000 pit heaps in Britain. Together they contain 3,000 million tonnes of spoil. The coal industry is currently depositing 45 million tonnes of spoil annually and requires more than 250 ha of additional land each year for tipping and other industrial uses.

While the heaps cause the most extensive damage to the environment, coal mining leaves other problems requiring rigorous remedial measures. Holes in the ground, often associated with subsidence and filled with water, disused railway sidings and old colliery buildings are the most common. Sometimes abandoned brick-works, clay tile works and coke ovens which were established to use the readily available coal, have to be knocked down before land reclamation can start.

PROGRESS IN DERELICT LAND RECLAMATION

In the 1950s serious attempts were made to improve the appearance of some old colliery spoil heaps. Usually there was little or no reshaping of the slopes other than the removal of the peaks of the tips to lessen the effects of wind exposure. Most were then blanket planted with trees. A large part of this cosmetic reclamation was carried out in Lancashire and County Durham, and some valuable woodland can now be found growing on colliery spoil in these two counties. However, tree planting has not always prevented spoil erosion on the steeper slopes, while on many heaps the spoil has remained surprisingly bare even where erosion has not occurred.

In 1967, programmes of derelict land reclamation, aimed at bringing the heaps and the surrounding waste land into beneficial use, were started by several local authorities. The work gathered momentum in the 1970s.

The heaps are reshaped to make them more attractive and safer, and to permit movement over the whole of the reclaimed site of agricultural tractors and farm equipment. The spoil is deliberately compacted to improve surface stability and to lessen the possibility of spontaneous combustion. Sometimes after regrading, soiling has been carried out, especially on sites restored to agriculture. Occasionally, sites earmarked for tree planting have been soiled as well. Without exception, all the reclaimed land has been sown with grass seeds mixtures on completion of regrading and after appropriate physical and chemical amendment of the surface horizons.

While some sites have been restored to agriculture, some to public open space, and a small number to encourage industrial development, tree planting has featured in most schemes. Generally the planting has been done primarily to shelter farmland or to improve local amenity, though in some instances timber production has been a stated aim. In such cases the whole of the reclaimed heap has been afforested,usually with fast-growing conifer species predominating.

However, because of low survival and growth rates, and prolonged periods of tree replacement, planting on reclaimed spoil has not always been successful.

Since the reasons for failure and slow establishment have not been entirely clear, ameliorative measures have been difficult to devise. As early as the mid-1970s local authority officers concerned with land reclamation considered that formal studies would have to be undertaken to identify the main factors limiting tree survival and vigour, and to effect significant improvements in tree growth after planting.

DEPARTMENT OF THE ENVIRONMENT CONTRACTS

For 12 months in 1976-77, revegetation practices were critically examined to identify the problems adversely affecting tree and shrub establishment on reclaimed spoil. For 18 months in 1978-79, spoil compaction and its assessment and relief, and the relationship between root extension and the physical and chemical properties of the spoil were reviewed in detail. The work involved an examination of excavated whole root systems and the collection and examination of large numbers of spoil samples. Foliage was collected for chemical analysis from a substantial number of the excavated trees. Experiments were started to compare different methods of relieving spoil compaction. Certain problems and some results of the work are discussed below. This work was carried out under contract to the Department of the Environment.

PLANTING IN COMPACTED SPOIL

Planting in spoil which has not been recently cultivated is physically difficult. The presence of large stones in the spoil may be more of a hindrance to good planting than the hardening (or concretion) which typically occurs at the spoil surface as it dries out. A stony or compacted spoil encourages shallow planting, root deformation and drying out of the exposed roots just below the root collar. Trees so planted which survive the first season or two may socket later, while the worst affected specimens may still be subject to windthrow some six or seven years after planting. Where planting standards have been less than adequate Lodgepole pine *(Pinus contorta)* and Corsican pine *(Pinus nigra* var *maritima)* appear to be the least stable of the commonly planted species.

Wet spoils are easier to penetrate with a spade than dry spoils so that, in theory at least, the quality of planting improves after rain. The timing of tree planting therefore assumes some importance. Mattocks and planting spades of the Schlich type, which may be expected to improve both notch and pit planting, are not commonly used.

The speed and quality of tree planting are substantially improved by spoil cultivation carried out shortly ahead of the planting. Ripping along the planting lines is the most common cultivation practice. Sometimes two rippings are done at right angles and the trees planted at the intersections of the two slots. Forest ploughing, practised by a few local authorities some years ago, is no longer carried out on reclaimed land because of the surface disturbance caused and deterioration in the visual appearance of the site.

Different local authorities employ different tractors and ripping equipment. As a consequence, ripping specifications vary widely from place to place. Some counties specify ripping to a depth of 600 to 750 mm, others rip to only 450 mm. Lateral spoil disturbance and lifting at the surface vary accordingly. Experiments have been started to examine different practices and their effects on tree survival and early growth rates. In the first planted experiment, started at the end of 1978 at North Beechburn, County Durham, trees of three species survived better in the first season in spoil cultivated before planting than in uncultivated, compacted spoil (Table 1). Curiously, Scots pine *(Pinus sylvestris)* were slightly more vigorous in uncultivated spoil than in ripped spoil. Dieback of the two broadleaved species, oak *(Quercus robur)* and Sycamore *(Acer pseudoplatanus)*, occurred regardless of spoil condition. The ripping was done at the end of October 1978 and the planting carried out five months later, after winter settlement of the highly disrupted spoil.

Table 1

Survival (percentage) and height increase (mm) of Scots pine, oak and sycamore in first season (1979) in cultivated and uncultivated spoil North Beechburn, County Durham.

Species	*Survival (%)*			*Height increase (mm)*		
	C_0	C_1	C_2	C_0	C_1	C_2
Scots pine *(Pinus sylvestris)*	76	87	89	10	9	7
Oak *(Quercus robur)*	88	92	98	-3	-2	-2
Sycamore *(Acer pseudoplatanus)*	76	96	92	1	-1	1

<u>Key</u> C_0 = No ripping (direct notch planting)

C_1 = Ripping along planting lines to 600 mm (notch 10-15 mm from slot)

C_2 = Ripping in two directions at right angles to 600 mm (notch 10-15 cm from intersection)

A single season's results in one experiment cannot be regarded as being helpfully informative. What does seem important, however, is that the cost of ripping along the planting lines, together with the cost of planting in the ripped spoil, is less than the cost of planting in unripped compacted spoil. Thus the decision to rip may be made solely on economic grounds. It follows that in these circumstances improvements in survival and vigour due to ripping may be regarded as bonuses.

On sites where ripping is not carried out, for example on steep slopes unsafe for tractors, soil augers and crumblers are sometimes used to cultivate the spoil locally at the planting position. Experiments have been started at Alma, County Durham, and Oulton Brickworks, Water Haigh, West Yorkshire, to compare behaviour of trees in spoil disturbed by a soil crumbler with that of trees planted in both ripped and unripped spoil.

At Ellis Laithe, West Yorkshire, an experiment was started in 1978 to examine the behaviour of trees planted in spoil subjected to different subsoiling treatments undertaken preparatory to sowing the grass seeds mixtures, the first stage of revegetation.

ROOT EXTENSION IN RECLAIMED COLLIERY SPOIL

Whole tree root systems were excavated on seven sites to examine critically and record the relationship, if any, between root development and the chemical and physical properties of the spoil into which the roots had extended. Both young relatively slow growing and vigorous, well established trees up to 10 years of age were examined. In most cases penetrometer readings were made on site and bulk density, particle size distribution and pH values of spoil samples were assessed in a laboratory. The main findings may be summarised as follows:

1. at six of the seven sites roots of Common alder *(Alnus glutinosa)*, the most commonly planted species on reclaimed spoil, were found to have widespread lateral root development and downward growth below known depths of cultivation, regardless of spoil type and previous site treatment;

2. False acacia *(Robinia pseudoacacia)*, Grey alder *(A. incana)*, Scots pine and European larch *(Larix decidua)* were found to have widespread and deep root systems similar to those of Common alder;

3. birch *(Betula pendula)* had the most surface root systems of any tree. None of the specimens showed downward root growth into uncultivated spoil. To

compensate, however, the lateral roots generally extended over greater distances than the roots of trees of other species;

4. Corsican pine had the most surface root systems of the conifers. Like birch, trees were not deeply rooted but most lateral roots were exceptionally long;

5. no significant downward root growth was found on any tree at Choppington 'B' Northumberland. At this site, a concreted pan at a depth of 250 to 400 mm appeared to be inhibiting rooting below this depth. Further, serious water-logging following heavy rain was thought to be responsible for periodic death of roots. This phenomenon was not observed at any other site. Trees of all species were much less stable at Choppington 'B' than elsewhere;

6. direction of rooting appeared at all sites to be totally independent of previous cultivation. At West Sleekburn, Northumberland, where forest ploughing was carried out before planting and the trees notched into the ridge slope, root extension was largely at an angle to, rather than in the direction of ploughing. Most root ends were found to be below the furrow bottom. At Byers Green, County Durham, where the spoil was ripped before planting, most roots were found to have developed at an angle to and not along the slot;

7. no clear relationships could be established between penetrometer readings and tree root development. It is beyond the scope of this paper to discuss bulk density and particle size distribution assessments;

8. root extension appeared to be unhindered by acid spoil. At Mitchell Main, South Yorkshire, where spoil samples were always more acid than those collected at other sites, healthy roots of birch, Common alder, False acacia, Red oak *(Quercus borealis)* and Corsican pine were regularly found growing into and through spoil with a pH of 3.0. At this site the mean pH was 3.4; the lowest pH 2.8;

9. nodules were regularly found on the roots of Common and Grey alder and False acacia regardless of spoil type and previous site treatment. There was no evidence that the presence of nitrogen-fixing species benefited other trees. The shrub-like behaviour of False acacia on reclaimed spoil and the proneness of Common alder to die-back in dry summers suggest that the role of at least these two species on regraded heaps should be re-evaluated;

10. on soiled sites with a soil depth greater than 250 mm, few roots were found growing downwards through the soil into the underlying spoil. Mixing of the soil

Table 2.

