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Trees: from nursery to independence in the landscape – Recommendations

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Foreword

Publishing information

This British Standard is published by BSI Standards Limited, under licence from The British Standards Institution, and came into effect on 28 February 2014. It was prepared by Technical Committee B/213, *Trees and tree work*. A list of organizations represented on this committee can be obtained on request to its secretary.

Information about this document

BS 8545 is a new British Standard and is intended to assist people involved in planning, designing, resourcing, producing, planting and managing new trees in the landscape.

The purpose of this standard is to explain how new trees can be successfully grown and planted so that they flourish in the landscape without excessive maintenance. The standard promotes the principle that successful new tree planting relies on the integration of careful design, nursery production and planting site management, into one continuous process. All parts of the process are important and need careful consideration if new trees are to successfully achieve independence in the landscape.

The large amounts of research and anecdotal evidence on good practice throughout the breadth of preparing, planting and maintaining new trees, make it impossible to comprehensively list all that information within this standard. Instead, the standard seeks to distil the best of that information into discrete recommendations that summarize the process. It is structured so that users can access an overview of all parts of the process quickly and easily through the flowcharts and the body text. This is supplemented by more detailed discussion in the annexes, which is supported by technical referencing of relevant scientific research. The intention is for users to be able to easily identify the clauses that are relevant to their needs and, if necessary, then drill down into more detail in the annexes, and follow that up with accessible research references, if even more explanation is required.

The standard does not seek to be prescriptive or to provide a simple solution to cover all eventualities, recognizing that there is no single route to achieve its ends; but rather traces a series of good practice options, providing guidance and enabling an optimal route to be planned, defined by individual site constraints. It is for those involved in the process of achieving independence for young trees in the landscape to decide on which of the options outlined in the body of this standard are appropriate to their own requirements. These options will be conditioned by design and strategic intentions, individual site constraints and requirements, nursery availability and quality of tree stock, budget size and maintenance schedules.

This standard recognizes that each site is different, and its successful use depends on the depth and integrity of individual site assessment. Additionally, it recognizes that there is a wide range of experience, credentials and local knowledge of individual users, which could affect how recommendations are implemented. For example, local knowledge of, and familiarity with, the site conditions (as with the retrofitting of street trees) could dispense with the need for detailed site investigations. Conversely, designers working at a new location would clearly need detailed investigations to fill in the gaps in their knowledge and inform the decision-making process.

In most situations, a great diversity of information needs to be accumulated to inform the decision-making process, which requires skill, knowledge and experience to transform ideas on paper into successful results on the ground. This is an intellectual process that involves weighing the accumulated information to arrive at a balanced decision that has properly and fully accounted for all the relevant influencing factors. This process is technically difficult and intellectually challenging, but is absolutely necessary to consistently successfully deliver new trees that are independent in the landscape.

This standard recognizes that the word "establishment" can be taken as meaning the tree is present and alive, but those physical characteristics have very little bearing on whether the tree will survive and flourish. Indeed, trees can stay alive for decades, but remain moribund and make no significant contribution to the landscape. An obvious objective of all new planting is to reach the position as quickly as possible where a tree is healthy and has every prospect of achieving its full potential to deliver the benefits it was planted for, without any excessive or abnormal management input. It is for this reason that the phrase "independence in the landscape" is preferred in this standard to the word "establishment".

Use of this document

This British Standard takes the form of guidance and recommendations. It should not be quoted as if it was a specification and particular care should be taken to ensure that claims of compliance are not misleading.

Any user claiming compliance with this British Standard is expected to be able to justify any course of action that deviates from its recommendations.

It has been assumed in the preparation of this British Standard that the execution of its provisions will be entrusted to appropriately qualified and experienced people, for whose use it has been produced.

Presentational conventions

The provisions in this standard are presented in roman (i.e. upright) type. Its recommendations are expressed in sentences in which the principal auxiliary verb is "should".

Commentary, explanation and general informative material is presented in smaller italic type, and does not constitute a normative element.

Contractual and legal considerations

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Compliance with a British Standard cannot confer immunity from legal obligations.

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Introduction

It has been a widely recognized fact that a significant proportion of newly planted trees fail to survive to maturity. The *Trees in towns II* report [1] commissioned by the Department of Communities and Local Government highlighted that as much as 25% of all planting undertaken in the public sector actually fails. Although there has not been any comparable survey undertaken in the private sector, anecdotal evidence indicates that the failure rates are similar.

It is difficult to pinpoint the reason why the failure rate of new planting is so high, but one contributory factor is the present disjointed approach to production and planting. This standard seeks to define all the parts of the process as a continuous and joined-up sequence, rather than isolated parts that have no tangible connections.

An important objective of this standard is to assist practitioners in making balanced and informed tree planting decisions. Ideally, all newly planted trees need to be able to grow with vigour appropriate to the species and situation, in good health, and with minimal nuisance to achieve the desired planting objectives.

The standard sets out good practice in strategic and policy formation and then follows the whole transplanting process through to independence in the landscape, under the following clause headings:

- policy and strategy;
- site evaluation and constraints assessment;
- species selection;
- nursery production and procurement;
- handling and storage;
- planting;
- post-planting management and maintenance.

These clause headings are intended to be considered consecutively as illustrated in the flowchart in Figure 1 (see Clause **4**). This flowchart cascades down to a separate flowchart for each of the separate clause headings (see Clause **5** to Clause **11**). Each of these individual flowcharts is immediately followed by a series of recommendations relating to that particular subject. Each clause is cross-referenced to a series of annexes which explores each subject in greater depth, with figures and tables to add further clarification.

Each clause in this standard can be read independently from the others, but the combined clauses outline a process which is continuous. The whole process is only as strong as its weakest link; every part of the process needs to be given equal weight.

1 Scope

This British Standard gives recommendations for transplanting young trees successfully from the nursery, through to achieving their eventual independence in the landscape, specifically covering the issues of planning, design, production, planting and management.

This British Standard applies to trees where a distinct crown has been prepared in the nursery. It does not apply to whips, transplants and seedlings, or to other woody material.

NOTE Although this standard does not give specific recommendations for other woody material, many of its provisions can be applied to such material, e.g. to shrubs.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

BS 3998, *Tree work – Recommendations*

3 Terms and definitions

For the purposes of this British Standard, the following terms and definitions apply.

3.1 backfill medium
material used for refilling an excavated planting hole

3.2 bare root tree
tree grown using bare root nursery production system (**3.16.1**)

3.3 bulk density
<of soil> ratio of dry soil mass to bulk soil volume, including pore spaces

NOTE Bulk density is also known as "soil density" or "dry density".

3.4 cavitation
break in the continuity of water columns in the xylem and hence the water supply to transpiring leaves

NOTE Cavitation is usually caused by extreme soil/weather conditions, such as drought or freezing, when the tension of water within the xylem becomes so great that dissolved air within the water expands to fill either the vessel elements or the tracheids.

3.5 clonal selection
process of selecting an individual parent plant with required attributes to create a single genotype that, through vegetative propagation, can be used to create genetically identical progeny

3.6 containerized tree
tree grown using containerizing nursery production system (**3.16.2**)

3.7 container-grown tree
tree grown using container-growing nursery production system (**3.16.3**)

3.8 decurrent tree
tree exhibiting natural growth habit characterized by strong lateral or branch dominance that eventually produces a rounded or spreading tree crown

3.9 excurrent tree
tree exhibiting natural growth habit characterized by strong apical dominance that eventually produces an upright crown form dominated by one or a few central leading shoots

3.10 field capacity
maximum amount of water a soil can hold after free drainage has occurred

3.11 formative pruning
crown pruning when a tree is young or early mature with the objective of producing a tree which in maturity will be free from any major physical weaknesses and which will complement the management objectives for the site

3.12 independence in the landscape
point at which a newly planted tree is no longer reliant on excessive or abnormal management intervention in order to grow and flourish with realistic prospects of achieving its full potential to contribute to the landscape

3.13 landscape character
pattern of elements in a landscape that makes one landscape different from another

3.14 leaf fluorescence
measure of photosynthetic efficiency that indicates plant vitality

3.15 nursery pruning
pruning on the nursery to produce well-balanced crown formation, straight leader and subordinated lateral branches while retaining the photosynthetic integrity of the young tree during its development

3.16 nursery production systems

3.16.1 bare root production system
nursery stock process whereby trees are planted and grown on in open land or fields and lifted with the root system free of soil

NOTE This is also known as "open ground".

3.16.2 containerizing production system
nursery stock process whereby trees grown in open ground are lifted and potted up into containers

3.16.3 container-growing production system
nursery stock process whereby trees spend all or most of their time in the nursery in containers

3.16.4 rootball production system
nursery stock process whereby trees are undercut or transplanted and lifted with a soil ball wrapped in hessian or other breathable material and secured with non-galvanized wire netting

3.17 root circling
debilitating spiralling action of roots over time in a restricted root ball or container that, if not rectified by pruning, will lead to root girdling

NOTE Trees with circled roots are often referred to as "pot-bound" or "root-bound".

3.18 root girdling
spiralling of roots on planted trees at or below ground level

NOTE Girdling is caused by the failure to prune out root circling in the nursery or at the time of planting that might strangle the tree and ultimately result in instability or even failure.

3.19 root flare
thickened and expanded base of a tree stem at ground level from which buttress roots form

NOTE This is also referred to as "stem flare" or "trunk flare".

3.20 root shank
portion of root tissue on a young tree's stem above the adventitious root flare

NOTE Adventitious root flare is the area in which adventitious roots occur out of sequence from the more usual root formation of branches of a primary root system, usually after primary root pruning and the loss of natural laterals has occurred in nursery production.

3.21 rootballed tree
tree grown using rootball nursery production system (**3.16.4**)

3.22 soil biota
all the organisms that spend a significant portion of their life cycle within a soil profile, or at the soil–litter interface

NOTE For example, earthworms, nematodes, protozoa, fungi, bacteria and different arthropods.

3.23 stem taper
decrease in diameter of a tree's stem from the base upwards

3.24 structural soil
medium that can be compacted to pavement design and installation requirements yet permits root growth

3.25 tree pit
excavated hole of adequate dimensions to accommodate the root system of a specified tree

3.26 tree population
group of individual trees growing in a defined area at the same time

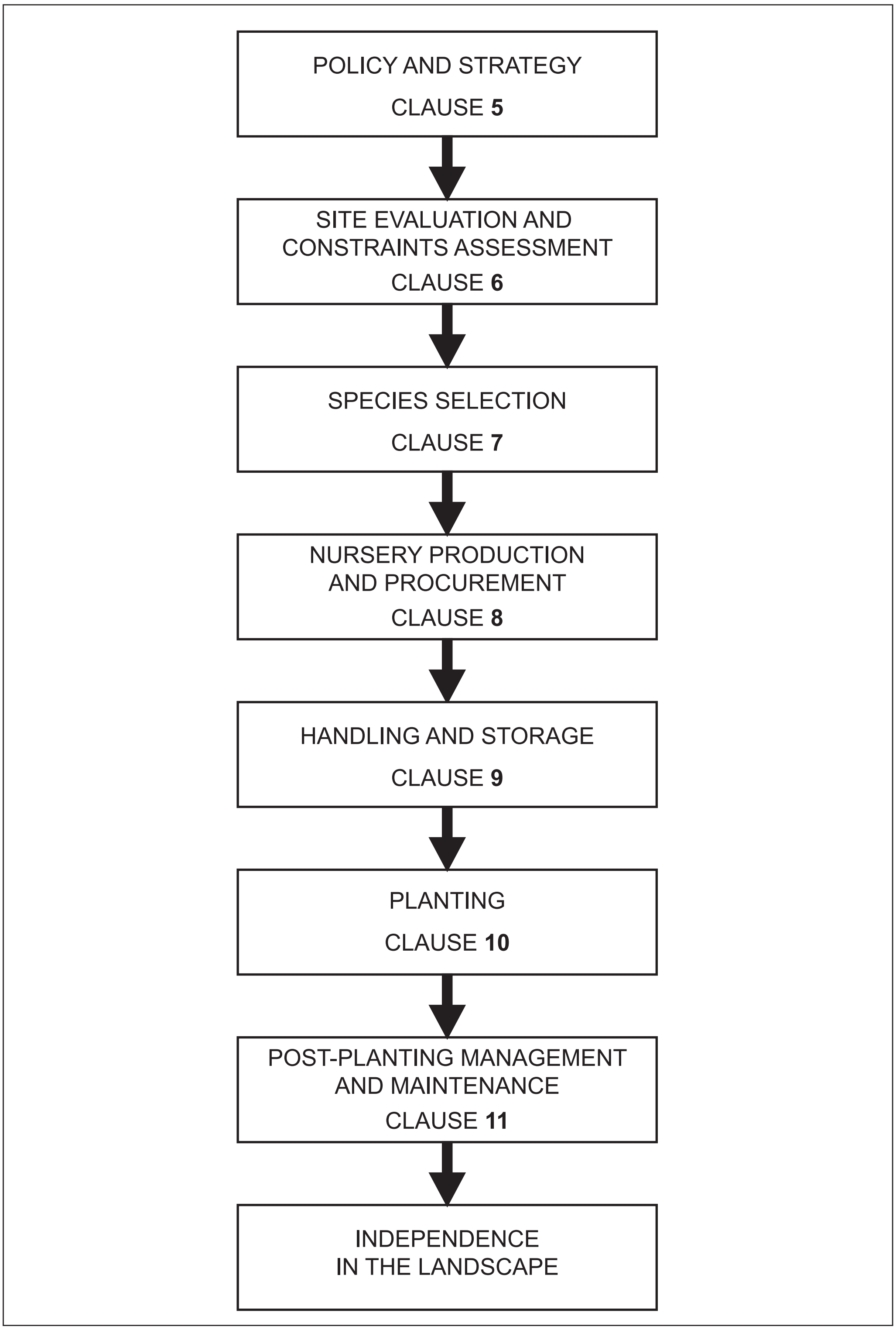
3.27 underground cellular system
modular, suspended or load-bearing pavement system that incorporates uncompacted soil volumes to accommodate tree root growth

4 General process

For all planting projects, the process shown in Figure 1 should be followed.

NOTE Figure 1 and the flowcharts in the clauses that follow are conceptual diagrams that summarize the principles rather than the detail of each process. Although the flowcharts are presented in linear form, the practical application is likely to involve revisiting, cross-referencing or reviewing different stages of the process.