Concentrations of elements nitrogen (N), phosphorus (P), potassium (K) and calcium (Ca) in the foliage of trees on highly acid colliery spoil and neutral or slightly acid spoil

Species	*Site*	*pH Value*			*Element Concentration (% oven dry weight)*			
		Min.	*Max.*	*Mean*	*N*	*P*	*K*	*Ca*
Common alder	Mitchell Main, S. Yorks	3.1	3.4	3.2	3.04	0.227	0.94	1.870
" "	" " " "	2.9	4.4	3.4	3.35	0.194	1.52	1.120
" "	West Sleekburn, Northumberland	6.4	7.1	6.8	3.33	0.203	1.23	1.220
Silver birch	Mitchell Main, S. Yorks	3.0	4.1	3.6	3.28	0.299	1.24	0.816
" "	" " " "	3.2	3.4	3.3	3.45	0.391	1.15	0.674
" "	Waleswood, S. Yorks	4.0	6.6	5.1	3.35	0.368	1.40	0.463
False acacia	Mitchell Main, S. Yorks	3.0	6.1	3.9	4.68	0.319	2.03	2.420
" "	" " " "	2.9	3.4	3.1	4.50	0.287	1.56	2.990
" "	Choppington 'B', Northumberland	4.3	7.5	5.7	4.44	0.223	1.74	1.550
Corsican pine	Mitchell Main, S. Yorks	3.1	3.4	3.2	1.23	0.156	1.00	0.185
" "	" " " "	2.8	3.4	3.2	1.16	0.143	0.87	0.139
" "	Choppington 'B', Northumberland	4.3	8.2	6.4	1.41	0.188	1.08	0.150

and spoil at the interface by subsoiling encouraged downward root penetration; compaction of the spoil at the interface discouraged root penetration;

11. examination of annual rings at the root collar of excavated trees disclosed in many instances a direct relationship between growing season rainfall and ring width.

TREE GROWTH IN ACID SPOIL

At none of the sites where roots were excavated could death of trees be attributed solely to spoil acidity. Where trees were found to be growing slowly or where discoloured or mis-shapen foliage was observed - characteristics generally associated with low pH values - other factors such as low rainfall or weed competition were also involved.

The chemical analysis of foliage taken towards the end of the growing season from selected vigorous trees at Mitchell Main, the most acid site where roots were excavated, showed satisfactory levels of the elements nitrogen, phosphorus, potassium and calcium. The levels also compared favourably with element levels in the foliage of well-grown trees examined at the same time in neutral or slightly acid spoil at other sites. Data for four species, two of each at Mitchell Main and one at a contrasting site are given in Table 2. The data show that some of the tree species commonly planted on reclaimed spoil are highly pH adaptable.

ACKNOWLEDGEMENTS

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ROADSIDE AND OPEN SPACE TREES

by

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SUMMARY

Tree plantings on roadsides and in urban open spaces are subject to problems of soil compaction, impaired drainage and reduced fertility common to all sites with disturbed soil. Trials of container grown stock have not shown advantages over well handled, bare-rooted stock. Competition by grass sward is severe. On one site newly planted trees represented only 3.5 per cent of the above-ground vegetation. Trials to assess herbicides and mulches for sward control and the timing and extent of control required for optimum response are described.

INTRODUCTION

It is relevant to include urban open spaces with roadsides because the problems of tree plantings in areas left for amenity, especially in new towns, are very similar to those encountered on newly constructed roadside verges. The problems of motorway plantings have been summarised by Dunball (1979). Apart from site problems, largely related to construction methods, condition of planting stock at the time of planting and subsequent maintenance both affect establishment success.

SITE CONDITIONS

Three common problems occurring on both motorway and new-town sites are caused by the movement of soil. These are soil compaction, impeded drainage and denitrification, which may all interact. Compaction impairs drainage, and both compaction and anaerobic soil conditions (prevalent where drainage is blocked and the soil waterlogged) lead to denitrification. Fertility of these sites is also reduced by the mixing of subsoil and parent material with topsoil. Movement and storage of topsoil also result in denitrification and a general reduction of bacterial populations, although these changes are quickly made good when the soil is restored (Hunter and Currie, 1956; O'Flanagan *et al.* 1963).

On many urban sites compaction caused during site construction can be relieved by ripping, which has been shown to be effective provided it is done when the soil is dry enough to be disturbed, and to sufficient depth and intensity to disturb the compacted layers (Fourt and Carnell, 1979). However, compaction is frequently a deliberately engineered feature of road construction, so that in only a very few instances on level interchange sites is it possible to use a ripper. Trees and shrubs must, therefore, be planted and maintained so that they will survive and grow in spite of the underlying compaction.

STOCK TYPE

A frequently advanced alternative to the use of bare-rooted stock on difficult sites is the container-grown plant. A series of experiments have been carried out to compare survival and early growth of stock grown in Japanese Paperpots (JJPs), F.C. transplants and trade transplants. Replicates of these have been planted on embankments, in cuttings and on either side of the road so that all possible site types have been tested. Table 1 shows the mean height, height increment (cm) and survival of the three stock types in an experiment on the A45 trunk road at Newmarket, two years after planting. While there were differences in survival and height growth between embankments and cuttings and on different aspects, the overall comparison of container-grown (JPP) with bare-rooted stock does not justify the use of container-grown plants. The greater mean height of JPP stock was the result of these plants being taller at planting, after being grown in heated polyhouses. Since planting, the *Nothofagus obliqua* JPP stock have, on average, lost height through dieback. For both Silver birch *(Betula pendula)* and beech *(Fagus sylvatica)* JPP stock simply maintained their initial height advantage.

The differences in survival do not show any advantages resulting from the use of container-grown stock, and indications are that well handled, bare-root stock will survive just as well.

This conclusion is also supported by another series of experiments comparing bare rooted with JPP stock, in which the two stock types have been planted at monthly intervals throughout the year.

As indicated in Table 2 (page 86), between September and April inclusive, the difference in survival of bare-rooted and container-grown plants was not significant. From August to October, and in April and May, all plants were in leaf. Although the bare-rooted stock was replanted within a few hours of lifting

Table 1.

Height increment (2 yrs) and percentage survival of container-grown (JPP) and bare-rooted (F.C. and trade) stock of three species on a trunk road site at Newmarket, Suffolk

	Height		
	Mean (cm)	*Increment (cm)*	*Survival %*
	Sept. '79	*Dec. '77–Sept. '79*	
Beech			
JPP	69.0	5.3	63.2
FC	46.3	15.7	75.6
Trade	49.8	6.6	67.9
Birch			
JPP	112.0	27.8	64.0
FC	76.2	36.3	60.8
Trade	93.8	34.6	64.9
Nothofagus obliqua			
JPP	76.5	-21.5	60.9
FC	32.1	8.2	52.8
Trade	51.3	7.8	62.1

Table 2.

Comparison of the survival (%) of container-grown (JPP) White birch *(Betula pubescens)* grown in Japanese Paper Pots with open nursery bare-rooted seedlings when planted at monthly intervals (from August 1976 - May 1977) on a roadside site at Esher, Surrey

Planting date	*Bare-root seedlings*	*JPP stock*	*Difference*
30 Aug.	39.7	83.4	43.7
27 Sept.	74.5	82.7	8.2
25 Oct.	79.8	78.8	-1.0
27 Nov.	81.7	81.8	0.1
20 Dec.	72.2	75.4	3.2
17 Jan.	70.7	69.2	-1.5
Feb.	No planting - frost and snow covering site		
14 March	68.9	61.7	-7.2
11 April	58.0	59.6*	1.6
9 May	52.2	81.8*	31.6

*The JPP stock used in April and May were from a different batch and are not comparable with those used previously.

from the nursery, the results do demonstrate that, except under the extreme conditions of mid-summer, bare-rooted stock handled carefully can give as good a survival rate as container-grown stock. It is therefore safe to conclude that use of container-grown stock, during the normal planting season (October - March) is not justified and is probably only worthwhile if our of season planting cannot be avoided.

SWARD COMPETITION

Schmidt-Vogt and Gürth (1969) stated that maintenance of trees after planting can be more important for survival than physiological degrade during handling and transport. Nevertheless the extent of competition between the vegetation on grassed down sites, such as road verges and urban open spaces, and newly planted trees remains largely unrecognised by arboriculturists.

Roadside and open space sites are invariably grassed down soon after construction has been completed. For open spaces grassing is to improve the site appearance, but in the case of road verges it is also used to stabilize topsoil. The seed mix (Table 3) used for roadside verges by the Department of Transport is functional in that it achieves its objectives rapidly, but it concedes little to the subsequent establishment of planted woody plants.

Assessment of two separate roadside sites has shown (Insley and Buckley 1980) that two years after sowing with this mixture, the sward was dominated by a thick mat of *Festuca rubra* (Red fescue) and the only diversification to have occurred was by common agricultural weeds, most of which were probably introduced with the topsoil spread on the sites.

Table 3

Constituents of the Department of Transport seed mixture
(Department of Transport, 1976)

Species	*% by weight*	*No. seeds as % of total no. in mixture*
Lolium perenne L. (S.23)	53.4	34.2
Festuca rubra L. (S.59)	18.0	19.2
Cynosurus cristatus L.	10.6	10.1
Poa pratensis L.	9.0	25.0
Trifolium repens L. (S.100)	9.0	11.5
	100.0	100.0

Both *Lolium perenne* (perennial rye-grass) which germinates rapidly and *Festuca rubra*, which later replaces it as the dominant component of the sward, are severe competitors with other plants. Under unfavourable conditions and with limited phosphate and little available water, even legumes such as *Trifolium repens* (White clover) can damage trees rather than assist them by supplying nitrogen (Richardson 1977; Hodgson and Buckley 1975).

On motorway sites sown with the sward mixture, the newly planted trees can be considerably outweighed by the surrounding vegetation. On one site assessed by Insley and Buckley *(ibid)* at Ripley, Derbyshire the planted trees represented only 3.5 per cent of the above-ground biomass on site.

There are two alternatives to such competition. One is to remove competing plants by changing the sward to less competitive species. Pure legume swards are frequently suggested because of their contribution to the available nitrogen supply. However, as already noted, legumes such as *Trifolium repens* can themselves provide competition and alternatives such as *Melilotus* spp. (Sweet clover) are now being tried in conjunction with trees (Fourt, pers. comm.). A second alternative is to remove the locally competing sward from the vicinity of the tree either by mulching or use of herbicides.

Although both mulches and herbicides exclude competing vegetation to varying degrees, their effects upon the soil physics vary. Since swards compete for soil moisture their removal results in a higher soil moisture level, while under mulches moisture content tends to be higher than under bare ground. Mulching reduces daily soil temperature fluctuations, but has less effect on seasonal temperature variation (Bredell and Barnard 1974). However, overall soil temperature is lower under mulch than under sward (Dancer, 1964) while under herbicide treated ground the soil is warmer than under sward (Larson and Schubert 1969). These differences in soil temperature, moisture and, as a result of these, nutrient availability, produce variations in the responses of trees to the treatments.

Two separate trials have been carried out to measure the difference in response with several types of mulch material compared with controls (no control of surrounding weed growth). In a trial on the A3 at Ripley, Surrey, three mulch materials were used, unground pine bark, pulverised pine bark and a sheet mulch consisting of a 0.25 m^2 sheet of bitumized felt. Four species were used - Scots pine *(Pinus sylvestris)*, beech, Grey alder *(Alnus incana)* and Silver birch.

At the end of the first growing season so many deaths had occurred in the beech and Scots pine that height growth was not analysed. However, although there was no significant difference in the height growth of treated and untreated birch, mulched alder had grown significantly more than untreated trees. There were no significant differences in the height growths with the different mulch materials used. Equally there were no significant differences in survival between treated and untreated trees for any of the four species, so that the poor survival of beech and Scots pine was due to other factors.

After two years the height increment of treated alder was very significantly greater than that of untreated trees, but there were no significant differences with the other species. After two years beech showed significantly better survival of treated compared with untreated trees.

In another mulch trial carried out at Milton Keynes, loose mulches of pulverised bark, sewage sludge, and a 'Pressboard' sheet mulch were compared with controls with no treatment. The species used were Small-leaved lime *(Tilia cordata)*, sycamore *(Acer pseudoplatanus)* and Italian alder *(Alnus cordata)*. As with other motorway experiments small planting stock was not successful on this type of disturbed soil where shallow root systems are susceptible to summer drought. Because of this the lime and sycamore, both of which were small stock, exhibited poor survival.

Italian alder responded well to mulching. There was a considerable growth response to the bark mulch treatment, and although the sheet mulches showed benefits initially they soon broke up and were scattered around the site, so losing their effect. The sludge treatments produced a huge surge of weed growth which competed with the trees to such an extent that sludge-treated trees appeared to be checked compared with the controls.

It is noteworthy that in both of these experiments it was alder which grew well in response to mulching. This was almost certainly an indication of nitrogen deficiency and impeded drainage on both sites after construction, and had the other species included not been subject to these other limiting factors they might also have been able to respond to the treatments imposed. Mulching has certain disadvantages (transport of materials, rapid breakdown and re-invasion by weeds) which control of sward with herbicides does not suffer. Favourable response by young trees to the herbicide control of competing vegetation has been frequently demonstrated. However, much less has been done to measure the optimum area of weed control required. Complete removal of all competing weeds can be expensive and not necessarily any more effective than spot control. Change in the area of influence of the weeds or sward may occur as root systems of the planted trees extend.

An experiment has been set up on a trunk road interchange at Ripley, Derbyshire, to compare survival and growth of transplants at four levels of sward control, with and without the addition of nitrogen. The species being used are hawthorn *(Crataegus monogyna)*, Italian alder and sycamore. Weed control has been applied using paraquat and the treatment levels are control (no treatment), weed control to 27 cm radius, 38 cm radius and 53 cm radius, representing 12½, 25 and 50 per cent respectively of the area between plants. As well as this examination of response to treatment area, a second experiment at Corbridge, Northumberland is being used to compare mulches with herbicide, and change in response with time of treatment application. Ten treatment levels including the control are included, with herbicides applied in all combinations of years 1, 2 and 3 and mulching in years 1 and 2.

The two experiments should demonstrate how much weed control is required and when to apply it to optimise survival and early growth of transplants on this type of site. What will not be explained is how sward control produces a response in terms of tree growth. In an attempt to clarify this a further experiment has been set up at Alice Holt Forest, Hampshire in which the soil temperature and moisture content are being monitored under plots in which the sward has been controlled using different methods. This includes five treatments, a control of unmown motorway type sward, mown sward, herbicide treated ground, loose mulch and a sheet mulch.

CONCLUSIONS

There are no advantages in using container-grown plants compared with well-handled conventional bare-root stock of the same size, during the normal October to April planting season.

Survival and height growth of all stock types are adversely affected by competition from herbaceous weeds especially during the first few years after planting. Further research is needed before a prescription for the timing and area of weed control for optimum response can be given.

ACKNOWLEDGEMENTS

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GROWING TREES IN DIFFICULT ENVIRONMENTS

by

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SUMMARY

There are four major problems that can affect trees planted into difficult sites, particularly those where there is no top soil. Investigations have shown that each of these can be overcome.

1. Establishment - physical problems mainly concerned with lack of water: use organic absorbtive planting media.

2. Nutrition - mainly lack of nitrogen: use appropriate fertilisers over a number of years or plant nitrogen-fixing trees, shrubs and herbaceous plants.

3. Toxicity - mainly due to heavy metals but also to acidity and other factors: choose tolerant species, or cover with substantial depth of innocuous material, or treat with a suitable chemical treatment such as lime.

4. Social - vandalism and lack of aftercare: ensure proper management and ensure that trees grow rapidly.

If these steps are taken trees can be established even on the most difficult site.

INTRODUCTION

It must be obvious to anyone who has sympathy and enthusiasm for trees that they are being planted in some very difficult situations where survival and growth can be extremely poor. In a recent survey of the growth of several thousand trees, mostly newly planted standards, in urban areas on Merseyside, Capel (1980) found that survival was only about 60 per cent and that average growth of all the plantings, measured as shoot elongation, was less than 40 per cent of that of the best plantings. Poor performance and losses are obviously interconnected. Taken as a whole they indicate that the costs of achieving a particular end result are far greater than they need be.

Urban environments are particularly difficult because the original soil has been degraded or lost. There are many similar situations, particularly the areas of derelict land produced by mining, quarrying or waste didposal, where the soil has been totally lost during extraction or buried under waste materials such as colliery spoil or pulverised fuel ash. Ideally trees should be planted in situations where the original soil is present. When top soil is not available severe problems will occur, each of which must be overcome if trees are to be grown successfully. These are:

a) establishment - particularly physical problems of water shortage;
b) nutrition - lack of major plant nutrients especially nitrogen;
c) toxicity - particularly due to heavy metals or low pH
d) social - especially vandalism but also lack of after-care.

In different situations these problems are manifest to different extents (Table 1).

Table 1

The problems which must be covercome when planting trees in different materials

	Establishment	*Nutrition*	*Toxicity*	*Social*
Colliery spoil	++	++	++/·	+/·
Fly ash	+	++	++	·
Heavy metal wastes	++	++	+++/+	·
China clay wastes	+	+++	·	
Hard rock wastes	+++	++		+/·
Sand and gravel	+	++/·	++/·	+/·
Urban land	++	++	·	+++
Roadsides	++	++	·	+/·

Scale · + ++ +++
not serious most serious

It is possible to overcome all the problems at once by the importation and spread of top soil. This provides a good supply of water and nutrients, isolates the trees from extreme acidity and encourages good growth which makes trees less likely to suffer from vandalism. However, the use of top soil also provides weed seed and better conditions for the growth of weeds which may increase the need for after-care to remove competition. But since the current costs for supply and spread of only 100 mm of top soil are about £3000/ha; this is only practical in special situations. The alternative is to deal with each problem individually.

This approach has been very successful for the establishment of herbaceous plants, as the current derelict land reclamation programme has shown (Bradshaw and Chadwick 1980).

ESTABLISHMENT

The primary problem for newly planted trees is to establish adequate physical contact between roots and the materials which surround them so that they can, from the outset, obtain adequate water for growth. During the first few months after planting they can survive almost without nutrients: but even a short part of the growing season without water can be fatal. In derelict land materials, e.g. rock or sand waste, a combination of extreme texture and lack of organic matter results in a water holding capacity less than half that of normal soil. The trees must therefore be helped over the early stages until they have developed a sufficiently extensive root system to have access to adequate water supplies.