Figure 1 **General process for new planting projects**



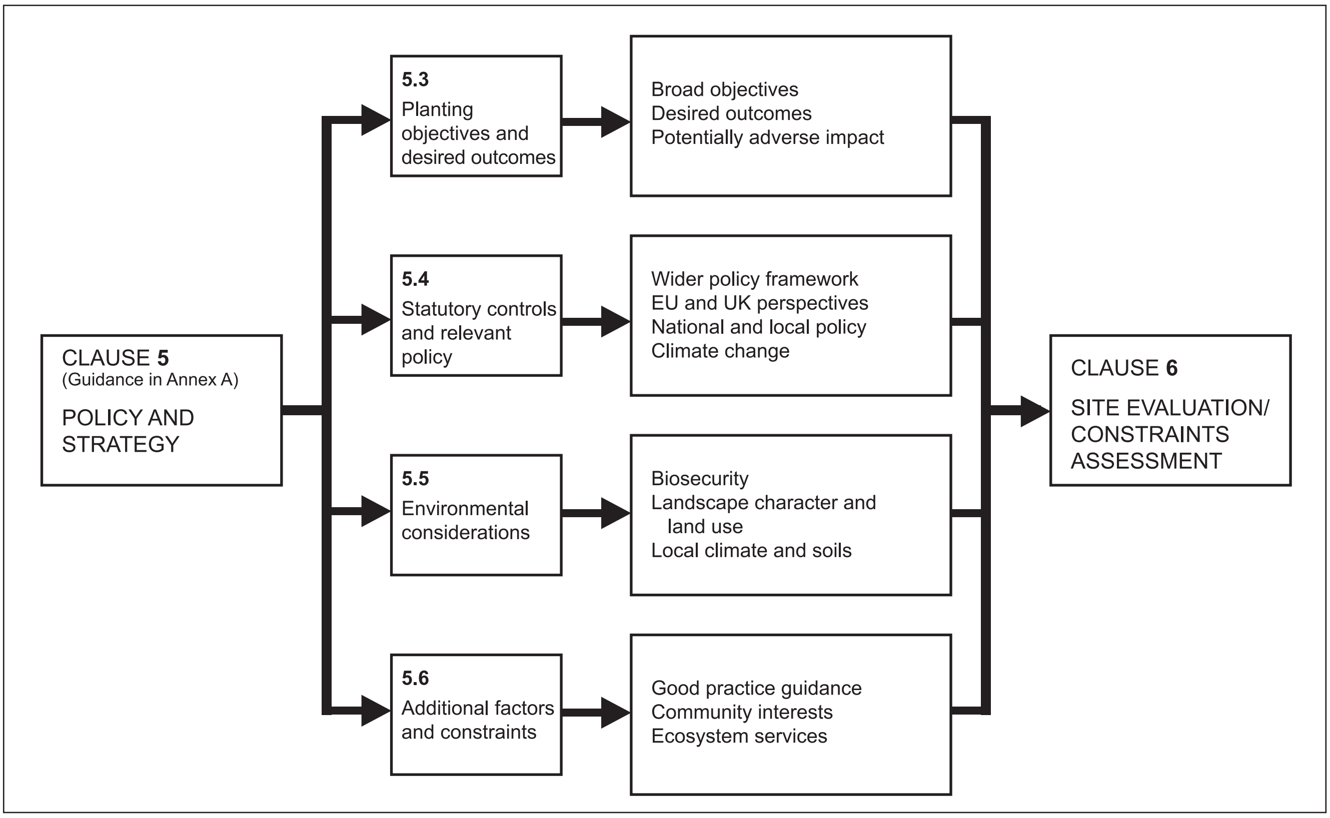
5 Policy and strategy

5.1 General

The policy and strategy part of the process should follow the order shown in Figure 2, and should meet the recommendations given in **5.2** to **5.6**.

NOTE Further guidance on policy and strategy is given in Annex A.

Figure 2 **Process flowchart for policy and strategy**



5.2 General recommendations on policy and strategy

5.2.1 Individual trees form parts of the broader tree population, often referred to as the urban forest in built-up areas. The risks, benefits and characteristics of the urban forest should be taken into account when planning new planting.

5.2.2 Tree planting projects should identify and respond to relevant local planning and environmental policies and objectives.

NOTE Relevant policies might include those that relate to ecology, sustainability, landscape, climate change, biosecurity and the wider environment.

5.2.3 Tree planting projects can range from one tree in a residential setting to a large landscaping scheme involving thousands of individual trees. Irrespective of the scale of the project area, the same principles of design and integration of new tree planting into the existing planning and policy framework should be applied for all projects, whether in the public or the private realm.

NOTE Trees can be large, long-lived organisms. Their health, safety and life expectancy are influenced by various environmental factors and, conversely, their presence has effects on their surrounding environment.

5.3 Planting objectives and desired outcomes

5.3.1 An integral part of preparing a list of objectives is to consider the desired outcomes, and this process should be given significant weight in the design of the planting project.

NOTE Well-informed planting seeks to maximize the benefits of trees, whilst recognizing and minimizing or mitigating any adverse effects posed, e.g. by choice of species or location, taking the planting and future context fully into account.

5.3.2 In addition to benefits, trees can also have adverse impacts, which should be identified and taken into account in the design of the planting project.

5.4 Statutory controls and relevant policy

5.4.1 Trees grow within both rural and urban environments which are subject to diverse policy controls. These controls might be supportive, neutral or adverse in respect of tree planting and management but, where they are relevant to a proposed tree planting project, they should be taken fully into account.

NOTE 1 Attention is drawn to the legislative controls that affect tree planting, plant passports, quarantine controls, etc. Further guidance is given in Annex A.

NOTE 2 Local government authorities produce local plans and supporting documents, such as supplementary planning documents and area action plans, and these are likely to include policies on trees within defined areas. Such local policies can be informed and supplemented by technical studies, such as landscape character, open space, biodiversity, heritage and climate change adaptation assessments.

5.4.2 Land owners and managers other than local authorities might also apply policies that relate to trees, which should be taken into account in the planning and design of new planting projects.

NOTE Examples of such bodies include rail and utility service operators, housing associations, Ministry of Defence, the National Trust and other large land or estate owners.

5.4.3 All planting projects should be designed with the climate adaptation benefits of trees in mind and should specifically aim to contribute to the national climate adaptation initiative.

NOTE Attention is drawn to the Climate Change Act 2008 [2].

5.5 Environmental considerations

5.5.1 The design of a tree planting project should account for the vulnerability of new trees to pests and diseases.

NOTE This can be done by assessing existing tree populations, with the objective of reducing reliance upon a single or limited range of species and encouraging diversity within a given area.

5.5.2 Within the prevailing policy framework, in principle, tree populations should be managed to maintain, enhance or restore relationships with identified local landscape and heritage character, particularly at the rural urban interface. In urban areas, trees should relate to, improve or enhance the character of their surroundings, whilst simultaneously providing other identified benefits and services relevant to their context.

5.5.3 The design of tree planting projects should take account of local soil and climate conditions, which will have influenced landscape character.

NOTE Trees in significantly modified or disturbed environments, such as urban areas and reclamation sites, can be selected and managed to grow in such conditions. Alternatively or additionally, the local environment in which trees are to be planted or managed might need to be specially designed or modified to improve conditions for survival and growth.

5.5.4 The design of tree planting projects should make allowance for the anticipated effects of climate change and the local environmental changes that might result from it, as well as accommodating existing environmental conditions.

5.5.5 The design of tree planting projects should take account of existing and proposed land use and the activities associated with this, particularly in areas of proposed change where existing environmental conditions are likely to be modified or where the effects of tree planting would be beneficial.

5.6 Additional factors and constraints

5.6.1 The design of new planting projects should be informed by up to date, relevant and authoritative sources of technical and good practice guidance. It should draw on input from competent persons with appropriate and relevant expertise.

NOTE There is a substantial body of guidance available. Such sources inform all aspects of tree husbandry including selection, planting, handling and management, some of which are incorporated within this and other British Standards. There are also sources of expertise such as arboriculturists, horticulturists, landscape architects, ecologists, soil scientists, hydrologists and engineers whose inputs might also be of particular value.

5.6.2 Where appropriate, the design of new planting projects should be informed by the responses to community consultation and local interest groups.

5.6.3 Trees make a significant contribution to ecosystem services, which should be taken into account in the design of new tree planting projects.

6 Site evaluation and constraints assessment

6.1 Process flowchart

The site evaluation and constraints assessment part of the process should follow the order shown in Figure 3, and should meet the recommendations given in **6.2** to **6.5**.

NOTE Further guidance on site evaluation and constraints assessment is given in Annex B.

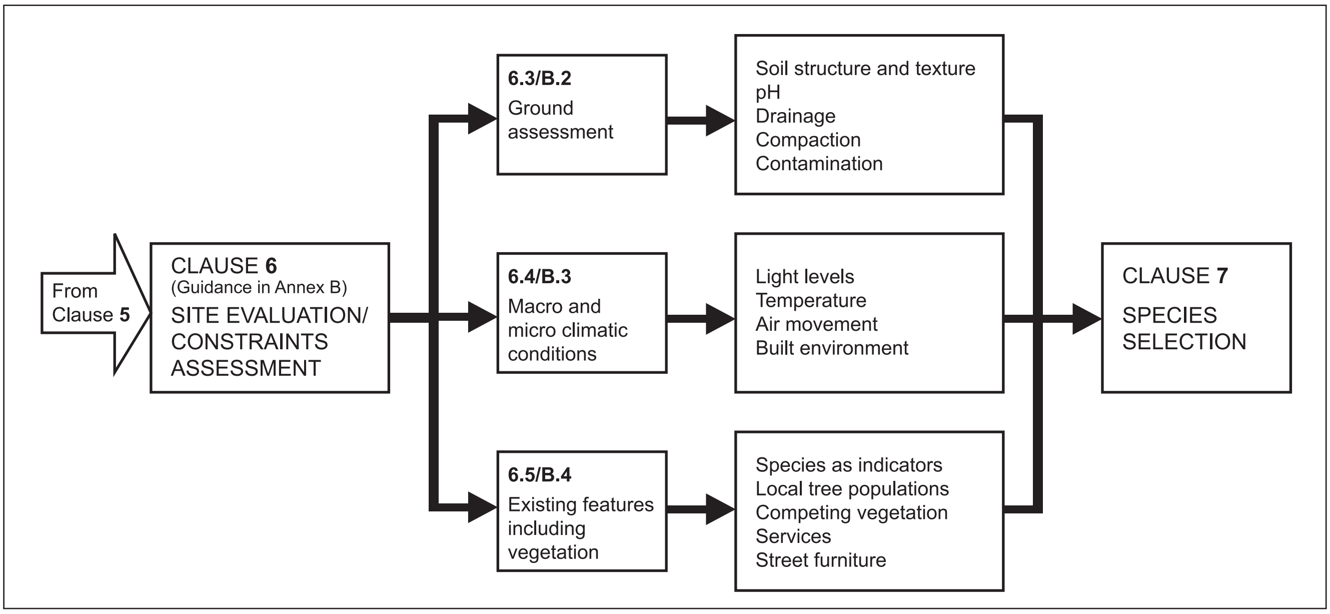
6.2 General recommendations for site evaluation and constraints assessment

*NOTE See also **B.1**.*

6.2.1 A full and comprehensive site evaluation and constraints assessment is essential to assist in the selection of the most appropriate species, nursery production method, site preparation and maintenance regime. Where familiarity with the site and experience do not allow sufficient interpretation of conditions, further investigations should be carried out to inform the decision-making process. Where appropriate, important information on site conditions should be recorded and made available to all involved in the decision-making process.

6.2.2 Vandalism can have a significant adverse impact on planting success, and the potential for vandalism should therefore be included in the assessment.

Figure 3 **Process flowchart for site evaluation and constraints assessment**



6.3 Ground assessment

NOTE 1 Planting sites are extremely variable, ranging from good quality undisturbed natural soil in existing soft landscaped areas, to highly disturbed and poor quality soils in urban environments. Similarly, the local knowledge and familiarity with site conditions of the person/team carrying out the assessment are also wide-ranging. These variables affect the depth of the assessment process necessary to achieve a sufficiently good understanding of the site conditions and to ensure that the planting proposals are properly informed and effective.

NOTE 2 See also ***B.2****.*

6.3.1 The characteristics, structure and texture of the soil should be assessed.

6.3.2 The soil profile should be taken into account, especially the depth of topsoil and subsoil.

NOTE This is important when assessing backfill depths.

6.3.3 If the soil pH is not known, it should be assessed.

NOTE pH is critical in species selection and the availability of nutrients in the soil.

6.3.4 If the drainage capacity of the soil is not known, it should be assessed using a percolation test or equivalent.

6.3.5 If excessive soil compaction is suspected, the levels of compaction should be assessed.

6.3.6 If soil contamination is suspected, the levels of contamination should be assessed.

6.4 Macro and micro climatic conditions

NOTE See also ***B.3****.*

6.4.1 Where light levels are considered to be low they should be assessed, taking particular account of shade patterns throughout the day, and the amount of daylight that any newly planted young tree can be expected to experience once planted.

6.4.2 There can be wide variations of air movement around trees planted in the built environment. These are often localized and extreme. An assessment of these extremes should be made and the potential impact on any new tree planting allowed for.

6.4.3 Air, soil and surface temperatures, drainage, gaseous exchange and the availability of water and nutrients are all affected by the type of surface surrounding newly planted trees. The potential impact on new tree planting of both existing and new surface types should be assessed.

6.4.4 The presence and use of buildings and other structures close to the planting site that could affect the new trees should be assessed.

NOTE Buildings affect shade, air movement and temperature. Their use determines the volume of pedestrian and other traffic which could adversely affect growing conditions and the potential for vandalism.

6.5 Existing features including vegetation

*NOTE See also **B.4**.*

6.5.1 Existing tree cover can provide a useful indicator as to which tree species will thrive on any site. The composition, condition and species mix adjacent to a site for new tree planting should therefore be assessed.

NOTE This can inform species choice with regard to monocultures, clonal selections, population imbalances, population resilience and landscape character.

6.5.2 Shade cast by other trees and the available space for crown development should be assessed.

6.5.3 Existing tree, shrub and grass cover can compete with new trees for available water, air and light. The amount of this cover and its potential impact should be assessed.

6.5.4 The position and location of all street furniture, including CCTV cameras, should be assessed as these can limit the suitability of any site for tree planting.

6.5.5 All sites, especially when planting street trees, should be fully assessed for the presence of underground services. The location of such services should be identified [e.g. using cable avoidance tools (CAT) scanners or ground-penetrating radar, or by referring to drawings], before any excavations commence.

7 Species selection

7.1 Process flowchart

The species selection part of the process should follow the order shown in Figure 4 and should meet the recommendations given in **7.2** to **7.5**.

NOTE Further guidance on species selection is given in Annex C.

7.2 General recommendations for species selection

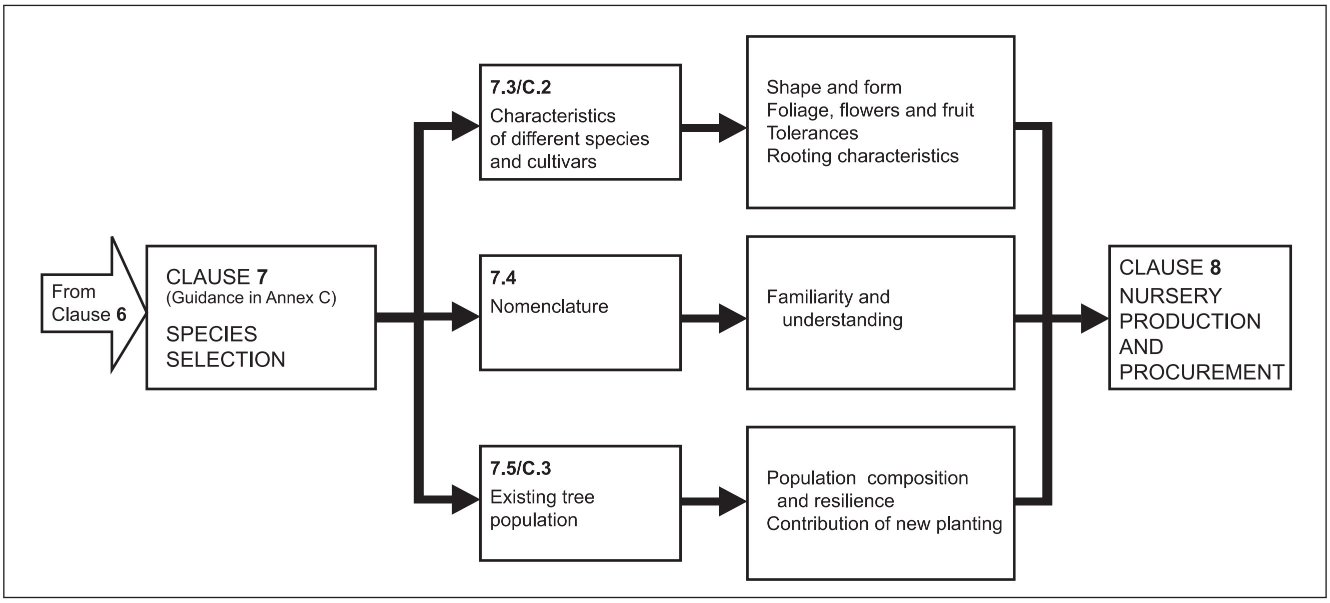
*NOTE See also **C.1**.*

7.2.1 It is essential for transplanting success that those specifying and/or procuring young trees have a detailed knowledge of tree species and their clones. This knowledge should include understanding the characteristics of tree performance under different environmental and climatic conditions. Specialist advice should be sought where necessary.