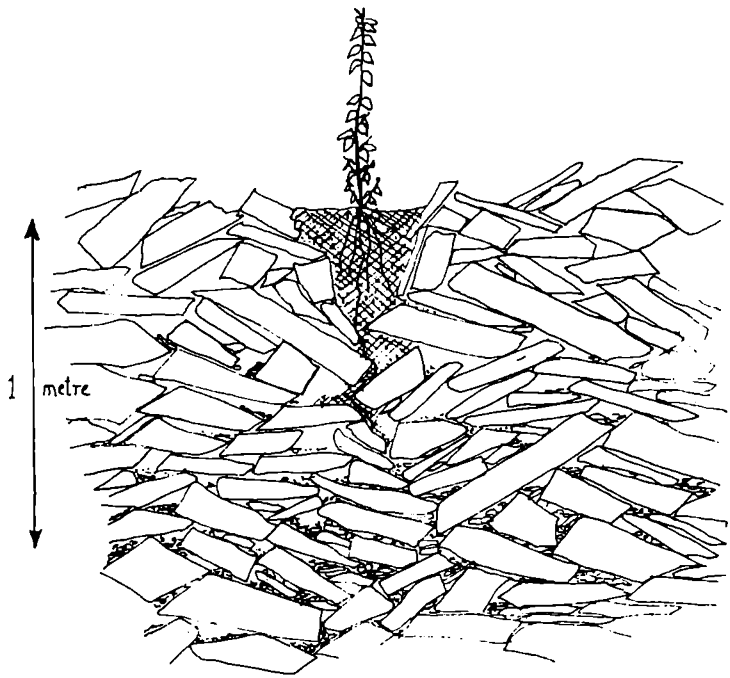

Figure 1. The technique of pocket planting for coarse wastes : the trees rapidly extend their roots out of the moisture retaining peat in the pocket (Sheldon and Bradshaw 1975)

The problem can be overcome in a wide variety of materials by a system of pocket planting (Sheldon and Bradshaw 1975), in which the tree is planted into a pocket of imported material (Figure 1). This works extremely well even on steep slopes and with very coarse materials such as slate waste. However, the type of material used in the pocket is critical - it must have maximum water holding capacity. Composts containing absorptive unhumidified *Sphagnum* moss peat, including those commercially available, are very effective (Table 2). Nutrients must be provided, but in slow release form; addition of a wetting agent ensures rapid rewetting by rain.

Table 2

Survival of transplants over the first season in a very dry summer (1972) in different types of rooting media (in pots containing 7500 cm^3 of material, receiving natural precipitation only) (Sheldon 1974)

	Survival %	
	July	*October*
Shale	10	10
Shale + peat 1:1	70	40
Shale + peat 1:2	70	50
Peat	90	90
Shale + Urea formaldehyde foam 1:1	0	0
Shale + Urea formaldehyde form 1:2	20	0
John Innes compost	90	50

The size of the pocket is critical - large pockets provide greater insurance against periods of drought. If rocks can be arranged to form a collecting collar this compensates for pocket size (Table 3, page 97). From field experiments the continued growth of transplants appears to require a volume of about five litres, providing the trees can root out into the surrounding material. Pockets can be dug and filled by hand, but in large scale schemes they can be made with a crow-bar and filled with a peat slurry pumped onto the site.

This technique is now being applied successfully to several different materials, such as the rock wastes produced by tunnelling in hydro-electricity schemes in Norway (Hillestad 1973). The critical point is that the trees should root out of the pocket into the surrounding waste. Humphries (1977) has shown this readily occurs on limestone quarry materials (Table 4, page 97) and that it is encouraged by the moisture retention by the pocket material.

Table 3.

The effect of size of pocket and presence of collecting collar on the survival and growth of transplants of birch over two seasons (pockets not surrounded by other material, trees planted February 1972) Sheldon (1974)

Pocket size (cm^3)		3600		7200	
Collar	with (+) without (-)	-	+	-	+
Measured at		*Survival (%)*			
Sept.	1972	70	100	100	100
May	1973	40	100	90	100
Oct.	1973	0	100	70	100
		Mean growth (cm)'			
Oct.	1973	0	30	40	60

Table 4.

The survival and root growth of ash *(Fraxinus excelsior)* transplants after 30 months when planted in pockets (3000 cm^3) filled with peat or soil in different limestone quarry wastes (Humphries 1977)

		Survival (%)	*Root penetration from pocket (mm)*
Limestone	(1/8" to dust)		
	alone	100	482
	+ peat pocket	100	750
	+ soil pocket	100	693
Limestone	(2" stone and clay)		
	alone	40	277
	+ peat pocket	100	979
	+ soil pocket	100	712
Limestone	(6" to 2" stone)		
	alone	30	129
	+ peat pocket	100	870
	+ soil pocket	100	384

In less extreme materials, such as coal waste, planting can be direct into the waste. But in this case Chadwick (Bradshaw and Chadwick 1980) has shown that a different problem can now arise - competition for water from accompanying vegetation exacerbated by the poor water holding capacity of the waste (Figure 2). Initially derelict land materials usually do not have vegetation - which is an advantage - and the development of a vigorous vegetation must be prevented.

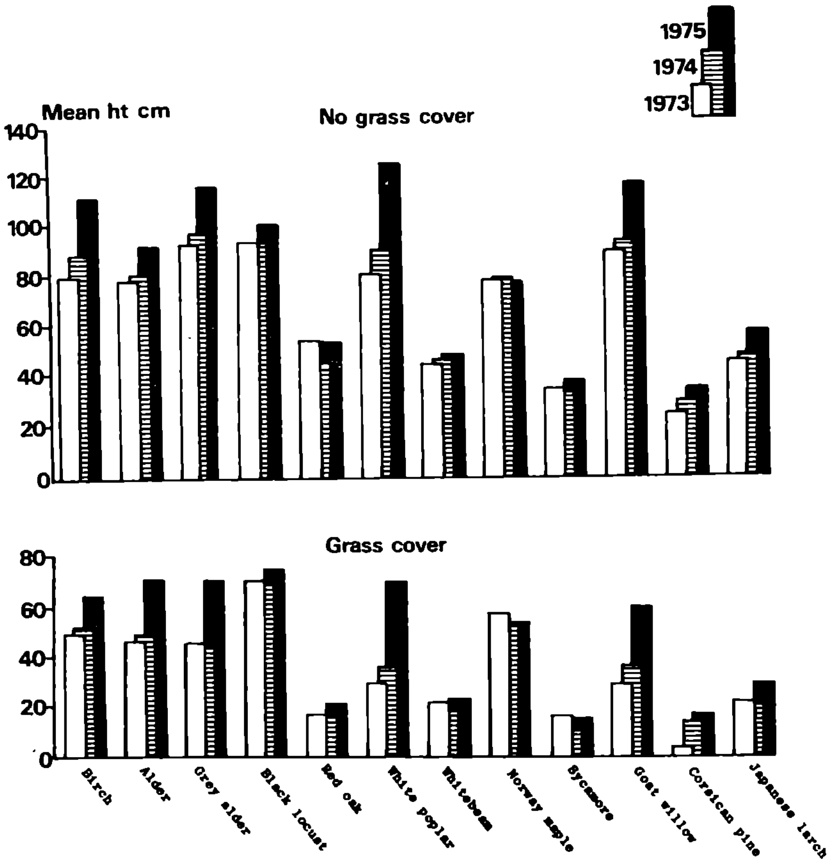

Figure 2. The effect of a grass cover on the growth of a range of tree species on colliery spoil at Water Haigh, W. Yorkshire (Bradshaw and Chadwick 1980)

Bare ground suggests an alternative tree establishment technique - direct seeding. Seedlings will root naturally and escape the physical problems which have to be endured by planting stock. It is particularly applicable to inaccessible areas such as quarry faces. A slurry of sewage sludge or equivalent containing seeds of appropriate tree, grass and legume species poured down a rock face can give excellent establishment (Bradshaw *et al.* 1977). The tree seedlings reported in that paper are continuing to grow excellently, achieving considerably more than one well-established seedling per square metre.

Where restoration of original native woodland and scrub vegetation is required, immediate replacement of the original top soil can provide an important method of seeding those species which possess seed dormancy. It can be combined with hand spreading of seed specially collected from the site before mining and stored, or collected from adjacent areas. In some operations seedlings are raised in tubes or other containers prior to planting. Excellent results have been obtained in the restoration of dune and subtropical savannah vegetation in Australia (Lewis and Brooks 1979, Bradshaw and Chadwick 1980).

NUTRITION

Trees need nutrients as much as any other plant and derelict land materials are grossly nutrient deficient, particularly of nitrogen, because of the absence of organic matter. Very low growth rates can ensue unless fertiliser is provided (Figure 3). It is important to remember that an adequate supply of mineral nitrogen for plants depends on a low rate of mineralisation of the large stores of organic nitrogen usually found in soils. From work on china clay wastes the minimal capital of soil nitrogen for tree growth appears to be about 1000 kg/ha (Marrs *et al.* 1980). The total nitrogen in derelict land materials is usually less than a fifth of this.

How can such a capital be achieved? Direct use of inorganic fertilisers is expensive and there are likely to be substantial leaching losses: legumes are a much more satisfactory method of supply (Handley *et al.* 1978). High levels of mineralisable nitrogen rapidly develop under herbaceous legumes (Table 5, page). Positive effects of clover on tree growth have been found on pulverised fuel ash (Hodgson and Buckley 1975). However, since Chadwick has shown that competition between legume and trees for water can occur, especially when the legumes are vigorous, sufficient to have a substantial negative effect, more work is necessary to find out how to achieve a balance.

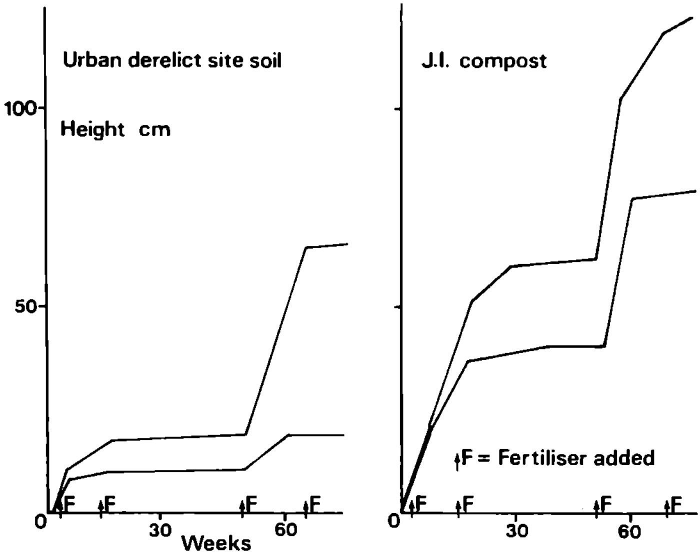

Figure 3. The rate of growth of seedlings of sycamore *(Acer pseudoplatanus)* on derelict land material compared with its growth on compost, with and without fertiliser (Capel 1980)

Table 5.

The levels of mineralisable nitrogen in reclaimed colliery spoil under naturally occurring White clover *(Trifolium repens)* of different ages (total mineral N µg/g before and after incubation for 10 days at 30°C)

	Age of Clover Patch (years)			
	2	3	4-5	mean
Clover absent	4.3	4.7	5.6	4.8
Clover present	85.4	141.5	23.4	83.5

An alternative is to use nitrogen fixing shrubs: broom *(Sarothamnus scoparius)* has been found to be particularly valuable in Britain (Nimmo *et al.* 1961), and tree lupin *(Lupinus arboreus)* in New Zealand (Gadgil 1971). Tree lupin grows very well on china clay waste and can accumulate 180kg N/ha/yr over its six-year life (Palaniappan *et al* 1979): field experiments have shown that it has positive effects on associated trees.

A further alternative is to use nitrogen fixing trees. Common alder *(Alnus glutinosa)* fixes at least 100kg N/ha/yr (Silvester 1977) and therefore has

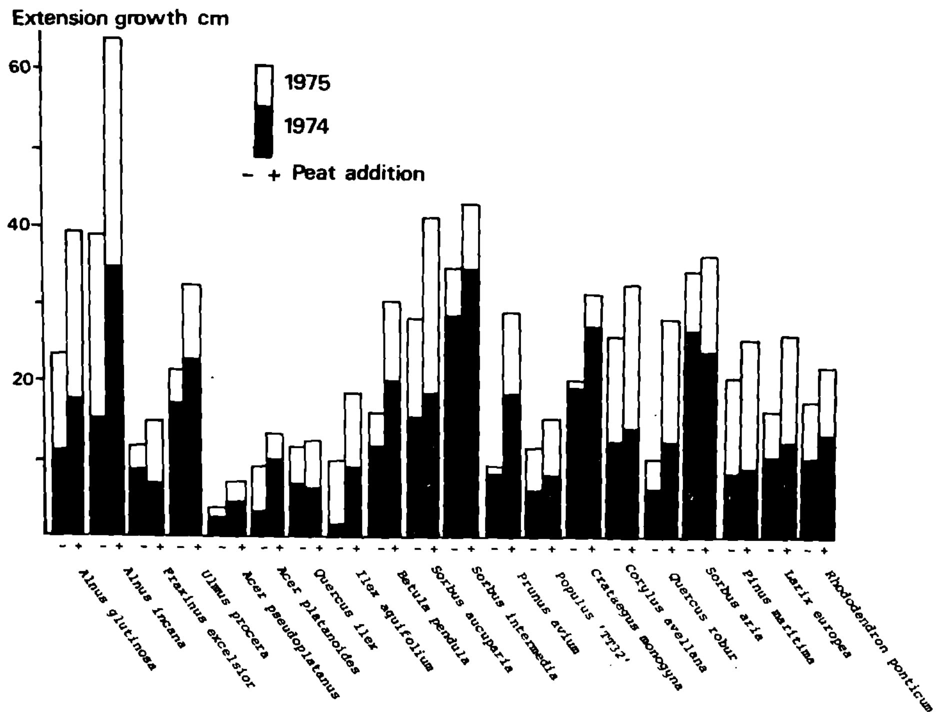

Figure 4. The growth of twenty tree species on china clay sand waste with and without peat (all trees fertilised annually) (Capel 1980)

its own very adequate nitrogen supply. The value of this can be seen in a comparative experiment by Capel (1980) on china clay waste (Figure 4). The cumulative effect of the superior growth increments of two species of alder (*A. glutinosa* and *A. incana)* after the establishment year has resulted after six years in them being twice the height of all other species, which have made little growth even with a peat addition. The same is observable in other materials such as colliery spoil. False acacia *(Robinia pseudoacacia)* is very successful on coal waste in Germany. *Acacia* spp. especially *A. saligna* are increasingly successful in southern Africa and Australia. Nitrogen fixing trees release into the soil part of the nitrogen they accumulate: this can be seen from the green grass growth around each tree. The optimum solution, especially if some timber is required, could be a mixture of commercial and N fixing species.

Although nitrogen is the most important nutrient, deficiencies of other nutrients can also be expected. This will depend on the substrate, but phosphorus is likely to be the most significant (Gemmell 1974). Addition of a small amount of phosphorus can give a considerable response on three quite different materials (Figure 5).

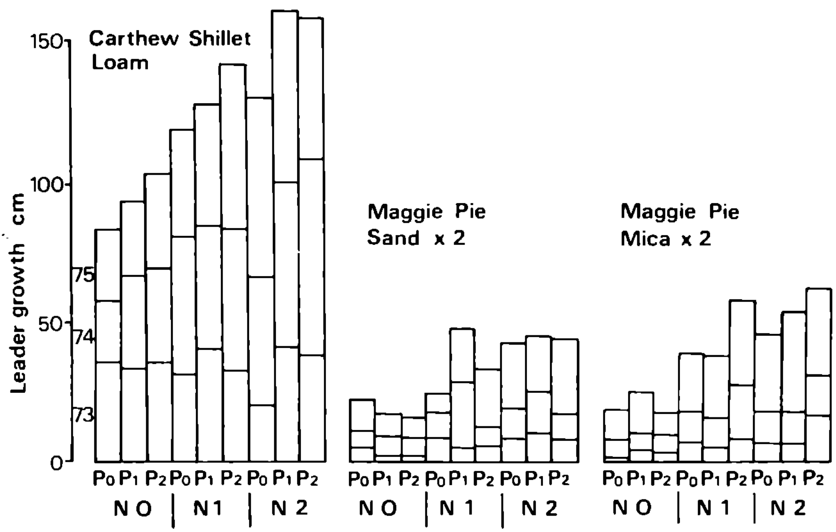

Figure 5. The effect of nitrogen and phosphorus on the growth of sycamore *(Acer pseudoplatanus)* in field trials on loam and on two china clay wastes (Capel 1980)

For long term success it is also important to select trees of known tolerance to difficult conditions. This is apparent from Figures 3 and 5 and is fully discussed by Bradshaw and Chadwick (1980).

TOXICITY

Toxicity caused by heavy metals in a substrate can be overwhelming. There are several instances where trees have been planted in small areas of toxic metalliferous wastes in Wales as part of larger normal plantings: in all cases they have failed. Unfortunately there are no indications of metal tolerant populations in any tree species, although these are common in wild herbaceous species and are being used in land reclamation (Bradshaw, *et al.* 1978).

As a result the only way in which trees can be established on toxic metalliferous waste is by covering the waste with a layer of inocuous material deep enough (not less than 1m) to provide an adequate volume and depth for long-term root growth. But this material need not be top soil: it could be subsoil or an innocuous waste found on site.

Boron toxicity occurs in pulverised fuel ash. It can seriously affect tree growth but it disappears from the ash with leaching. Fortunately some tree species have been found to be boron tolerant, (*Populus tacamahaca* x *trichocarpa* Clone 32, *Alnus glutinosa* and *Picea sitchensis*), and grow very well despite high concentrations of boron (Hodgson and Buckley 1975).

Flooding problems can be coped with in the same way. There are many species, both native and introduced, which have remarkable abilities to tolerate anaerobic soil conditions and associated toxicities produced by flooding (Gill 1977) (Table 6, page 104. As a result no flooded gravel pit or similar area need lack for trees.

Toxicities produced by low pH are the only example of toxicity which can be readily remedied. Colliery spoil can develop pH <3 by the oxidation of pyrite contained within it. This can be neutralised by applications of ground limestone. It is now common practice to apply lime not only to counter the immediate acidity but also that produced by subsequent weathering of further pyrite (Gemmell 1974). On some sites over 100 t/ha are now being applied.

Table 6.

Tree species tolerant of flooding (Gill 1977)

Very tolerant	*Tolerant*
Alnus glutinosa (Common alder)	*Betula pendula* (Silver birch)
Alnus incana (Grey alder)	*Cornus stolonifera* (Red osier dogwood)
Populus x euramericana - cultivars Robusta, Heidemij, I-214, Serotina, Regenerata, Marilandica (Hybrid black poplars)	*Pinus contorta* (Lodgepole pine)
Salix alba (White willow)	*Populus nigra* (Black poplar)
Salix cinerea (Common sallow)	*Populus trichocarpa* (Black cottonwood)
**Salix hookeriana* (Hooker's willow)	*Salix caprea* (Goat willow)
**Salix lasiandra* (Pacific willow)	*Salix fragilis* (Crack willow)
Salix triandra (Almond willow)	*Salix phylicifolia* (Tea-leaved willow)
Salix viminalis (Common osier)	*Salix purpurea* (Purple osier)
Taxodium distichum (Swamp cypress)	

* recently introduced from Oregon and tested in the United Kingdom with some success.

SOCIAL PROBLEMS

In urban areas trees have to endure damage and destruction from human beings. There is no doubt that it is a major source of failure and poor performance. It has been too little studied, but there are a number of ways by which, from common experience, it can be minimised (Table 7). If these precautions are taken properly and without delay there is no doubt that damage can be minimal even in very heavily used areas.

Table 7.

Actions which reduce vandalism

1. Involve local children in planting schemes.
2. Do not plant trees where they will intrude on other activities.
3. Use tree guards where trees are very exposed.
4. Use substantial stakes properly treated with preservative.
5. Ensure high standards of planting so failures are minimal.
6. Fertilise regularly to ensure rapid growth.
7. Replace broken tree ties immediately
8. Remove dead or damaged trees immediately and replace as soon as possible.