NOTE It is important to remember that characteristics indicating resilience, such as drought tolerance and frost hardiness, identified in a supplier's catalogue are not always immediately apparent, and a period of acclimatization might be necessary.

7.2.2 Nursery catalogues should not be used as authoritative references.

Figure 4 **Process flowchart for species selection**



7.3 Characteristics of different species and cultivars

NOTE See also ***C.2****.*

The following characteristics should be taken into account when making a species choice for any given site:

- the ultimate dimensions of the tree and whether there is space for those dimensions to be realized;
- the speed of growth and final form of the tree;
- the potential longevity of the tree;
- the foliage characteristics of the tree (size, shape, density, length of season, evergreen or deciduous);
- the floral characteristics of the tree (pollen, colour, flowering season and length, scent, prominence of flowers);
- the fruit and seed characteristics of the tree (size, toxicity, edibility, persistence);
- the bark and twig characteristics of the tree (colour, texture, peeling or not);
- resistance or susceptibility to pests and diseases and inherent structural defects such as weak branch attachments;
- other relevant characteristics including thorns, honeydew, autumnal leaf decomposition, attraction to insects, branch drop, allergies;
- the rooting characteristics of the tree (depth, spread, vigour, stability);
- tolerance of pruning, including formative pruning;
- tolerance of pollution (air, waterborne, salt, gas, chemical);
- tolerance of variable soil conditions (pH levels, presence of contaminated material, structure, texture, profile, clay content, moisture retention, nutrients);

- resistance or susceptibility to drought, solar heat scorch and flooding;
- tolerance of exposed positions and wind.

7.4 Nomenclature

All those involved in species selection should have an understanding of and should use the binomial system of nomenclature.

NOTE Guidance on nomenclature is given in the National plant specification *[3].*

7.5 Existing tree population of the landscape into which young trees are planted

*NOTE See also **C.3**.*

7.5.1 Most young trees are planted into an existing tree population that often extends beyond the boundaries of any particular planting site. The composition and resilience of that existing population, including species mix, age–class structure, and vulnerability to pest and disease, should be taken into account when selecting species, clones and genotypes.

7.5.2 The contribution that young trees will make to the benefits provided by the whole tree population of any geographic area should be taken into account when selecting species.

8 Nursery production and procurement

8.1 Process flowchart

The nursery production and procurement part of the process should follow the order shown in Figure 5 and should meet the recommendations given in **8.2** to **8.6**.

NOTE Further guidance on nursery production and procurement is given in Annex D.

8.2 General recommendations for nursery production and procurement

*NOTE See also **D.1**.*

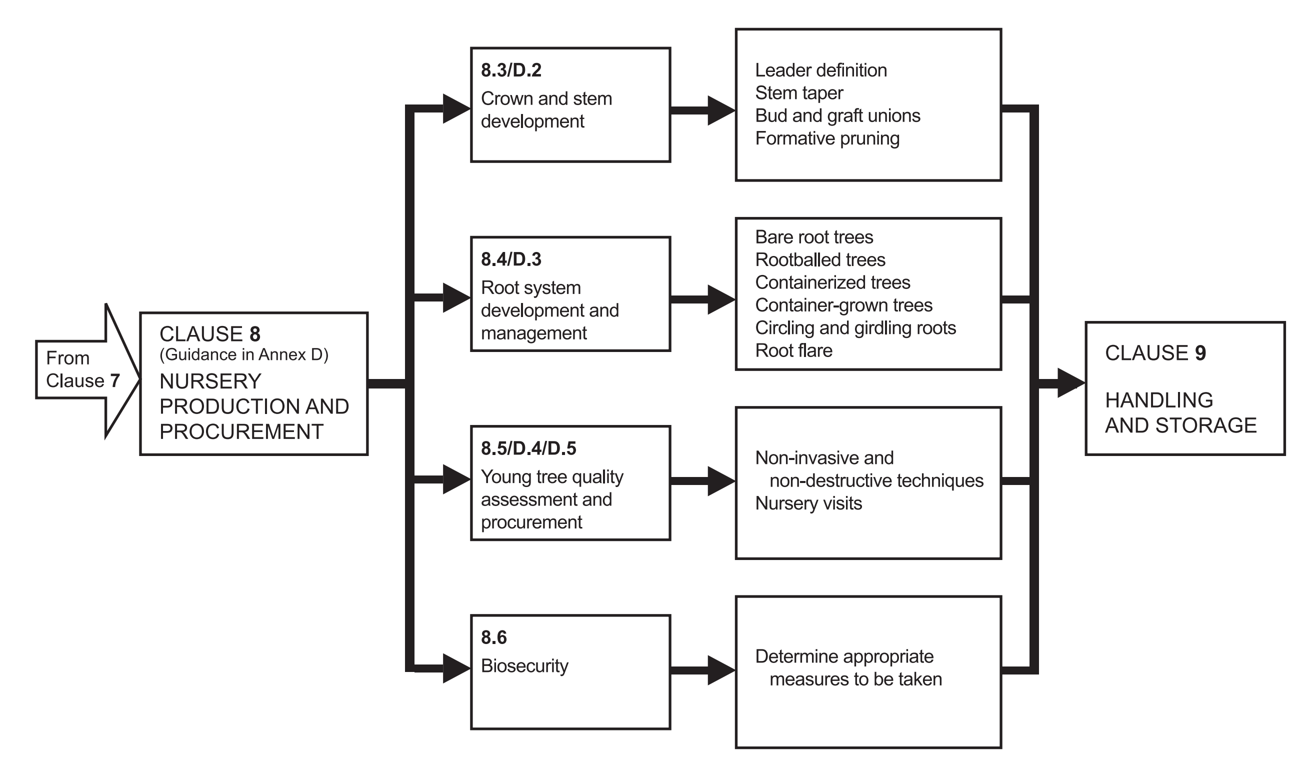
8.2.1 Everyone involved in design using young trees, in the selection and procurement of young trees, and in the planting and management of young trees, should have knowledge of nursery production and the attributes of different production systems used. Specialist advice should be sought where necessary.

8.2.2 As a minimum, nurseries should be able to supply the following information for each tree they produce:

- age of tree;
- method of propagation;
- method of production;
- formative pruning regimes;
- type of growing media if trees are containerized;
- country of origin;
- date of import;

- complete audit trail from supply to sale;
- pest and disease control programme.

Figure 5 **Process flowchart for nursery production and procurement**



8.3 Crown and stem development

NOTE 1 See also ***D.2****.*

NOTE 2 Some or all of the recommendations in this subclause might not be applicable if there are specific design considerations or specific external requirements to be met on or by the nursery.

8.3.1 All bud and graft unions should be checked to ensure full compatibility between stock and scion and that there are no weak unions or disproportionate growth at the grafting/budding joint. Evidence should be sought as to the type of stock and scion wood used in budding and grafting in the context of their long-term compatibility.

8.3.2 A young tree should not be accepted from a nursery if the bud union has been set below the soil surface.

8.3.3 All young tree stock should have a straight leader (see Note), irrespective of whether excurrent or decurrent in natural habit, and an even, well-balanced branching system. Decurrent trees should retain a leader until they have reached two-thirds of their mature height.

NOTE This does not apply to weeping trees, trees produced as multi-stemmed specimens or other trees where a straight leader is not a natural characteristic.

8.3.4 All young trees should exhibit a clearly defined stem taper, evident from crown through to root flare, appropriate to the species.

8.3.5 All young trees should have a proportionate, balanced height/stem girth ratio appropriate to the species.

8.3.6 All young trees should be self-supporting and able to stand upright without the use of cane, stake or other form of support at the point of dispatch.

8.3.7 All young trees should be formatively pruned at the nursery to give well-balanced crown formation, a well-formed straight central leader and lateral branches subordinated to that leader. Co-dominant branches and stems should be removed or subordinated.

8.3.8 Poorly attached branches with included bark, and inward-growing branches, should be removed or formatively pruned. Where branches cross or rub, the most significant branch should be retained and any others removed.

8.4 Root system development and management

*NOTE See also **D.3**. A description of the principal nursery production systems in the UK is given in **D.3.1**.*

8.4.1 All bare root trees should have a well-balanced radial root system comprising at least four obvious and substantial lateral roots.

NOTE A guide to root spread is given in Annex D, Table D.3.

8.4.2 All rootballed (balled and burlapped) trees of 12 cm to 14 cm girth and above should be transplanted at least three times on the nursery.

NOTE 1 Trees are sometimes lifted with a loose soil ball for root protection during dispatch. These are not true rootballs and the supplying nursery needs to make this clear.

NOTE 2 The principles of undercutting and transplanting rootballed trees, and the effects of not carrying out the process correctly, are illustrated in Annex D, Figure D.9 and Figure D.10.

8.4.3 All rootballs should contain a fully fibrous root system with obvious evidence of root pruning or transplanting.

8.4.4 The rootball should be a proportionate size to the stem diameter.

NOTE Guidance on the relationship between tree size and size of rootball is given in Annex D, Table D.5.

8.4.5 Containerized or container-grown trees should be free from circling or girdled roots. All nurseries should be able to supply evidence of the length of time for which young containerized trees have been in a container, giving potting dates. Purchasers of containerized trees should request these details.

NOTE All containerizing and container-growing production systems produce girdled roots if the tree is left in the container too long.

8.4.6 The natural root flare should be visible at all times.

NOTE Rootball, containerizing, and container-growing production systems can all result in the natural root flare of the young tree being too deep and buried. Additionally, root flare development varies with age and from species to species.

8.4.7 Since the root systems of rootballed, containerized or container-grown trees are not visible until the time of planting, a sample of the actual root system should be checked where practicable by breaking open a small percentage of rootballs or containers.

*NOTE This is to check that good practice has been followed as detailed in **8.4.1** to **8.4.5**.*

8.4.8 All wire used for rootballing should be non-galvanized.

8.5 Young tree quality assessment and procurement

*NOTE See also **D.4** and **D.5**.*

8.5.1 Non-destructive, non-invasive techniques should be used, as appropriate, to evaluate the physiological condition of young trees.

8.5.2 An effective way to evaluate the condition of young trees is to visit the nursery growing them. Any purchase of young trees should be accompanied by a nursery visit, wherever practicable, to check that production good practice is being followed. Nursery visits should ideally take place when trees have full foliage and stress indicators are more likely to be apparent (see Annex D, Figure D.13).

8.5.3 Adequate time should be allowed for procurement, particularly where planting involves special requirements (e.g. unusual species, exceptional sizes or large quantities).

8.5.4 Selected tree stock should be marked or tagged on the nursery.

8.6 Biosecurity

Biosecurity is an important consideration, and appropriate measures should be taken to minimize the introduction and spread of harmful organisms.

NOTE Advice on biosecurity is available from the Forestry Commission (www.forestry.gov.uk/biosecurity [1)]) and the Food and Environment Research Agency (http://www.fera.defra.gov.uk/ [1)]).

9 Handling and storage

9.1 Process flowchart

The handling and storage part of the process should follow the order shown in Figure 6 and should meet the recommendations given in **9.2** to **9.5**.

NOTE Further guidance on handling and storage is given in Annex E.

9.2 Lifting on the nursery

*NOTE See also **E.1**.*

9.2.1 The lifting of bare root and rootballed trees should take place only in the dormant season.

NOTE This season is usually identified as the period when deciduous trees have lost their foliage. It is normally between early November and March, although it varies from year to year.

9.2.2 Ground conditions at the time of lifting should be favourable; the ground should not be waterlogged, excessively dry or frozen. Particular attention should be paid to the protection of root systems in drying winds and from direct sunlight.

9.2.3 Container-grown and containerized trees can be dispatched at any time of the year. Irrespective of the time of year when such trees are dispatched, the fibrous roots in the container should hold the compost ball together once the container is removed. If the compost ball falls apart, the tree should be rejected as there has been inadequate root development.

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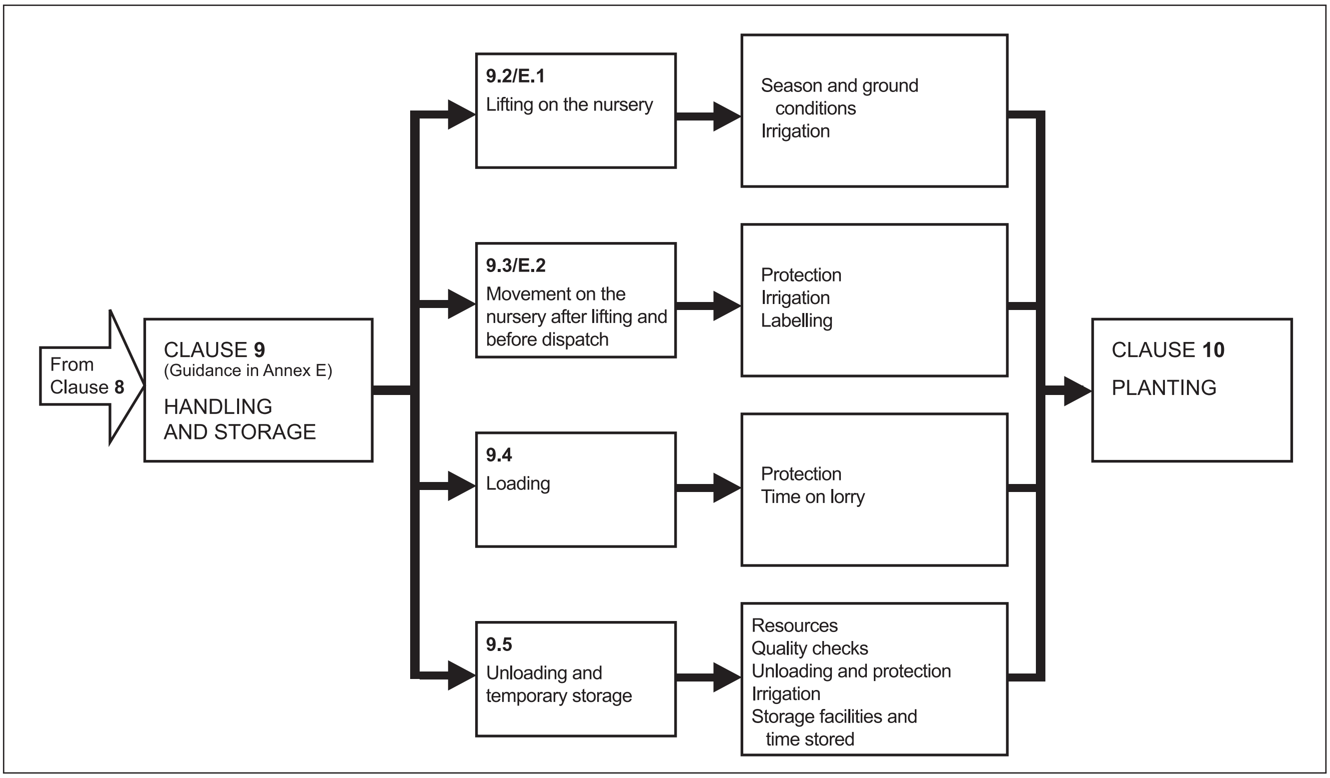
1) Last accessed 24 February 2014.

9.2.4 Not all containerized or container-grown trees are dispatched in the containers they were grown in. Some production systems require that the container is removed at the time of dispatch and the root system wrapped in hessian, which makes the roots vulnerable to drying out. At all times following wrapping, the wrapped root system should be kept fully irrigated. The length of time between removal of the container and wrapping in hessian should be kept to a minimum.

Figure 6 **Process flowchart for handling and storage**



9.3 Movement on the nursery after lifting and before dispatch

*NOTE See also **E.2**.*

9.3.1 All bare root trees should have their root systems covered and fully protected during this period to prevent desiccation. Co-extruded bags, which are black inside and white outside, should be used for bare root trees.

NOTE The white outer covering prevents roots from overheating and drying out while the black inner covering prevents light penetration.