Unfortunately in many urban areas not only are these precautions not adopted, but standards of aftercare are often appalling and watering is omitted when needed in severe drought. Tree ties are left broken for months so that trees bend over into the reach of small children: broken stakes are not replaced: weeds are left to grow. Children are sensitive to the atmosphere created by care or lack of it: they will respect trees which are cared for, and use trees that seem not to be wanted, for their own purposes.

Nevertheless a certain amount of wilful and accidental damage is bound to occur. A small, weakly growing tree will be much more susceptible than a large, vigorous tree. For this reason heavy standards are often preferred in urban areas. But these are expensive and often do not transplant well. One major way therefore that vandalism and damage can be reduced is by ensuring rapid growth of planted material so that it quickly grows out of its most vulnerable phase. This means that problems of establishment and nutrition in particular must be properly overcome.

CONCLUSIONS

Difficult environments are a challenge. In some of them growth may be impossible. But for most difficult environments there are solutions which are neither difficult nor expensive. They require, however, that the specific problems are identified and dealt with efficiently and thoroughly. It is unfortunate that this does not always happen. In particular insufficient attention is paid to aftercare. But there are an ever increasing number of sites where the work has been carried out properly, which bear witness to the very important and effective contribution trees can make to the environment.

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CLONAL SELECTION

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CLONAL SELECTION OF AMENITY TREES

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SUMMARY

Breeding of agricultural crops has produced economic benefits. Similar increases in yield may result from breeding of forest trees. It is suggested that selection and breeding of trees for use on sites of industrial dereliction could ensure better establishment and early growth. Methods for selecting and screening plants are outlined and current research work is reviewed.

A cautionary note is sounded about the dangers of single clone populations of plants.

INTRODUCTION

Agricultural crops are notable for their uniformity, the result of many centuries of repeated selection, intentional and unintentional, for desirable characters (high yield, disease resistance, climatic adaptation, etc.), augmented more recently by concerted breeding programmes. Generally forest crops are very variable (heterogeneous) although some selections have been made especially among exotic conifers. Only recently has the potential for improvement been appreciated.

Most agricultural crops are annuals or biennials, easily grown in large numbers with individual plants occupying very little space. Trees, on the other hand, are long-lived perennials with, in most instances, an extended juvenile phase before flowering and fruiting commence. Even then, however, flowers and fruits are unlikely to be produced freely every year. Having successfully effected crosses, the assessment of offspring takes many years, and this requires large areas of land to be retained for protracted periods of time. Fortunately recent advances have greatly increased understanding of the physiology of (i) flower and fruit production and (ii) the maintenance of pollen viability in store. As a result breeding programmes are becoming increasingly predictable with fewer delays (Longman, 1975; Tompsett and Fletcher, 1977).

Selection of amenity trees falls somewhere between agricultural crops at one extreme and forest trees at the other. While few concerted efforts have been made to improve amenity trees by breeding, the greater nursery gate price of specimen trees compared with that of individual trees for plantations, and the ease and reliability with which a qualitative trait such as ornamental value can be assessed, has encouraged the propagation and distribution of many amenity tree varieties. However, selection has been haphazard depending on observant gardeners or nurserymen recognising the value of a spontaneous hybrid, or a distinctive seedling or mutant.

In some of the more popular ornamental genera *(Acer, Malus, Prunus, Sorbus)* many cultivars are now available, some differing considerably from their wild progenitors. Unlike many modern agricultural crops, these cultivars have not been selected and re-selected over many generations. Where seeds are produced they are usually the result of cross pollination and the progeny (seedlings) do not closely replicate their parents. In almost all instances, therefore, it is necessary to resort to vegetative (clonal) propagation if the qualities of the stockplant are to be closely reproduced. In arboriculture the costs of vegetative propagation are acceptable. However, in forestry, where tens of millions of trees are required routinely, plants produced from open cross pollination are most appropriate to the cost structure of the industry. The variable populations of seedlings are favoured by most British foresters as their inherent variability may be most able to exploit the diverse microhabitats of most forest locations. It is not by accident that the only significant plantings in Britain of clonal trees, other than those producing top-fruit, are widely spaced stands of poplar clones growing on uniform agricultural sites for the production of a specialist product. In these instances expensive site ameliorative treatments are countenanced even though the sites are infinitely more uniform and productive than most locations for plantation conifers. The shorter rotations, higher yields and prices available from specialist markets outweigh the increased production costs. Accepted tenets of forestry might be challenged if further field evidence supports the suggestion that similar large gains can be obtained by planting clones of selected conifers (Sitka spruce, *Picea sitchensis* and Lodgepole pine, *Pinus contorta*) (Cahalan, 1980).

Most stocks of amenity cultivars are nurtured in protected nursery conditions with the expectation that they will continue to receive favoured treatment after planting into private and public gardens and parks. But arboriculturists are being faced increasingly with the problem of planting sites for which these cultivars are unsuited. Development sites, roadside cuttings and embankments, city streets, derelict and restored industrial land share disadvantages which are discussed by Binns, Jobling, Insley and Bradshaw in earlier papers. Most notably they are often severely compacted by heavy machinery during site reinstatement and, even after ameliorative treatment, may remain inhospitable to root growth (Chapman, 1967). Some have toxic concentrations of heavy metals (especially copper and zinc) who effects, like those of other soil pollutants, may be exacerbated by excessive acidity or alkalinity. Within and downwind of conurbations and industrial locations, atmospheric pollutants may severely inhibit the establishment and growth of trees (Davis and Wilhour, 1976), sometimes without causing visible blemishes (Pollenschuetz, 1970).

Interestingly Farrar *et al.* (1977) have argued that the absence of mature Scots pine *(Pinus sylvestris)* from the Manchester/Leeds axis can be related to the formerly large winter concentrations of atmospheric sulphur dioxide. Is it surprising that ornamental cultivars selected in ideal growing conditions often fail when confronted with such adverse situations? There are several approaches to these problems:

a) Improve site conditions so that ornamental cultivars can be grown.

b) Only plant tree species known to be relatively tolerant of poor site conditions.

c) Select and breed tolerant variants within tree species.

Site improvement has been, and will continue to be, a major consideration, although with the rise in cost of fossil fuels amelioration is becoming increasingly expensive and, where heavy machinery is involved, can be harmful to soil structure. However, many sites are too small or too awkwardly situated to warrant the use of specialised equipment.

More recently species selection has received attention with the assessment of existing plantings and establishment of new trials on many types of degraded land (Wood *et al.* 1963; Dunball, 1978; Broad, 1979). Not surprisingly, pioneer species such as birches *(Betula* spp.), willows *(Salis* spp.), alders *(Alnus* spp.) and pines *(Pinus* spp.) are generally among the more successful.

Selection of tolerant variants within species has remained relatively unexplored although it probably offers the quickest and best method of improving establishment and long-term growth on difficult sites. Natural populations of plant and animal species are usually variable. Within a plant species, differences of growth rate, form, leaf shape, flower colour, are readily appreciated but differences in ability to withstand frost, exposure, drought and soil factors are less easily distinguished. Although they determine the appropriateness of a tree for a particular site, they have been overlooked. Natural populations of clover (Snaydon and Bradshaw, 1962) and grasses (Jowett, 1959; Snaydon and Bradshaw, 1961) show a range of responses to availability of nutrients. Populations from low phosphate or low calcium sites were able to grow better with low concentrations of these nutrients in culture than were populations from more fertile sites. Similarly some populations of common and creeping bent-grass *(Agrostis tenuis* and *A. stolonifera)* naturally occurring on mine sites with toxic concentrations of copper, were found to have innate tolerance to this element (Bradshaw, 1976). Among trees, different seedlots of birch *(Betula pendula* and *B. pubescens)* have been found to respond differently to readily available nutrients in aseptic culture (Mason and Pelham, 1976). Significant differences in survival and growth of different unselected populations of Virginia pine *(Pinus virginiana)* planted into acid opencast spoil have also been found (Plass, 1973). In the latter instance evidence suggested that success or failure was directly correlated with efficiency of nutrient utilisation. Clearly, then, a basis for selecting and breeding 'improved' varieties of woody plants suited to difficult sites exists, and the question becomes one of how best to exploit inherent variability.

Table 1.

Suggested methods of selecting and exploiting inherent variability of plants

Selection	*Propagation*	*Testing*	*Use*
1. Screen for tolerance a range of unselected seed lots from a range of habitats 2. Screen for tolerance seedlots obtained from selected trees growing on degraded land	Vegetatively propagate tolerant individuals	None	Use on site or use as parents in a breeding programme
3. Select individuals occurring on degraded land	Vegetatively propagate	Test tolerance of selections in a range of conditions	

The first of the selected methods outlined in Table 1 is unlikely to be very effective, at least in the short run, because relatively few of the seedlings from 'unselected' sites are likely to be tolerant - an inefficient procedure.

The second approach has more to commend it but large numbers of seedlings will have to be tested on a range of sites. It might be worth testing seedlots from young trees growing on old heaps of spoil as they may represent the third or fourth generation subject to the locally important selection pressure whether acidity, aridity, exposure, or heavy metal toxicity. Unfortunately progressive selection of tolerance will be continually diluted by fertilisation with air-borne pollen blown from trees at a distance.

Selection of individuals growing on difficult sites is theoretically likely to be the most rewarding. While there is a risk that the selected individuals might fortuitously be growing in favourable microhabitats in an otherwise inhospitable milieu, the degree of tolerance can be readily discovered in field trials with the rejection of sensitive clones. In adopting this procedure it must be assumed that trees growing successfully on difficult sites are most likely to have innate, genetically controlled tolerance than representatives of the same species from favourable locations. It is possible to test the merits of one clone against those of other clones of the same or different species on a range of difficult sites, the clonal nature of the planting stock eliminating between-plant genetic variability found in plants of seedling origin, so that responses can be readily assessed. In this way worthwhile clones can be identified at an early stage with the immediate initiation of the process of bulking-up undertaken knowing that the properties of the ramets will resemble those of the mother-tree.

EXPERIMENTAL PROGRAMME

Clones of birches, willows, alders and elder *(Sambucus nigra)*, have been obtained from a range of colliery spoil heaps mostly in Wales, northern England and central Scotland. Stocks have been increased by rooting softwood cuttings in propagating beds with bottom heat and intermittent mist in a glasshouse. The resultant plants are grown on in a soil-based compost until large enough to be used in experimental plantings. The compost was removed from the roots of some plants prior to planting out, others were planted with their soil balls intact. Different species and clones have been tested in factorial experiments in which responses to fertilizer treatments are also examined. These trials are being done on opencast coal sites and colliery spoil tips throughout Britain. Limited pot experiments have also been set up.

Table 2.

Percentage survival of selected clones and unselected controls of birch, willow and elder eighteen months after planting the Radar North restored opencast coal site, Northumberland

		Tree survival %			
		Fertilizer treatments (kg/ha)			
Genus	*Clone accession numbers*	*Nil*	*20kg N 80kg P_2O_5*	*60kg N 240kg P_2O_5*	*Mean*
	A. Selected				
	64	33	0	0	11
Birch	86	33	17	0	17
(Betula)	73	67	33	33	55
	34	100	100	50	83
	P7	100	100	67	90
	B. Unselected	0	0	17	5
	Mean	55	42	28	42
	A. Selected				
	51	0	33	17	17
Willow	50	50	50	33	55
(Salix)	90	83	57	100	83
	76	100	83	100	94
	12	100	100	83	94
	B. Unselected	83	50	100	78
	Mean	69	64	72	69
	A. Selected				
	40	67	50	83	67
Elder	77	83	83	83	83
(Sambucus)	49	83	100	83	89
	20	100	100	100	100
	63	100	100	100	100
	B. Unselected	67	67	100	78
	Mean	83	83	92	86

Most of the trials have been planted within the last two years. At Radar North, a restored opencast coal site near Newcastle-upon-Tyne, a significantly greater proportion of elders than of willow and birch have survived the eighteen months since planting (Table 2). Within each species there has been considerable variation in survival between clones with several clones performing better than the unselected controls. In birch all selected clones had a better survival rate than the controls. Perhaps the most important point to note, and it applies to all but one of the trials established so far, is the high survival of the most successful clones of all three species. The data suggest that a survival percent exceeding 90% would be obtained if *Betula* clones P7 and 34, *Salix* clones 12 and 76 and *Sambucus* clones 20 and 63 were planted, as compared with a mean of 68% for all selected clones and 53% using the unselected stock. It remains to be seen if they subsequently retain this advantage, but successful establishment is arguably the most important stage in successful restoration.

At all field sites, establishment was hardly affected by the application of fertilisers. If anything, large amounts (60 kg N/ha and 240 kg P_2O_5/ha) decreased survival, possibly because of competition from the stimulated growth of weeds which sometimes smothered young trees. This problem is important only on sites which have been grassed prior to tree planting or where the restored soil is relatively fertile; it is of little significance on infertile sites or those where there is no topsoil. On fertile sites, therefore, it is necessary to control weeds, either chemically or by using 'mulches' after applying fertilisers.

Table 3.

Mean height relative growth rates (cm/cm / yr) of selected and unselected clones of birch *(B. pendula* and *B. pubescens)* over the first growing season after planting at Bilston Glen Colliery, Midlothian

	Mean height relative growth rate cm/cm/yr			
	Fertiliser applications kg (Enmag)/ha			
Clone accession numbers	*NIL*	*364*	*738*	*Mean*
A. Selected				± 0.04
12	0.24	0.44	0.35	0.34
22	0.12	0.21	0.50	0.28
6	0.20	0.29	0.17	0.22
17	0.06	0.28	0.21	0.18
53	0.11	0.21	0.17	0.16
24	0.13	0.22	0.08	0.15
11	0.11	0.12	0.05	0.09
37	0.01	0.06	0.13	0.07
B. Unselected				
27	0.06	0.07	0.01	0.05
W8	0.01	0.03	0.08	0.04
Mean (± 0.04)	0.11	0.19	0.18	

On sites in Scotland where growth of birch and alder are being assessed, initial survival success was correlated with the coarseness of waste on site. Coarse waste, presumably of lower water-holding capacity, had lower survival rates. Preliminary results of growth rates have been obtained, the data from a slightly acid tip of deep-mined spoil at Bilston Glen Colliery, Edinburgh are given in Table 3, page 115. At this site, the selected birch clones generally performed better than the unselected controls, both in the presence and absence of fertilizer. Similar results have been obtained from other sites.

Future Work on Clonal Selection of Amenity Trees

The way forward is clear. There is already sufficient (i) evidence of clonal variation of survival rate and (ii) preliminary data on growth rates, to encourage maintaining observations of existing trials well into the post-establishment phase while continuing to seek new sources of tolerance. Additionally it seems desirable to include series of more precisely controlled trials, possibly in pots, which might enable mechanisms of tolerance to be unravelled. These are likely to be extremely complex, tolerance residing in a number of factors. For example, a plant that survives planting on coal waste has not only to be tolerant of the particular pH and nutrient status of the waste but may also have to tolerate low water status and other conditions. However tolerant a plant is of low nutrient status it will be unable to survive unless it is also drought tolerant. Hence survival may depend upon a chain of tolerances; controlled trials may enable attention to be focussed upon particular links in the chain. Soon the promising clones from already established trials should be planted on a larger scale and subjected to normal management practices along with unselected planting stocks of the type normally used. If it were deemed desirable, successful clones could be used for the production of lines combining tolerance with other valuable attributes but this is a relatively slow process. Every generation would have to be screened for tolerance, but this could be done without costly and time-consuming field trials if reliable and interpretable 'laboratory' methods were developed.

Another aspect of tree planting on difficult sites is the selection of suitable mycorrhizal fungi which are beneficial to tree establishment and growth. Mining waste not only presents plants with a physically and chemically difficult substrate but may also be deficient in mycorrhizal fungi due to the previous absence of vegetation and the disturbance of the waste. Just as trees selected for good performance in the nursery are not those most suited to difficult conditions, so mycorrhiza acquired in the nursery are also likely to be inappropriate. Yet due to lack of mycorrhizal fungi on waste they are unlikely to be rapidly supplanted by more appropriate fungi on site. Observations on strip-mined land in the United States suggested that good performance of tree seedlings was linked with heavy ectomycorrhizal infection (Schramm, 1966), the ectomycorrhizal fungus *Pisolithus tinctorius* appeared to promote vigorous growth and is now being used to successfully 'tailor' trees for reclamation (Marx *et al.* 1970). Preliminary work is now in progress at I.T.E., testing the effectiveness of different species and strains of ectomycorrhizal fungi on the growth and establishment of trees on coal waste.

CONCLUSION

In this paper one aspect of clonal selection has been discussed. However, principles which have been enunciated may be equally applicable to the clonal selection of other desirable characteristics such as disease resistance, tolerance of air pollution, the rapid formation of callus to protect wounds, frost hardiness, ease of vegetative propagation, unpalatability to grazing animals and visual appearance. The lessons to be learnt from the Dutch elm catastrophe should be remembered and planting should not be restricted to one or two clones unless it is possible to countenance programmes of intensive pest and pathogen control. This is possible but rarely economical for intensively managed plantations but for most amenity plantings it is unrealistic. In short, when vegetatively propagating amenity trees it is prudent to have a number of clones available.

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SUSCEPTIBILITY OF LONDON PLANE CLONES TO ANTHRACNOSE

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SUMMARY

The hybrid origin and characteristic features of London plane are described. The symptoms of anthracnose are separated into four distinct forms of damage: bud, twig, shoot and leaf blight. The initial results from research studies in the United States and Britain indicate there is marked variation in susceptibility of London plane trees to the disease.

INTRODUCTION

London plane is one of the most commonly planted trees in urban Britain, especially in the southern half of the country. From time to time serious outbreaks of a disease, known as anthracnose, have occurred on London plane and the most recent was in 1979. Although anthracnose rarely kills trees, it can cause serious defoliation during spring leading subsequently to dieback in parts of the crown. Recent outbreaks have provided the opportunity for examining more closely the variation in characters of individual London planes especially in relation to susceptibility to anthracnose. Research is also being undertaken in the United States on selection and breeding of cultivars of London plane resistant to anthracnose.

LONDON PLANE

London plane is a hybrid between *Platanus occidentalis*, the Occidental plane and *Platanus orientalis*, the Oriental plane. The species has been treated by some authorities as a single clone, or group of clones with similar features, but it seems more sensible to apply the name London plane to the whole population and to use *Platanus* x *acerifolia* (Ait.) Willd. as the latin binomial. In general the leaf and fruit characters of London plane are intermediate between those of the parent species. Thus the leaves of the Occidental plane are wider than they are long and shallowly 3-lobed, the lobes extending less than one third the length of the blade. The leaves of the Oriental plane, on the other hand, are longer than they are wide and deeply 5-lobed, the lobes extending more than half the length of the blade. The fruit clusters of the Occidental plane are usually large (3.5 - 4 cm in diameter) and solitary, whereas those of the Oriental plane are smaller (2.5 cm diameter) and borne in clusters of 2-7.

London plane leaves are usually 5-lobed, indented for about half their length and the fruits are mostly 2-4 per cluster, each being about 3 cm in diameter. However, it should be noted that there is considerable variation in the size and shape of London plane leaves, even on an individual tree.