9.3.2 Rootballed trees are often lifted in the dormant season and stored for dispatch in the late spring. These trees should be stored in an upright position, supported and irrigated during the time of storage.

9.3.3 Containerized or container-grown trees should be irrigated regularly once off the nursery production line, and fully irrigated immediately before loading and dispatch.

9.3.4 The movement of lifted trees of all production systems should be kept to a minimum on the nursery before loading for dispatch, to minimize the possibility of accidental damage occurring.

9.3.5 All trees should be individually clearly labelled, indicating the supplier's name, species, variety, cultivar and size. Labels should also indicate the customer's name, any batch numbers used on the nursery and, in the case of containerized trees, the date of containerization.

9.4 Loading

9.4.1 All trees should be loaded and stacked in such a way as to minimize the possibility of breakage or crushing by the weight of the plants above or from the security ropes.

9.4.2 The method of loading rootballed and containerized trees can result in the main stem of trees being unsupported and therefore subjected to movement during transport and pressure when unloading. Such movement and pressure can result in damage to the main stem. All main stems should be fully supported on loading by straw bales or suitable pressure-absorbing materials.

9.4.3 On open lorries, the trees should be completely covered with opaque sheeting which has been firmly secured. In closed lorries or containers, provision should be made to ensure that the trees remain cool and moist at all times during transit.

9.4.4 The time that young trees are kept on any lorry during the loading, transit and unloading process should be kept to a minimum.

9.4.5 Delivery times should be agreed between the nursery and the recipient. Additional information such as access arrangements, height restrictions and parking restrictions should be supplied by the recipient at the same time.

9.5 Unloading and temporary storage

9.5.1 Recipients of young trees from the nursery should ensure that they have the resources, both human and mechanical, necessary to unload the lorry in a speedy and efficient manner.

9.5.2 A full quality check should take place at the time of unloading.

9.5.3 Any defects or breakages should be reported to the dispatching nursery immediately. Trees that do not meet the specification or are otherwise unsatisfactory or damaged should be rejected and returned.

9.5.4 Rootballed or containerized trees should be lowered intact from the lorry by hand or machinery. They should not be dropped onto the ground, as this can cause damage to the root system.

9.5.5 All bare root trees should also be unloaded carefully and should have their root systems protected immediately after unloading, either by heeling in on site in a temporary trench, or by covering with a moisture-retentive, breathable material.

NOTE Bare root trees delivered in co-extruded bags can be left in those bags until planting but need to be protected from sun, wind and severe frost.

9.5.6 Any non-porous protective material should be removed at this stage. Heeled-in root systems should be kept moist at all times.

9.5.7 The length of time that trees are held in temporary storage should be kept to a minimum. There are occasions when rootballed trees are lifted during the dormant season and stored for supply at a later date. Such trees should be stored in an upright position and irrigated until dispatched.

9.5.8 All sites of temporary storage should be specific for that purpose. Such sites should be isolated from areas where there is the potential for contamination from other stored materials on neighbouring sites or damage from vehicles.

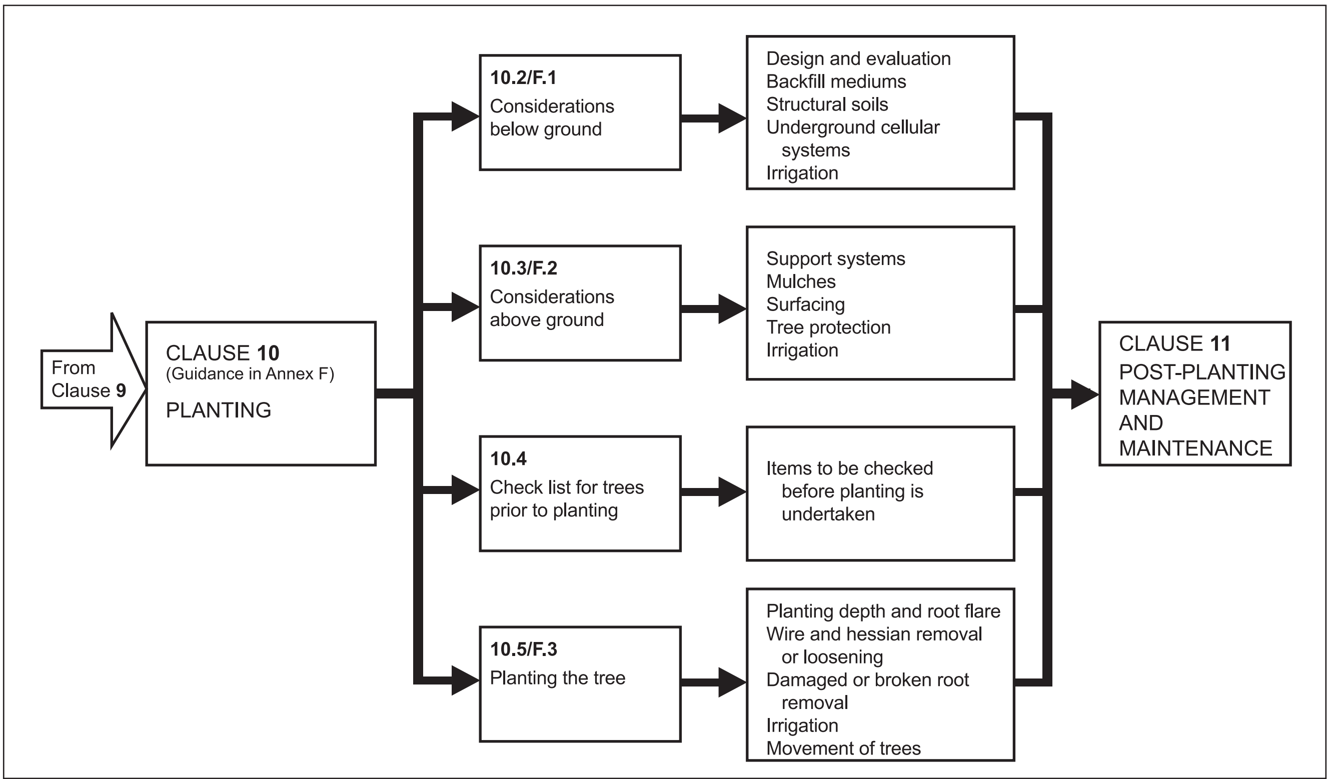
10 Planting

10.1 Process flowchart

The planting part of the process should follow the order shown in Figure 7 and should meet the recommendations given in **10.2** to **10.5**.

NOTE Further guidance on planting is given in Annex F.

Figure 7 **Process flowchart for planting**



10.2 Considerations below ground

*NOTE See also **F.1**.*

10.2.1 Design of the planting pit and site preparation should be based on the comprehensive evaluation of site conditions and constraints as outlined in Clause **6**, and modified as necessary to ameliorate any limiting conditions.

10.2.2 The high variability of soils, particularly in the urban environment, requires that all professionals involved in specifying the planting of young trees should have a high level of knowledge relating to tree development under prevailing soil conditions. Where such knowledge is unavailable or where site conditions are complex, specialist advice should be sought.

10.2.3 During the preparation of the tree pit, the soil is disturbed, but the base of the tree pit should remain undisturbed unless there are specific problems such as poor drainage, soil smearing or pans resulting from pit construction which need to be rectified.

10.2.4 The use of geotextiles or any other barrier to root growth, either at the base of or along the sides of tree pits, can limit root development into surrounding soils. Unless there is a specific requirement to inhibit root growth, such barriers should not be used as a tree pit lining.

10.2.5 The backfill medium used should be as close as possible in texture and structure to the soil excavated from the tree pit. Ideally the soil dug from the excavated pit should be used as the backfill medium.

NOTE If modifications to the soil are necessary, soil ameliorants may be used sparingly.

10.2.6 All backfill applied should, as far as is practicable, replicate the horizons within the original soil profile.

NOTE In urban areas, such horizons might not be visible.

10.2.7 Topsoil should not be used below the depth of the original topsoil layer.

10.2.8 Imported topsoil can be extremely variable, and there are different grades and mixes available. These should be fully evaluated, and the most appropriate mix chosen for the relevant site. Any imported soil that does not meet project specifications for structure, texture, quality or chemistry should be rejected.

10.2.9 Structural soils and underground cellular systems are a solution where the planting area requires a load-bearing capacity and where adequate soil volume is unavailable. The use of structural soils and underground cellular systems is a specialism, and specialist experience and advice should be sought as to their suitability before their use is recommended.

NOTE Structural soils are usually a mixture of washed, often rounded, aggregates or gravels, clay loam, and a stabilizing agent to keep the mixture from separating. They can provide an integrated, root penetrable, high strength pavement system that shifts design away from individual tree pits.

10.2.10 There are several below-ground irrigation aids commercially available. Site constraints should be taken into account when determining which, if any, irrigation aids to use.

10.2.11 The use of various soil ameliorants, which include auxins, mycorrhizae, biostimulants, sugars and hydrogels, have been advocated as means of reducing transplant loss. Data from several independent trials demonstrate widely conflicting opinions as to their efficacy and therefore they should not be used as a matter of routine.

10.3 Considerations above ground

*NOTE See also **F.2**.*

10.3.1 There are many methods of securing newly planted trees, where external support is necessary. Each has its place and the choice should relate to stock size and type, specific site constraints or other requirements.

10.3.2 All systems should allow for canopy and stem movement as low down a tree as practically possible, whilst supporting the structural function of the root system.

10.3.3 Before a young tree is planted, all tree stakes used should be driven into the ground to a sufficient depth to provide full support for the tree.

NOTE It might be necessary to orientate the tree for the staking system selected.

10.3.4 The choice of materials used to attach a stake support system to a tree should allow for the radial expansion of the stem.

10.3.5 The tensioning wires or straps used with underground guying systems should be placed as shallowly as possible and should have only a light covering of soil or mulch applied.

NOTE Burying the tensioning wires is likely to result in the natural root flare of the tree also being buried and the tree being planted too deep. Planting too deep is likely to lead to future failure.

10.3.6 The length of time for which a temporary support system is left in place should be assessed using the root development, stem taper and overall vitality of the newly planted trees as indicators. All support systems should be removed as soon as possible.

10.3.7 Mulches are beneficial to transplanting success and should be used wherever practical. The root flare and the base of the stem should be maintained free from mulch. The tree should be irrigated (see **11.3**) before mulch is applied.

NOTE A mulch depth of 50 mm to 100 mm is effective.

10.3.8 Landscape mulches include both organic and inorganic material, but organic rather than inorganic mulches should be used in preference.

10.3.9 Where permeable and impermeable surfacing is to be used to cover the tree pit surface, evidence of successful long-term use with newly planted trees should be sought. There are advantages and disadvantages to each surface type, which should be fully evaluated before use.

NOTE Some advantages and disadvantages of different surfacing materials are shown in Annex F, Table F.1.

10.3.10 There are several above-ground irrigation aids commercially available. Site constraints should be taken into account when determining which, if any, irrigation aids to use.

10.3.11 There are many forms of tree protection, such as tree grilles/grids and tree cages/guards. Where these are used, the future development of the tree should be prioritized over the aesthetic qualities of the tree protection.

10.3.12 When choosing a form of tree protection, account should be taken of the nature and potential severity of the risk of damage to the newly planted tree. Any tree protection should be kept to the minimum necessary to remove the risk of damage as the tree develops.

10.3.13 Tree protection should not normally be used as a permanent feature.

10.4 Check list for trees prior to planting

The items listed in Table 1 should be checked before any planting is undertaken.

10.5 Planting the tree

*NOTE See also **F.3**.*

10.5.1 Planting depth is critical to transplanting success. Planting too deep is often identified as a common cause of failure. The root flare of the newly planted tree should be clearly visible at the soil surface. It should not be buried by excess soil or mulch.

10.5.2 Where rootballed trees have been supplied with the root flare too deep, any excess soil should be removed from the uppermost surface of the rootball to reveal the root flare at the time of planting.

10.5.3 Where containerized trees have been planted too deep in the container during the production process, there is often a matting of fibrous roots above the root flare and across the container surface. These roots should be removed and the root flare exposed prior to planting.

Table 1 **Check list for trees prior to acceptance of delivery to site and planting**

The tree	Points to check
Above ground	Check that the tree is true to type as specified. Check that there is a clearly defined straight leader. (This does not apply to multi-stem and weeping trees.) Check that there is a balanced branching framework typical of the species. Check that all lateral branches are subordinate to the central leader and evenly spaced along the central stem. Ensure that lateral branch diameter does not exceed 50% of stem diameter at the point of branch attachment. Check that there is a clearly defined stem taper Check that the ratio of height to stem diameter is balanced. Inspect for signs of incompatibility at graft and budding unions. Check that there are no crossing, co-dominant or included branches. Any minor damage incurred during transport should be rectified by pruning.
Below ground	
Bare root	Check that there is an evenly spaced lateral root system with a minimum of four major lateral roots. Check that there are evenly distributed fibrous roots at a density commensurate with the species being planted. Check that roots have been fully protected during transport and storage and do not show any signs of desiccation. Any minor damage incurred during transport should be rectified by pruning. Make sure the root system is fully protected until the tree is actually planted.
Rootball	Check that the rootball is intact (made-up rootballs with trees that have not been transplanted during the production process should have been rejected on delivery from the nursery). Check that the root flare is clearly visible at the top of the actual rootball. Any mounding of soil (which might or might not contain fine root) above the root flare should be removed. (The visibility of the root flare can be impeded by the hessian, wire or ropes used to wrap the rootball.) Check that the rootball has not dried out during transport and storage and take remedial action if necessary prior to planting. If there is wire or rope circling the main stem to secure the rootball cage, ensure that it is removed prior to planting. Remove the wire cage where practicable. If this cannot be done, peel back the wire cage and hessian once the tree is in the planting pit.
Containerized	Remove the container prior to planting. Fibrous roots in containers should hold the compost ball together once the container is removed. If the compost ball falls apart the tree should be rejected as there has been inadequate root development. Ensure that any fibrous root growth or excess compost above the root flare is removed and that the root flare is clearly visible prior to planting. Shave off any minor roots that are showing evidence of circling. (Trees with major circling roots should have been rejected on delivery.) Ensure that the container compost is moist at planting.
Trees with major damage, whether above or below ground, should be rejected.	

10.5.4 Once a rootballed tree has been positioned in the planting pit, hessian, twine and the wire cage should be loosened. If wire encircles the stem diameter as part of the wire cage of the rootball, this should be cut and removed.

10.5.5 Any minor branch damage incurred during transport should be rectified by pruning, ensuring that any branch removal does not include the branch collar attachment.

10.5.6 At no time should trees at the planting site be left with their root systems exposed or vulnerable to drying out.

NOTE Bare root trees are particularly vulnerable to desiccation at this stage.

10.5.7 In general, only the number of trees which can be planted on any one occasion should be loaded for transport from the temporary storage site to the planting site. This avoids the need for excessive handling and reduces the potential for damage. If there is an occasion when all trees need to be delivered to the planting site, the trees should be heeled in or fully protected.

10.5.8 The planting pit should be no deeper than the existing rootball or container depth.

10.5.9 Tree pit sides should not have compacted, glazed or smeared sides from digging. Sides of a planting pit that have been smeared or smoothed during excavation should be scarified.

10.5.10 Tree pits should have a diameter at least 75 mm greater than that of the root system.

10.5.11 During excavation of the tree pit, the soil dug should be placed to one side separating topsoil and subsoil as far as is practical.

10.5.12 The tree's root system should be wetted prior to planting.

10.5.13 The tree should be planted at the correct depth taking into account the position of the root flare and the finished level. Allowance should be made for settling of the soil after planting.

10.5.14 The rootball or root–stem transition should be level with the existing host soil or surface.

10.5.15 Backfill should be added gradually, in layers of 150 mm to 230 mm depth, ensuring the tree is held upright. At each stage the fill should be firmed in to eliminate all air pockets under and around the root system, but with care being taken not to excessively compact the soil.

10.5.16 The final layer of backfilling should not be consolidated, but should be of a sufficient depth to allow for settlement and mulching.