It has been conjectured that the original hybrid of London plane arose in England about 1670 but firm evidence for this is lacking. Both parent species are known to have grown in England at that time although Occidental plane is now an extremely rare tree in this country. One of the oldest surviving London planes is that planted by Bishop Gunning in the grounds of the Bishop's Palace at Ely Cathedral in about 1680. Since that time a large number of cultivars of the hybrid (F1 generation) and of seedlings from the hybrid (F2 generation) have been introduced into cultivation throughout Europe and the United States.

Identification of clones can be very difficult and cultivars can be recognised with certainty only by comparison with reference material. A few clones have been named in Rehder's *Manual of Cultivated Trees and Shrubs* (Rehder, 1960) and these include:

Cv 'Pyramidalis'   Cv 'Hispanica'   Cv 'Suttneri'

'Pyramidalis' appears to be one of the most commonly planted cultivars at the present time.

Appreciation of the hybrid nature of London plane is important when considering susceptibility to anthracnose because one parent, the Occidental plane, is susceptible and the other, the Oriental plane, is resistant to the disease.

ANTHRACNOSE

In 1915 the German mycologist, Klebahn, named the sexual stage of the fungus responsible for anthracnose of London plane as *Gnomonia veneta*. Later he discovered that the specific epithet *veneta* had already been used for another fungus. Klebahn therefore renamed the anthracnose fungus *Gnomonia platani* which remains the accepted binomial. Prior to the discovery of the sexual stage, other names, (e.g. *Gloeosporium nervisequum*) had been used for the asexual spore forms which commonly occur on the twigs and leaves, but these names are no longer strictly valid.

Severe outbreaks of anthracnose appear to have started early in the 19th century on Occidental plane, but at the time it went unrecognised and the damage was attributed to frost. Up to that time Occidental plane had grown successfully in this country since its introduction from N. America by Tradescant in 1636. However, following the appearance of the disease, this species, which seems to be especially susceptible, has become an extremely rare and short-lived tree. By the end of the 19th century there were numerous reports of London plane being affected by the disease both in Europe and the United States.

The symptoms of the disease on London plane can be separated into four distinct forms of damage (Neely, 1976).

Bud blight. The fungus overwinters in buds invading and killing the tissues so that the buds do not open in the spring. Frequently the fungus grows into the adjacent twig, killing the bark and cambium for a few centimetres above and below the bud. If, as often happens, the stem is not girdled a small oval canker develops at the infected node.

Twig blight. This symptom occurs when the fungus from an infected bud invades the stem, girdling it causing the distal portion to die back. Sometimes infection may spread down from a terminal bud to cause tip dieback. Twig blight may also occur when a twig is girdled following an attack during the shoot blight phase.

Shoot blight. Shoot blight is perhaps the most spectacular form of damage. Early in the growing season young developing shoots from 1 to 10 centimetres long, wilt and die. The whole shoot turns yellow or brown and the leaves are subsequently shed. These symptoms may occur in parts of the crown or may be distributed throughout the tree. In extreme cases, where the whole tree is affected soon after flushing, the crown may be entirely leafless for a period. Attacks which develop later in the growing season cause a generally discoloured crown and the ground below may be littered with fallen leaves, giving the appearance of a premature autumn.

Leaf blight. Distinct symptoms start to appear on leaves in early summer. Brown necrotic patches develop on either side of leaf veins, which themselves become clearly outlined in black. The necrotic patches vary in size from 1 to 5 centimetres across and can be found on almost any part of the leaf; in extreme cases they appear along all the main veins and down into the petiole.

Various observations have been made on the climatic conditions which favour development of the disease. American scientists (Neely, 1976), who have studied the disease on the Occidental plane, consider shoot blight arises as a result of latent infection in the bud and that damage develops if temperatures are low. Rainfall in spring and early summer may be an important factor in the development of leaf blight. Further research, however, is required before relationships between disease and climate are fully understood.

SUSCEPTIBILITY TO DISEASE

It has already been noted that Occidental planes are particularly susceptible to anthracnose. Oriental planes, on the other hand, show resistance, although not immunity. Different clones of London plane are intermediate in their reactions to the disease. Santamour (1976), an American plant breeder, crossed Occidental and Oriental planes to reproduce London plane. Hybrid seed resulting from the cross-pollination and seeds formed by self-pollination of the parents were produced from 1968 to 1970 and the resultant seedlings were exposed to natural infection in 1974. Two observers scored the seedlings on the percentage of the crowns exhibiting shoot blight. The average crown infection for the selfed Occidental plane seedlings was 19 per cent whereas that for selfed Oriental and hybrid seedlings was 1 and 3 per cent respectively. As no satisfactory artificial method of inoculation has yet been developed these results are presented on an interim basis. Santamour has made a preliminary selection from the hybrid material for disease resistance and these selections are now undergoing further testing.

Observations made in London during outbreaks of the disease in 1969 and 1979 have also yielded some information on the susceptibility of different types of London plane. In both years the disease was particularly severe in The Mall, Ladbroke Grove and along the Victoria Embankment. It was possible to distinguish two main types of tree: a 5-lobed leaf type and a 3-lobed leaf type. The 5-lobed lead type has 2-4 fruits in a cluster and a smooth-barked trunk, whereas the 3-lobed leaf type has 1 solitary fruit and a rough-barked trunk. The 3-lobed leaf type appears to be more closely related to the Occidental plane but its leaves and bark are distinct from the parent species. It is not possible to assign with certainty the trees in The Mall, Ladbroke Grove and Victoria Embankment to named clones (indeed some of them may be F2 seedling populations) but the broad grouping referred to above has proved to be of considerable interest in relation to disease assessments.

Table 1.

Anthracnose in London - Crown dieback scores

Location	*Year*	*3-lobed type*	*5-lobed type*
The Mall	1970	1.1	0.7
	1979	0.8	0.4
Ladbroke Grove	1970	1.9	0.7
	1979	0.7	0.4
Victoria Embankment	1979	0.7	0.4
Overall Mean		1.0	0.5

In Table 1 details of disease assessments are presented which were made in London during 1970 and 1979. The crowns of trees were assessed for dieback and scores from 0-4 allocated for healthy trees and those with slight, moderate and severe dieback respectively. At all three sites, in both years of assessment, the 3-lobed type was more severely affected than the 5-lobed type and the overall mean score of the 3-lobed type was 1 compared with 0.5 for the 5-lobed type.

CONCLUSIONS

These results are particularly interesting in view of the widespread planting of the 3-lobed type in Britain. 'Pyramidalis' is probably a cultivar or selection of cultivars of the 3-lobed type. Many replacement trees and newly planted avenues are of this type and many have shown dieback symptoms during 1979. There are clearly disadvantages in planting a susceptible type especially when some of the crown and trunk characters of this type are not wholly desirable. For example, the trunks of mature trees are covered with rough outgrowths and the characteristic flaky bark is often absent. Its greatest advantage appears to be the ease with which cuttings can be rooted (as in the Occidental plane) and this is perhaps the reason why it is so widely planted.

Little is known as yet about the susceptibility of other clones of London plane although a single tree of the cultivar 'Hispanica' in The Mall has remained remarkably healthy. The Forestry Commission, in collaboration with the nursery trade, has started to make a collection of the more visually interesting London plane clones. It is planned to test these clones for resistance to disease and to make observations on other important arboricultural characters.

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DISCUSSION

W.E. Matthews - Was the heavy shedding of bark experienced in 1979 a feature of anthracnose or some other malady?

D.A. Burdekin - This was certainly not associated with anthracnose. It appears to have been a normal physiological function which made London plane attractive for street planting in smoky cities during the 19th century.

Professor Brenan - Has selection for disease resistance been made from F_1 hybrids?

D.A. Burdekin - Yes, some selections have been made in the States by Santamour.

AND SO ON FROM HERE

Chairman T.T.W. Peregrine
Department of the Environment

AND SO ON FROM HERE

Chaired by T.T.W. Peregrine

Department of the Environment

In opening the final session Mr Peregrine expressed his satisfaction with the research results reviewed during the seminar. However, the contracts between the Department of the Environment, the funding agency, and the Forestry Commission and the Natural Environmental Research Council, the contractors, expire at the end of 1980. Although optimistic about the renewal of the contracts, Mr Peregrine indicated that it was by no means automatic; the Government's stated intention of reviewing and cutting departmental expenditure included scrutiny of contracted research. Criteria have been established to assist the decision making - 'any research should relate to an area of central government concern and must have a customer and be applicable'. In this context research projects leading to improved efficiency and saving of central and local government funds were more likely to receive favourable consideration. Mr Peregrine then invited comment on the direction of future research in arboriculture.

Mr Johnston, Director of Research, Forestry Commission, reminded delegates that the seminar had been organised to communicate what were in fact only interim results of the current research - five years being too short a time in the life of a tree to obtain definitive prescriptions. As a result, work in hand must be continued and expanded to draw it to a logical conclusion. In addition consideration must be given to research on roots and their manipulation; roots and their causal agents; and the influence of fertilizers on the establishment of young trees and development of mature trees.

Dr Good, Institute of Terrestrial Ecology, expanded on the theme of selection and breeding of trees for specific locations. The current work was regarded as merely the tip of the ice-berg considering a very limited range of species on one type of site. Extension of the work could consider ranges of genera and sites.

Dr Biddle, Arboricultural Association, reminded the meeting of the establishment of the original Arboriculture Research Working Party which primed the pump for the existing contracts. Dr Biddle stated that the industry was grateful for the results emanating from the contracted research but very anxious to see the work continued, expanded and applied to the very real problems - especially those of trees in towns. However, the work should be undertaken in complete consultation with the industry.

Dr I.R. Brown called for an examination of the plasticity of plants while Miss A. Brooks considered that research into Coral spot *(Nectria cinnabarina)* would be useful. Dr B.H. Howard expressed a belief that clonal selection, especially for urban situations but with a broad base, would be valuable and mentioned the developing work of the Clonal Selection Committee in conjunction with Long Ashton.

Mr Peregrine expressed thanks for the suggestions made, all of which would be considered in drawing up future research programmes.

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