10.5.17 Immediately after planting, the tree pit should be saturated to field capacity.

10.5.18 A support system should be used if necessary.

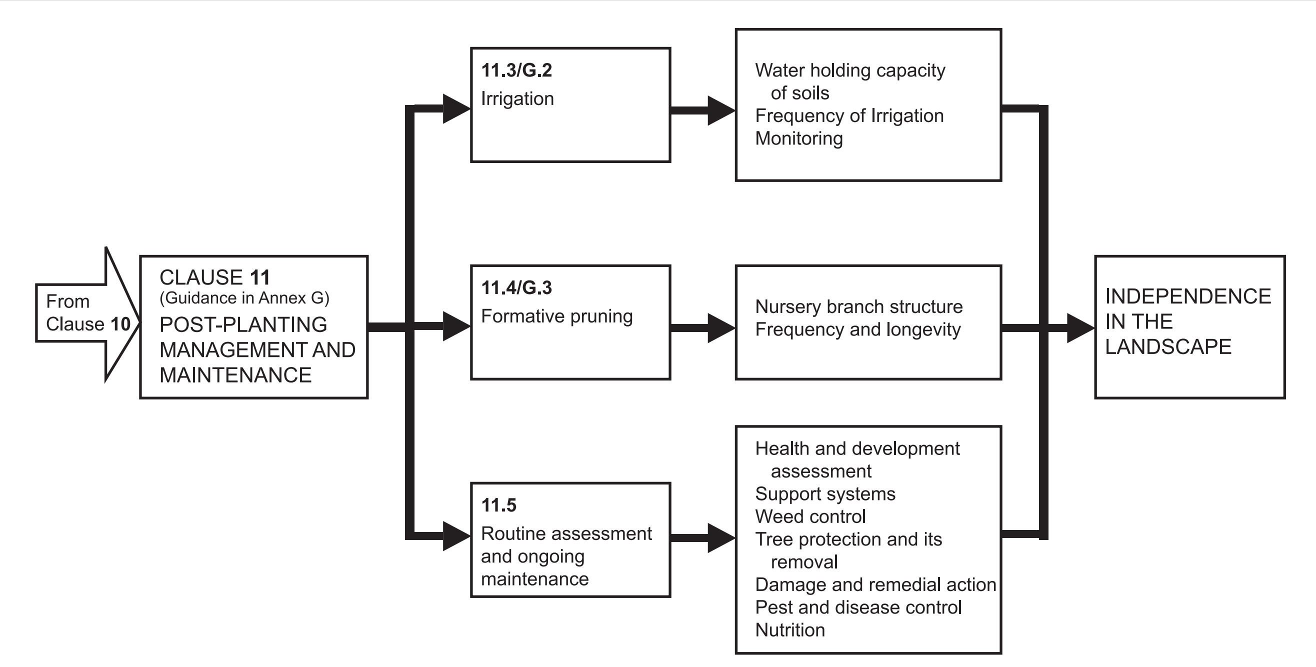
11 Post-planting management and maintenance

11.1 Process flowchart

The post-planting management and maintenance part of the process should follow the order shown in Figure 8 and should meet the recommendations given in **11.2** to **11.5**.

NOTE Further guidance on post-planting management and maintenance is given in Annex G.

Figure 8 **Process flowchart for post-planting management and maintenance**



11.2 General recommendations for post-planting management and maintenance

*NOTE See also **G.1**.*

Post-planting management and maintenance is important if longevity in the landscape is to be achieved. A full young tree management programme with budgetary provision should be in place for all planting schemes. This management programme should be in place for at least 5 years.

11.3 Irrigation

*NOTE See also **G.2**.*

11.3.1 The timing and frequency of irrigation should take into account the prevailing weather conditions, soil moisture release characteristics, and the response of the tree species to water deficits or periods of prolonged soil saturation.

NOTE Nursery trees produced in ideal conditions can take time to adapt to localized planting conditions.

11.3.2 Any given volume of soil has the capacity to hold a given volume of water. The water-holding capacity of the soil should be assessed and taken into account when determining irrigation needs.

11.3.3 In addition to water-holding capacity, the amount of water available to the tree should be assessed. Applying this to all newly planted trees is often impractical, but sample assessments should be made.

NOTE Guidance on determining the amount of available water is given in Annex G, Table G.1.

11.3.4 The frequency of irrigation is more important than the volume of water given at any one time. Increased water volumes cannot compensate for a lack of frequency. This should be accounted for in irrigation plans. Irrigation plans should also take into account the findings of the original site assessment and the subsequent species choice made.

NOTE It might not be sufficient to apply a given amount of water arbitrarily at a certain frequency after transplanting.

11.3.5 Monitoring is recommended if there are 10 consecutive days during the growing season at ≥25 °C. Water should only be added if soil moisture probe/tensiometer values indicate that it would be appropriate to do so.

11.3.6 The frequency and extent of irrigation should take into account the prevailing weather conditions (e.g. prolonged dry periods or rainfall patterns).

NOTE Where there is hard surfacing near to newly planted trees, careful design can be used to supplement irrigation needs. This can be achieved by using permeable surfacing, directional drainage channels, or other methods where natural rainfall is directed into the rooting environment.

11.3.7 If the use of irrigation tubes is proposed, it should be fully assessed in relation to the site constraints.

NOTE The use of irrigation tubes does not necessarily preclude the need for top watering.

11.4 Formative pruning

*NOTE See also **G.3**.*

Formative pruning should be carried out in accordance with BS 3998 as required throughout the early years of a tree's life in the landscape. Some of the nursery-prepared branching structure is temporary, and formative pruning should continue until a permanent structurally sound scaffold system of branches typical of the species and appropriate to the site circumstances is produced.

11.5 Routine assessment and ongoing maintenance

11.5.1 A formal assessment of young tree health and development should be carried out annually. This assessment should include foliar appearance (i.e. lack of leaf chlorosis and/or necrosis), leaf size and leaf canopy density, extension growth and incremental girth development. Continual assessment on an ad hoc basis should be carried out throughout the year, to inform maintenance requirements.

11.5.2 It is possible to assess young tree performance in the field using both leaf fluorescence and leaf chlorophyll content. These tests should be carried out wherever practicable.

NOTE 1 It might not be practical to individually assess large numbers of young trees planted in the same season, but sampling is a recognized method of assessment.

NOTE 2 Chlorophyll content is seasonal. This needs to be taken into account if chlorophyll content tests are being used.

11.5.3 All stakes and ties should be checked at least annually to ensure that the root system remains stable and firm in the ground, and that ties are still effective and not causing any damage to the tree. Any stakes and ties that are found to be not fit for purpose should be adjusted, replaced or removed.

11.5.4 All stakes and ties should be removed as soon as the developing root system is strong enough to support the tree.

NOTE Two full growing seasons are usually long enough for this to occur.

11.5.5 Wires or straps used in underground guying systems that could cause damage to the growing stem or structural roots should be cut as soon as the tree is self-supporting.

11.5.6 The area around the base of the tree should be free from competing vegetation (see also **10.3.7**).

NOTE Selection of an appropriate herbicide, when used to control competing vegetation, is essential to avoid environmental contamination and damage to the tree.

11.5.7 All mulches should be replenished to their original depth, 50 mm to 100 mm, and hand-weeded as necessary and at least once annually. The mulched area should be enlarged, if practicable, as the tree develops to the canopy drip line, taking care to avoid a build-up of mulch around the root flare and the base of the stem.

11.5.8 All grilles, grids, guards and other protective furniture should be checked at least annually. Such furniture should be removed as soon as it is no longer necessary to protect the tree, or where there is a risk of physical damage to the tree.

11.5.9 The soil around newly planted trees should be regularly inspected for soil capping or compaction. Remedial action should be taken as necessary.

NOTE Inspections can be visual, but where conditions are extreme, on-site testing and amelioration might be necessary. This can include manually loosening the pit surface with hand tools or more extensive action using an air spade or equivalent. Mulching can prevent further compaction.

11.5.10 All trees should be checked on a regular basis for mammal, human and other external damage. Remedial action should be implemented as soon as practicable following discovery.

11.5.11 All trees should be checked on a regular basis for pests and diseases. Remedial action should be taken promptly on discovery, where necessary.

11.5.12 Unless specific nutritional deficiencies are identified, no fertilizer should be applied to newly planted trees in the first season.

NOTE If visual inspection reveals symptoms of nutrient deficiency such as leaf scorching, pale foliage or necrotic spots, then further investigation will be necessary with remedial action taken. Remedial action may, in addition to fertilizer application, include pH testing, assessment of organic content and levels of compaction.

Annex A (informative) Further guidance on policy and strategy

Tree planting and continuing management are rarely without purpose. This purpose is influenced by a range of factors, many of which might be outside the control of those who manage the planting site or who are responsible for relevant design and management decisions. External factors might include overarching policies and strategies set at higher levels.
The following non-exhaustive list gives a guide to the wider policy and legislative framework:

- European treaties, conventions (e.g. European Landscape Convention) and directives (e.g. EIA Directive [4], SEA Directive [5], Birds Directive [6], Habitats Directive [7]);
- UK national legislation (e.g. Town and Country Planning Act 1990 [8], Localism Act 2011 [9], Town and Country Planning (Tree Preservation) (England) Regulations 2012 [10], Town and Country Planning (Environmental Impact Assessment) Regulations 2011 [11] and equivalents in Scotland [12] and Wales [13], Conservation of Habitats and Species Regulations 2010 [14], Forestry Act 1967 [15], Plant Health Act 1967 [16], Highways Act 1980 [17]);
- UK government planning and environmental policy (e.g. National Planning Policy Framework 2012 [18], *The natural choice: securing the value of nature* [19], UK Government Circular 11/95 [20], UK Government Circular 10/97 [21]);
- regional planning policy (e.g. *The London plan* [22] and relevant retained policies from regional spatial strategies);
- local plans or local development frameworks produced by local planning authorities (including saved and emerging policies as appropriate) and neighbourhood plans and development orders where applicable;
- supplementary planning documents produced by local planning authorities, as appropriate;
- corporate environmental, sustainability and safety policies, where relevant or appropriate.

The above framework illustrates the breadth and depth of the policy and strategy framework in which tree planting occurs, and while many of the policies outlined might not directly relate to trees and tree planting, their impact on issues such as climate change and biosecurity are inescapable. Issues such as these impact on tree planting decisions.

Direct policies for trees establish guidance on the parameters for and actions by decision-makers. Examples would be to increase tree canopy cover in a given area, to protect existing trees from avoidable damage or to plant trees of types and in locations that will deliver specific returns on investment.

A tree strategy, usually produced by the local authority and linked to the wider strategy and policy framework, addresses the way in which the established policy objectives will be delivered, taking into account resources, pressures and environmental opportunities and constraints that will affect delivery. It may exist without a formal policy, although it would normally be based on an implicitly understood policy principle, e.g. generally to promote and support tree planting and management.

A tree strategy covers a defined area, which might be the whole authority area or discrete locations. A tree strategy can also be produced by other bodies with land owning or management responsibilities. It guides and informs decisions relating to the authority's or other body's own estates and also on other land over which the authority or other body exercises powers or controls, particularly through planning or other formal management systems.

A strategy is typically produced for a defined period of time, and allows for monitoring and review and for modification where needed to achieve desired objectives.

Continuity of new tree planting is an essential component of the overarching strategic principles of establishing a sustainable tree population of mixed age and species range.

Where areas with separate tree strategies have common boundaries, each strategy needs to have full regard to neighbouring strategies, e.g. through a continuity of approach, use of transitional zones or through justification for lack of continuity or change.

Tree strategies are inherently relatively long-term, reflecting the life expectancy of trees and the broader aspiration of tree population management. The management of trees, particularly within urban areas, needs to address potential conflicts with other land uses or activities, or adaptation to changed circumstances. Management and maintenance are therefore essential parts of a tree strategy, and the financial and other resource implications of this need to be addressed.

Tree strategies incorporate provision for adequate financial and other resources to enable delivery of required levels of management and maintenance over a long-term period or, where possible, in perpetuity. They include reference to the anticipated scope of the management and maintenance inputs needed to deliver the desired objectives. Tree strategies seek to demonstrate good value by including, as far as possible, data on the estimated economic value of and return on investment from trees included in a strategy, with particular reference to ecosystem services and associated direct and indirect benefits.

Tree strategies primarily focus on the public estate, owned and managed by the local authority producing the strategy. However, around 70% of the urban tree population is owned and managed outside the public arena. It is the whole tree population, both publicly and privately owned, which delivers the benefits associated with tree cover and to which new tree planting contributes.
To maintain a resilient tree population capable of delivering its benefits into the future, it is important that linkages between the publicly and privately owned estates are established and maintained. Tree strategies provide a framework for this to happen and are therefore worthy of consultation before any planned tree planting is converted to action on the ground.

The linkages between the publicly and privately owned tree estate are beginning to be recognized through the growing understanding and valuation of ecosystem services and benefits to which trees make a significant contribution. The i-tree urban forest model, which is being used more extensively in the UK, evaluates both publicly and privately owned trees, assesses their combined benefits and enables coordinated policy and strategy development.

Annex B (informative) Further guidance on site evaluation and constraints assessment

B.1 General

All trees require fundamental environmental resources irrespective of their natural genetic composition. Many sites considered for tree planting are unable to provide these resources. Failure to address this lack of resources can contribute to eventual tree decline and failure.

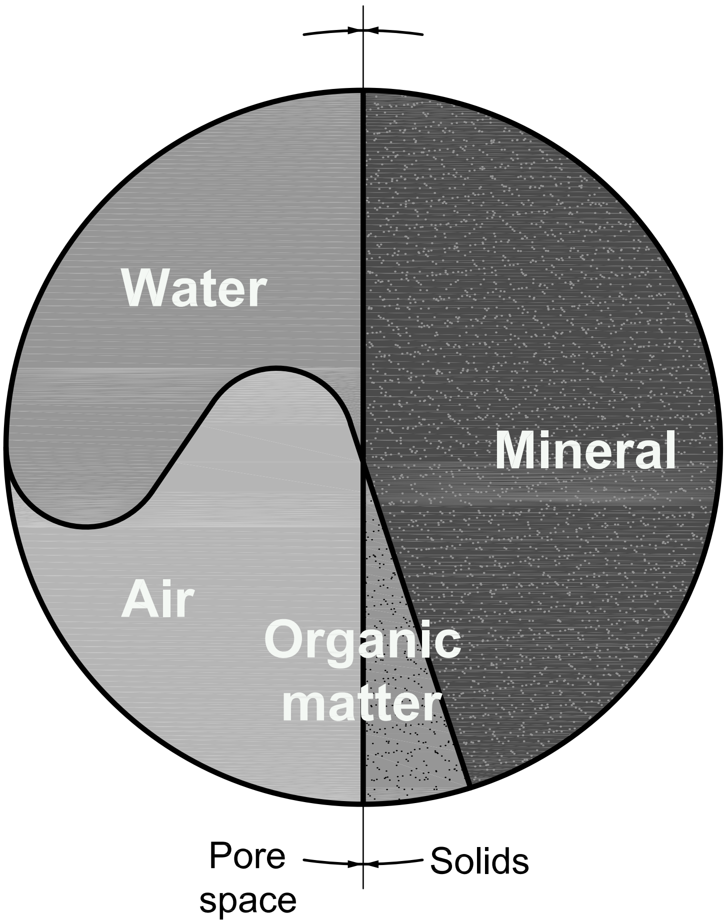
There are so many factors to consider when planting, particularly in the urban environment, that a process is necessary to methodically assess the many variables that will be encountered. This is essential as these factors impact on soil water retention and movement, drainage, nutrient availability, the severity of soil compaction and root development.

B.2 Ground assessment

B.2.1 Soil characteristics

The ideal soil contains approximately 45% mineral solids, 5% organic mineral solids and 25% each water and air, as shown in Figure B.1. In practice, this ideal is rarely found in the built environment.

Figure B.1 **Soil characteristics**



Soils that have not suffered extensive human disturbance have a distinct soil profile with clearly defined soil horizons.

In most urban soils these horizons are rarely seen and have been modified in many ways, all of which impact on the likely success of any tree planting. Such modifications can include the following.

a) Soils have a vertical variability caused by cutting and filling.

b) Soil structure has been changed.

c) Soils have an impervious crust that sheds water. Compaction compounded with the lack of vegetation gives rise to this condition. Compaction destroys the macropores in the soil, thus impeding air and water drainage.

d) Soil pH can be changed due to contaminants and from the run-off from built surfaces.

e) Nutrients and organic matter are often deficient.

f) Urban soils often contain human debris.

B.2.2 Soil structure and texture

B.2.2.1 General

The accurate assessment of soil structure and texture is critical in a site constraints assessment, as these two factors impact on soil water retention and movement, drainage, nutrient availability, the severity of soil compaction, root development and final transplanting success.

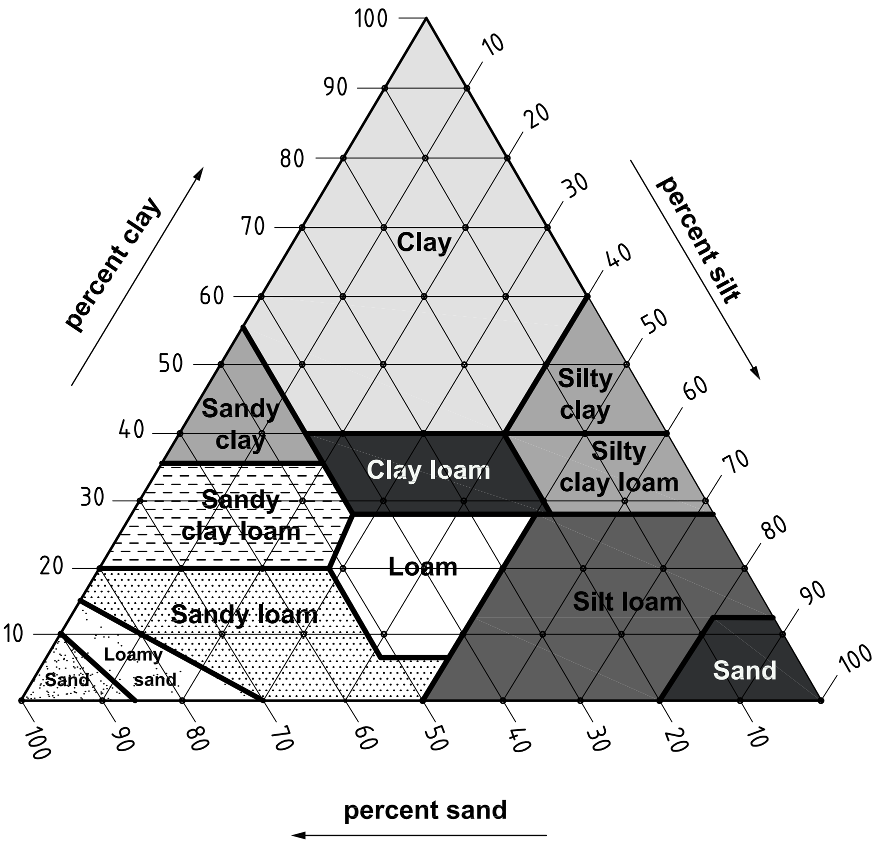
The mineral content of soil is composed of three types of particle which vary enormously in size. These are:

- sand: 2 mm to 0.05 mm in diameter;
- silt: 0.05 mm to 0.002 mm in diameter;
- clay: 0.002 mm and below in diameter.

The relative percentages of sand, silt and clay in a soil are collectively known as soil texture. Soil texture affects how suitable that soil is for tree growth.

Figure B.2 illustrates the soil texture type found when varying percentages of sand, silt and clay are present.

Figure B.2 **Soil texture triangle**



B.2.2.2 Soil texture determination

Each sample can be hand-moulded to determine the textural class and the proportion of clay, silt and sand. To do this, a ball of soil about 25 mm in diameter is taken and moistened with a few drops of water until it just begins to stick to the hand. The soil is then manipulated, and the extent to which the moist soil can be shaped is indicative of its texture, as described below and illustrated in Figure B.3.

a) Figure B.3, diagram A (sand): the soil remains loose and single-grained, and can only be heaped into a pyramid.

b) Figure B.3, diagram B (loamy sand): the soil contains sufficient silt and clay to become somewhat cohesive, and can be shaped into a ball that easily falls apart.

c) Figure B.3, diagram C (silt loam): as for loamy sand, but the soil can be shaped by rolling it into a short thick cylinder.

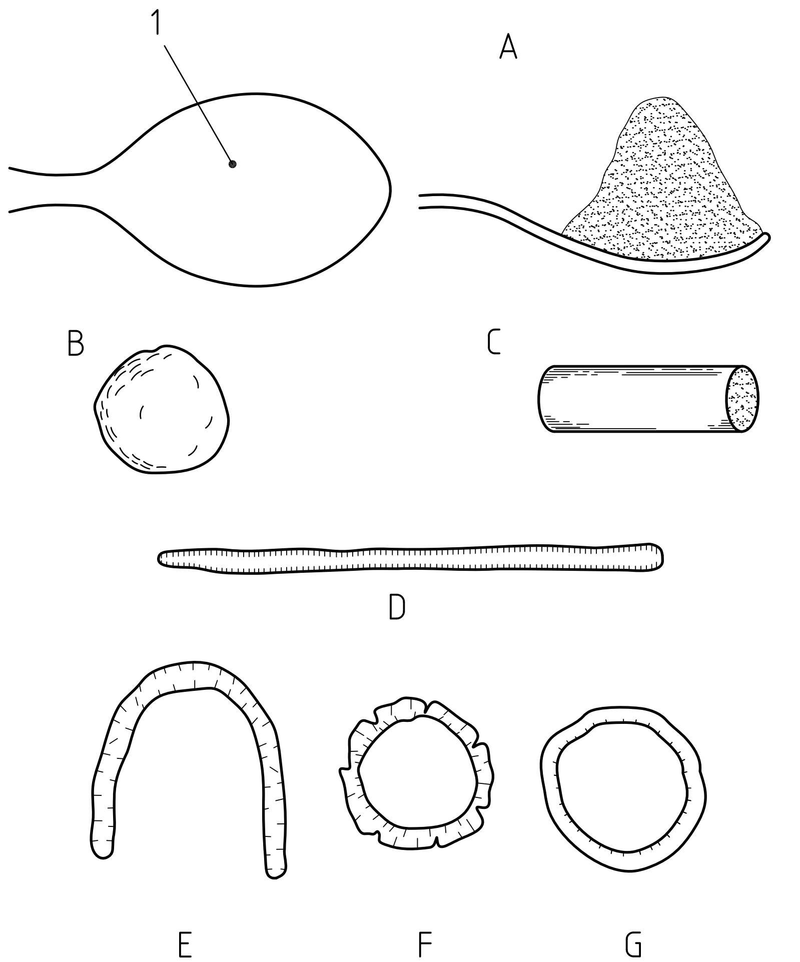
d) Figure B.3, diagram D (loam): because of equal sand, silt and clay content, the soil can be rolled into a cylinder that breaks when bent.

e) Figure B.3, diagram E (clay loam): as for loam, the soil can be bent into a U but no further without being broken.

f) Figure B.3, diagram F (light clay): the soil can be bent into a circle that shows cracks.

g) Figure B.3, diagram G (heavy clay): the soil can be bent into a circle without showing cracks.

Figure B.3 **Determination of soil texture by manual texture test**



Key

1 Size of sample spoon
A Sand
B Loamy sand
C Silt loam
D Loam
E Clay loam
F Light clay
G Heavy clay

Other features of textural classes include the following.

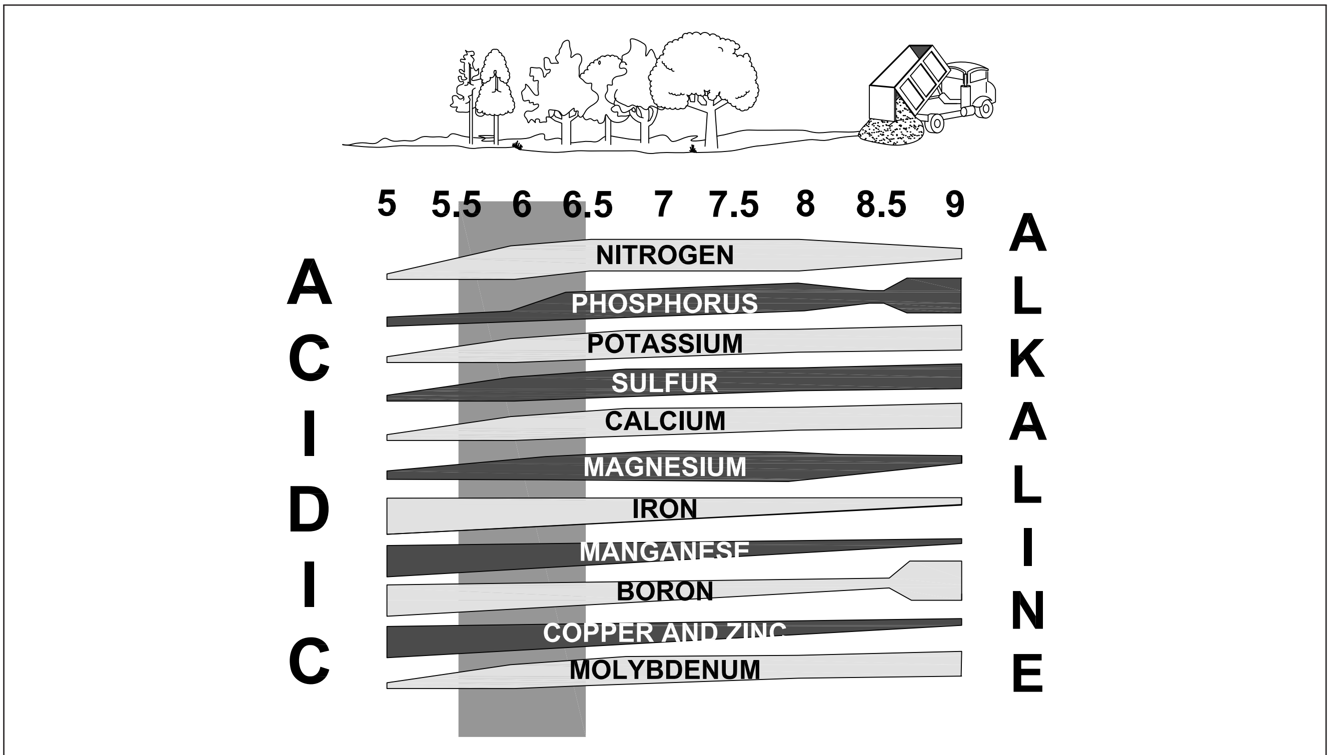
1) Loam or silt, when dry, gives off a fine powdery dust if scratched or blown upon, but a clay soil does not.
2) Loam, when wet, feels soapy and more or less plastic; when rubbed between the fingers until dry it leaves dust on the skin; clay does not.
3) Clay, when removed with a soil auger, displays shining faces if it has a slightly moist condition; a loam does not.

B.2.3 Soil pH

The pH of a soil has a major impact on the availability of nutrients. It also effects the growth of plant roots and micro-organisms. Root growth is generally favoured at slightly acidic pH values (5.5 to 6.5). Fungi generally predominate in the soil adjacent to roots in the acid pH range, whereas at higher pH values bacteria become more prevalent.

Figure B.4 illustrates the influence of soil pH on nutrient availability.

Figure B.4 **Influence of soil pH on nutrient availability**



It is difficult to modify pH in the landscape. Soils in the built environment tend to have a higher than neutral pH because of the limestone building materials used. Such conditions make it critical that specific tolerances of species to be planted are considered during the design/selection process.

B.2.4 Drainage

The speed with which water moves through the soil is dependent on soil texture, structure and the level of bulk density. A lack of adequate drainage results in poor aeration, which can result in rapid mortality rates in young trees. Roots need oxygen to respire. A lack of oxygen causes root death and subsequently whole tree failure, while high levels of carbon dioxide can be toxic.

To conduct a percolation test, dig a hole in the ground to be planted, approximately 300 mm square to a depth of 300 mm to 450 mm. Thoroughly wet the soil in the hole and an area of about 300 mm around the hole. When the soil is near saturation point, fill the hole with water and measure the depth of water. After 15 min, measure the height again. Subtract the second reading from the first to obtain the amount of water lost during the 15 min period. Multiply this by four to obtain an approximate measurement of water lost in an hour. The implications of differing dates of water drainage are reflected in Table B.1.

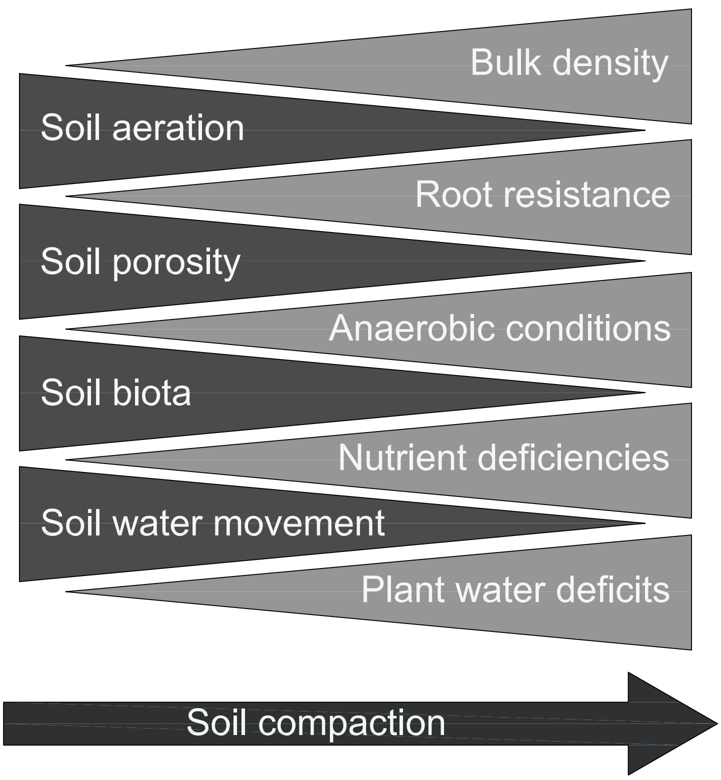
Table B.1 **Assessment of drainage using percolation test**

Rate of water drainage mm/h	**Condition of site**
<125	Poorly drained and suited to wet site species
125 to 250	Moderately well drained and acceptable for many species, including wet site species
>250	Well drained and suitable for all species including sensitive species

B.2.5 Compaction

Soil compaction modifies many soil characteristics, as illustrated in Figure B.5.

Figure B.5 **Impacts of soil compaction on soil characteristics**



NOTE Increasing or decreasing band width indicates the impact of soil compaction on the named soil characteristic.

The extent of soil compaction has particular significance because it acts on a range of factors which can limit tree vitality. As soil is compacted, physical resistance to tree roots is increased, soil aggregates break down and pore space is diminished. This detrimentally affects the respiration of roots and soil biota. This in turn impacts on nutrient recycling and availability. Degradation of soil structure significantly slows water movement through the soil, presenting both water deficits and waterlogging as potential problems.

Bulk density is influenced by the texture of the soil. Root growth is inhibited in sandy soils where there is a bulk density of 0.16 g/mm^3 to 0.17 g/mm^3. Root growth in a clay loam is inhibited where there is a bulk density of 0.14 g/mm^3 to 0.15 g/mm^3.

A soil penetrometer can be used to measure penetration resistance.

B.3 Macro and micro climatic conditions

In the built environment, several microclimates can exist within close proximity of each other, e.g. near bodies of water, or in heavily urban areas where brick, concrete and asphalt absorb the sun's energy and radiate heat, resulting in an urban heat island effect. South-facing slopes are exposed to more direct sunlight than north-facing slopes and are therefore warmer for longer. Tall buildings create their own microclimate, by overshadowing large areas and channelling strong winds to ground level.

The proximity of tall buildings and/or the movement of traffic can significantly affect air movement and/or direction on a localized basis. The movement of traffic increases air flow around tree canopies. Such variable and abnormal air movement influences the transpiration flow and consequently the irrigation demand of young trees in particular.

Tolerance of shade or partial shade varies from species to species.

NOTE The specific tolerances of tree species are dealt with in Annex C.

Some biological plant responses are governed by environmental triggers. Site conditions can impact on these environmental triggers, causing trees to respond. Such responses can include late flowering, delayed or advanced senescence, delayed or advanced bud burst, or modified leaf cover.

B.4 Existing vegetation

A close analysis of existing trees can provide valuable information as to which species are likely to thrive.

Existing vegetation near a newly planted tree can compete with the tree for resources, especially water. The management of such vegetation, for instance the frequency of grass cutting and the types of machinery used, can impact on newly planted trees.

All trees are part of a population which can be measured on a community, town or city scale. The more diverse a tree population is, the more resilient that population is in resisting the impact of pest and/or disease. Ideally, one species will make up no more than 5% to 10% of any town- or city-wide population. There are, however, specific occasions where single species have to be planted in numbers, such as avenue creation and on difficult sites where species selection is constrained by a range of environmental stresses.

Annex C (informative) Further guidance on species selection

C.1 General

There are many variables to be considered when choosing a species for any particular site. These variables relate to both the trees to be planted and the conditions in which they are to grow. Design demands are often paramount, but cannot be considered in isolation from all the other factors involved in suitable species selection. All impact on the likely success and longevity of any planting undertaken.

There are many publications available describing tree species and their characteristics. Nursery catalogues are a useful source of information regarding a species or cultivar to be used. However, catalogues are primarily designed to sell trees and the information contained in them is often partial and incomplete. Local experience and knowledge of young tree performance is often as valuable, and there are occasions when specialist advice is needed.

Trees are adaptive and respond to the local environment in which they are growing, often producing modifications of form which do not match the nursery catalogue description. Site constraints are likely to affect the eventual form, development, speed of growth and longevity of the young tree.

C.2 Characteristics of different species and cultivars

An integral part of any species selection process is a recognition that species and cultivars have different characteristics, all of which impact on the likelihood of transplanting success being achieved.

Each species has an inherent capacity for growth influenced by a complex array of morphological, anatomical and physiological attributes. These attributes influence tolerance to both climate and microclimate. A number of characteristics enhance tolerance to transplanting in varying environmental conditions. Only an extensive knowledge of the characteristics of the tree species will allow these attributes to be maximized.

Ecophysiology seeks to understand why trees are naturally distributed the way they are, and the underlying attributes which control this distribution. Such knowledge can be useful when making a choice of species, especially when site conditions are extreme and varied.

NOTE Cultivars might have been bred or selected, often exploiting mutations, and are less likely than seed-raised trees to demonstrate innate genetic characteristics.

C.3 Existing tree population of the landscape into which young trees are planted

C.3.1 General

When selecting species for transplanting into the landscape, it is important to realize that the young trees planted will become part of an existing tree population, which is usually composed of many species and cultivars.

A population which is over-reliant on one species and close to being a monoculture is vulnerable to pest and disease attack, and displays less resilience than a population composed of many species. Studies suggest that the optimum maximum proportion of any species is between 5% and 10% of the population, with the majority of researchers emphasizing 5%. It needs also to be recognized that some clonal selections are used for their individual resilience and therefore make a useful contribution to the overall tree population if not dominant.

When considering species selection, it is therefore important to take into account genotypic diversity. A detailed understanding of the composition of the existing tree population is essential, and will ensure that any new planting makes a contribution to the resilience of the overall tree population.

C.3.2 Clonal selections

A large percentage of young trees selected and subsequently planted in the landscape are clonal selections. The repeated use of a single clonal selection reduces the resilience of the overall tree population, making it more vulnerable to significant outbreaks of any pest and/or disease.

C.3.3 Evaluating the benefits of trees

Trees provide many benefits in addition to pure aesthetics. These include shade provision, pollution absorption and interception, carbon sequestration and storage, stormwater attenuation, wildlife and habitat conservation, and screening. Tree populations are now being valued as assets which accrue in value over time, providing services which can be quantified monetarily.

It is possible to produce both qualitative and quantitative valuation of the benefits delivered by trees, both individually and collectively. This full valuation of benefits strengthens the case for investment in tree planting. For new plantings it is possible to project forward and accurately forecast the benefits such plantings are likely to deliver fifty years or more in the future.

Annex D (informative) Further guidance on nursery production and procurement

D.1 General

Tree longevity in the landscape begins not at the planting site but at the nursery. The selection of physiologically healthy, mechanically sound and resilient trees is fundamental. Poor production practices on the nursery can cause problems years or even decades after the tree has been growing in the landscape.

In the UK there are four principal production systems used. In each of these production systems, the criteria for evaluating stem, crown and branch development are the same. Each of the production systems, however, takes a different approach to the way in which young tree root systems are developed and prepared for final dispatch to the planting site.

The production of young trees is a specialized and complex process, and specialist advice is needed when evaluating nursery production systems and good practice. The choice of production system is the responsibility of the specifier and is inextricably linked to the individual site constraints and species selection as discussed in Annex B and Annex C respectively. Each production system has advantages and disadvantages, which are discussed in **D.3**.

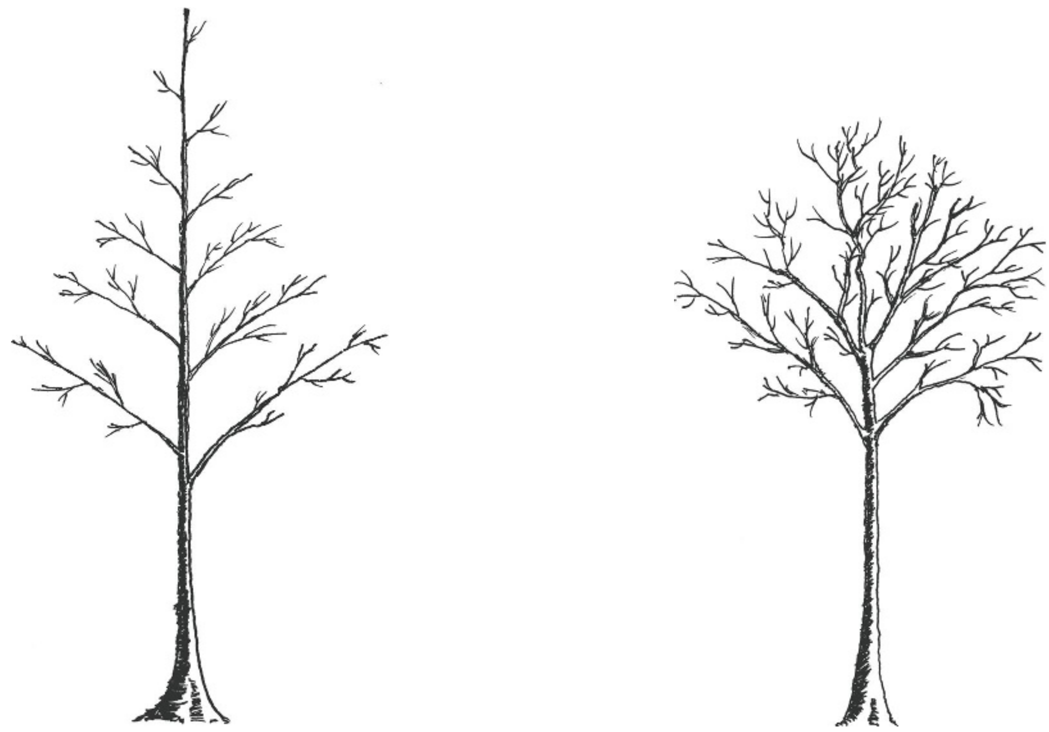
D.2 Branch and stem development

D.2.1 General

Each genus and species of young tree has inherent characteristics that shape branch and stem development, but trees can be categorized into two main groups: excurrent and decurrent.

Excurrent trees have a straight leader which remains prominent throughout the life of the tree, while decurrent trees lose the dominant leader as they develop, as shown in Figure D.1.

Figure D.1 **Excurrent and decurrent trees**



a) Excurrent tree b) Decurrent tree

The leader dominates when branches are less than half of its diameter at the branch union.

All nursery trees have typically been supported at some stage during the production process. The distance between trees in the nursery field, and the length of time for which support is retained, influence the way a young tree grows. Trees that are grown too close together exhibit a poor height to stem diameter ratio and are disproportionately tall (see Figure D.2). It is unlikely that such trees will successfully support themselves once transplanted into the landscape, being mechanically ill equipped to do so.

Trees which have been supported throughout their life also exhibit little or no stem taper. All young trees need to exhibit a thickening of the stem towards the root flare (see Figure D.2).

D.2.2 Height/stem girth measurements

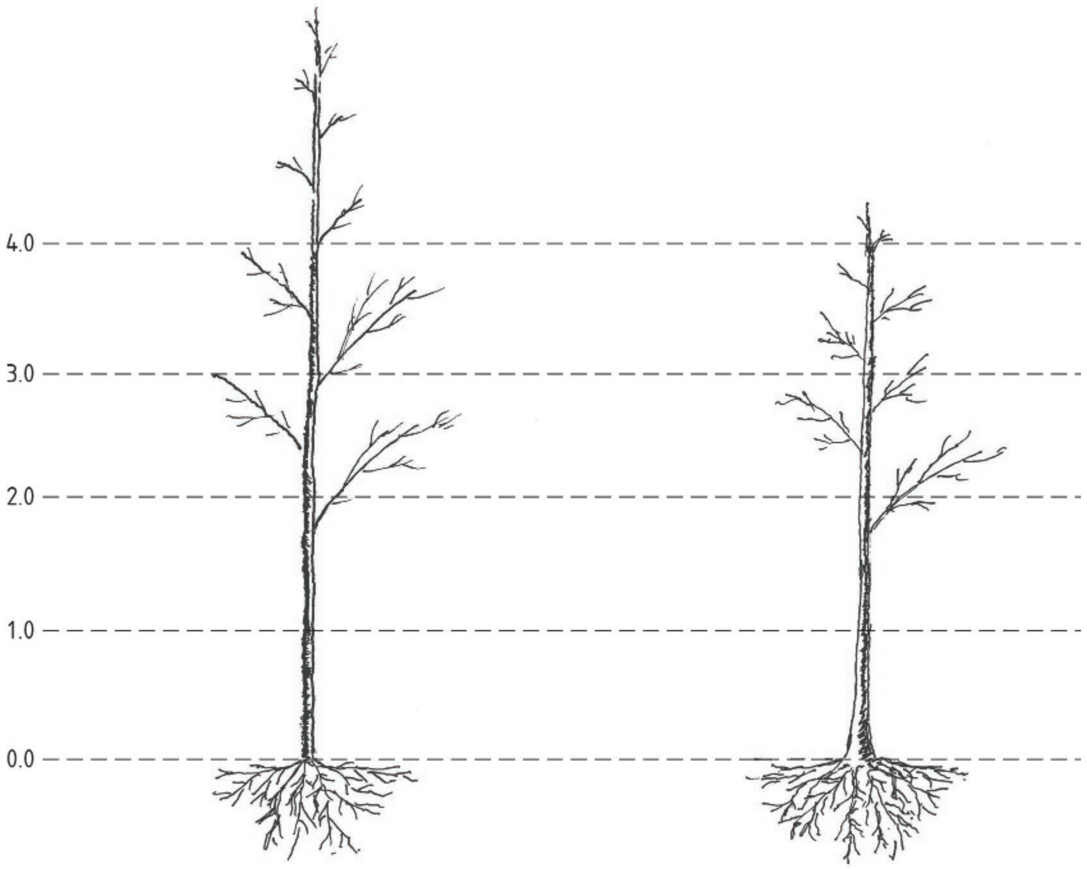
Young trees, irrespective of the nursery production system used, are measured by stem girth at 1 m above the ground or container surface. Table D.1 indicates the approximate height and clear stem for each stem girth range of trees bought from all European tree nurseries, as specified in BS 3936-1. The relative sizes of the trees listed in Table D.1 are illustrated in Figure D.3.

Table D.1 **Approximate height and clear stem of trees**

Size of tree	Girth at 1 m cm	Height from ground mm	Clear stem mm
Standard	8 to 10	2 500 to 3 000	1 750 to 2 000
Selected standard	10 to 12	3 000 to 3 500	1 750 to 2 000
Heavy standard	12 to 14	≥3 500	1 750 to 2 000
Extra heavy standard	14 to 16	≥3 500	1 750 to 2 000

Figure D.2 **Height to stem diameter ratio and stem taper** *(1 of 2)*

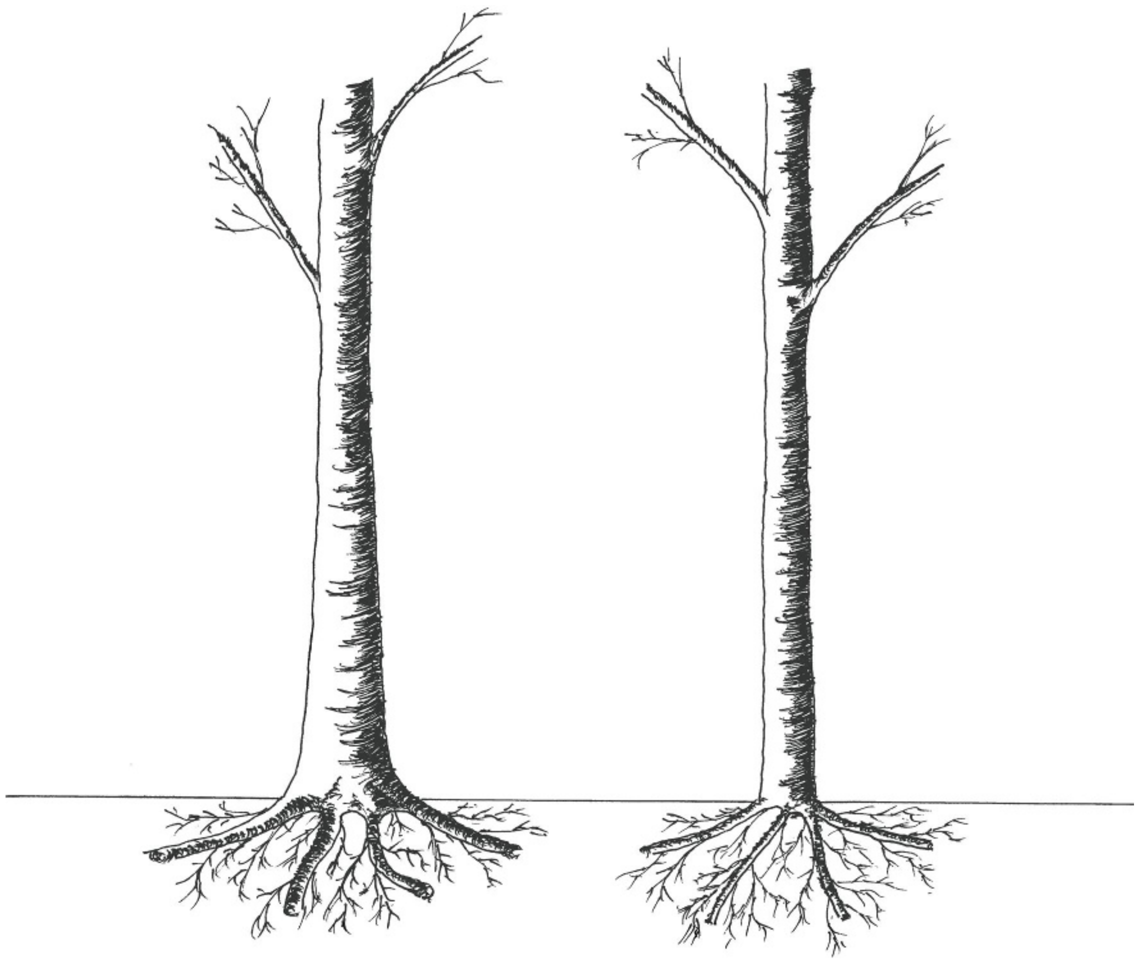
Dimensions in metres



a) Poor height/stem girth ratio caused by growing too close in nursery rows [note the tree is taller and with a thinner stem than the tree in b)]

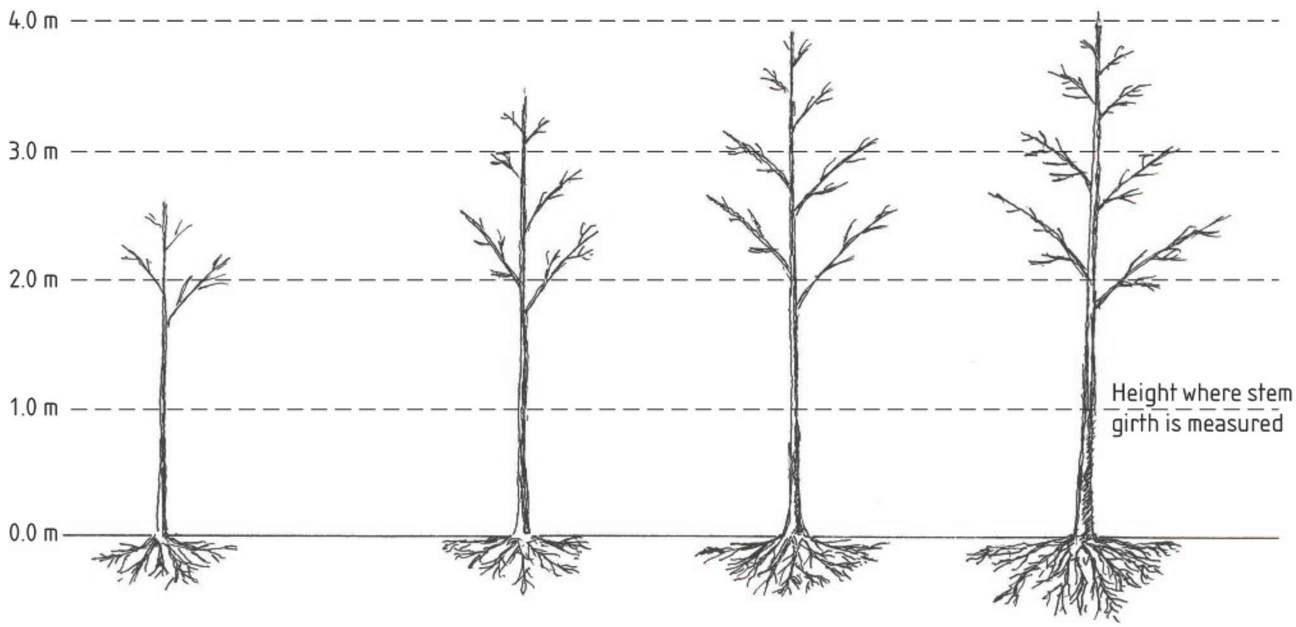
b) Good height/stem girth ratio [note stem taper, with the tree being generally shorter and stouter]

Figure D.2 **Height to stem diameter ratio and stem taper** *(2 of 2)*



c) Well-developed stem taper d) Poorly developed stem taper

Figure D.3 **Sizes of young tree nursery stock**



a) Standard 8 cm to 10 cm

b) Selected standard 10 cm to 12 cm

c) Heavy standard 12 cm to 14 cm

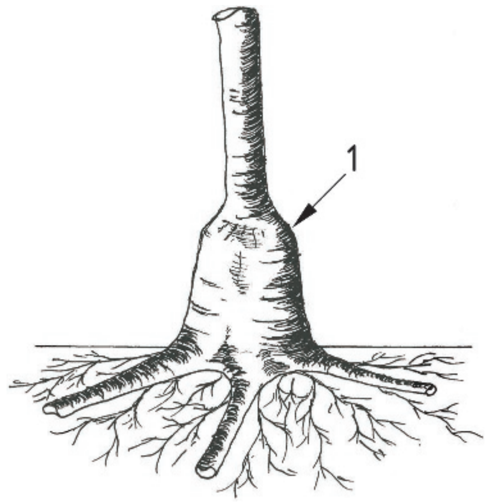
d) Extra heavy standard 14 cm to 16 cm

D.2.3 Budding and grafting

A high percentage of young trees produced on a tree nursery have been either budded or grafted. Success in forming a permanent bud or graft union between stock and scion wood depends on two things: their compatibility and the quality of contact between the cambium and other meristematic tissues.

Poor or incompatible bud or graft unions can be identified on the nursery where there is disproportionate growth of either stock or scion wood with a resultant swelling of either. A large amount of epicormic growth from the understock is also an indicator of incompatibility and/or a poor bud/graft union. Trees exhibiting these characteristics need to be rejected, as subsequent failure is likely. Poor bud/graft union is illustrated in Figure D.4.

Figure D.4 **Poor bud/graft union**

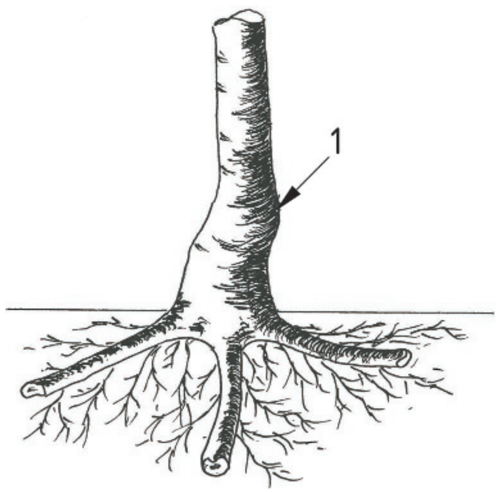


Key

1 Graft incompatibility: disproportionate growth between stock and scion wood

While trees budded close to the base exhibit a bend close to the bud union, this bend needs to be slight and not over-developed (see Figure D.5).

Figure D.5 **Bend of bud union**



Key

1 Compatible growth union

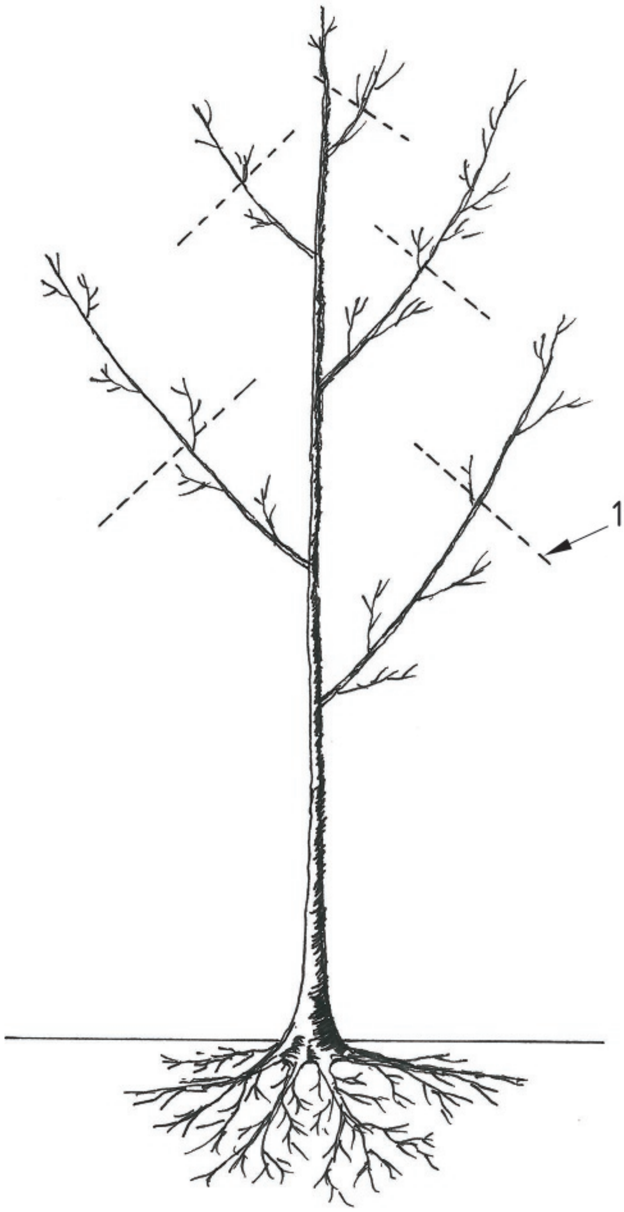
D.2.4 Nursery pruning

The purpose of nursery pruning is to select and define a central leader which becomes the main stem of the tree. It also controls and subordinates the lateral branches as necessary while retaining photosynthetic efficiency.

Much of the lower crown on a nursery tree is formed of temporary branches, which are removed as the tree develops in the landscape and a permanent structural branching system is created.

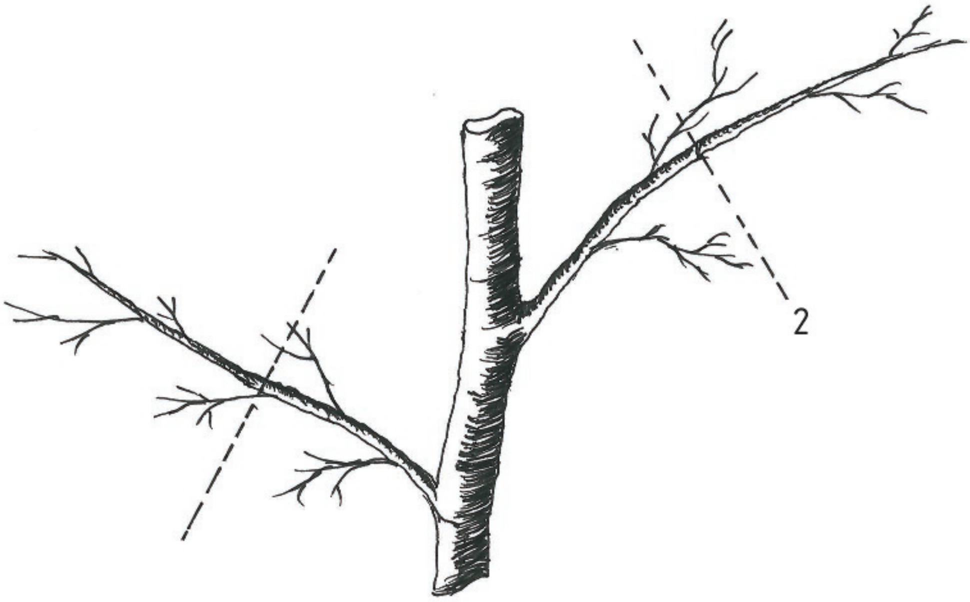
The leader dominates when branches are less than half of its diameter at the branch union. Branches with aspect ratios of more than one half the diameter of the main stem are likely to develop and produce future co-dominance. The best way to concentrate growth into the leader and ensure dominance is by pruning to subordinate overly vigorous lateral branches. Lateral branch subordination is illustrated in Figure D.6. More general lateral branch pruning is illustrated in Figure D.7.

Figure D.6 **Lateral branch subordination** *(1 of 2)*



a) Subordinate branches to define central leader

Figure D.6 **Lateral branch subordination** *(2 of 2)*

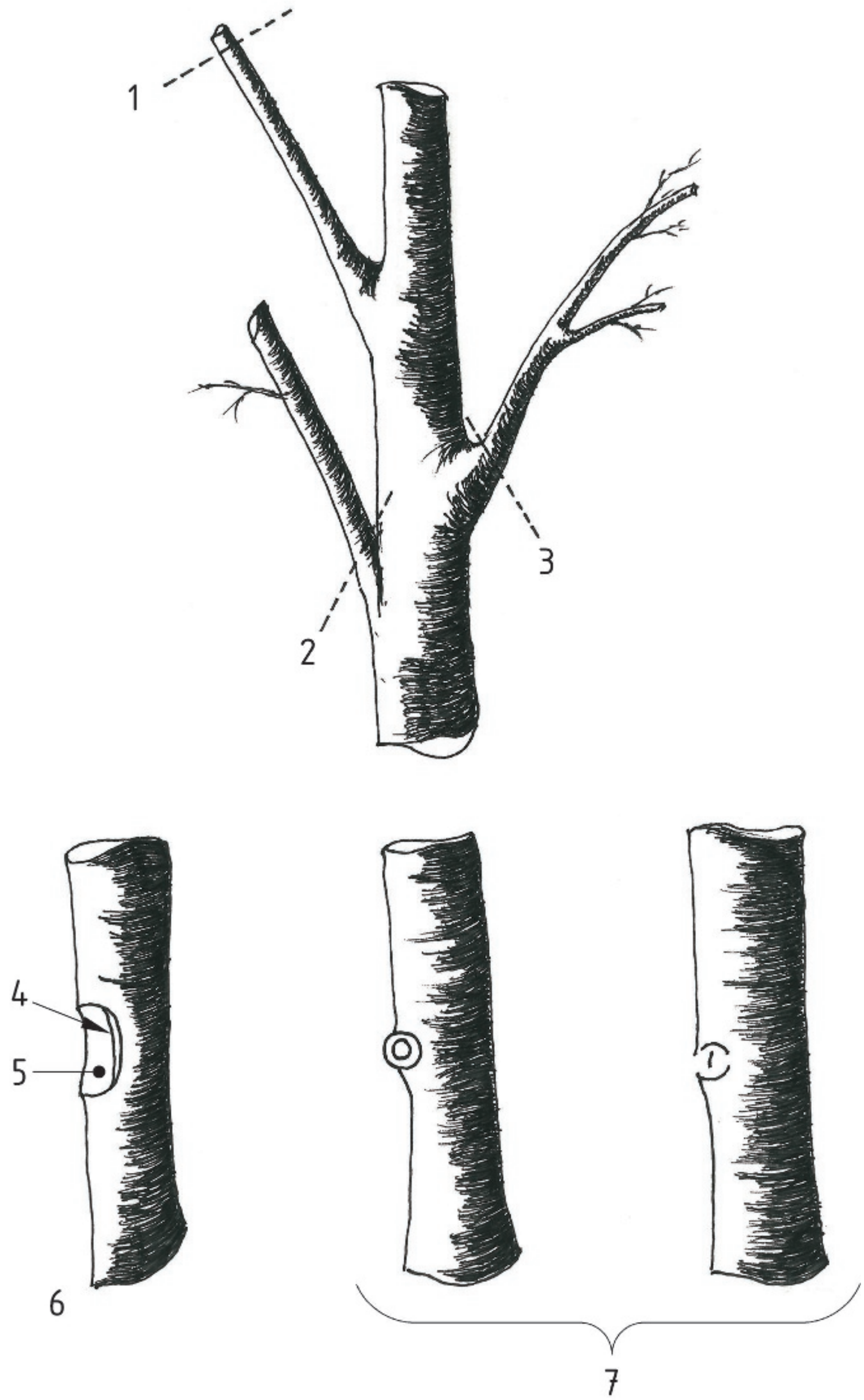


b) Subordinate laterals no more than one half diameter of main stem

Key

1	Subordinate lateral branches to define central leader
2	Subordinate laterals to not more than one half diameter of main stem
– – –	Nursery pruning cuts

Figure D.7 **Lateral branch pruning on the nursery**



Key

1 Potentially co-dominant laterals subordinated to main stem

2 Laterals with poor or included branch unions removed

3 Lower or unwanted laterals removed with branch collar left intact

4 Incomplete occlusion

5 Exposed internal wood

6 Laterals larger than 50% of main stem are unlikely to occlude completely, leaving internal wood exposed when removed

7 Laterals removed less than 50% of main stem at branch union with branch collar retained will occlude completely

D.3 Root system development and management

D.3.1 Nursery production systems

There are several nursery production systems which affect tree root development. The principal nursery production systems in the UK are as follows.

a) Bare root (open ground). Young trees are lifted from nursery rows without any accompanying soil. The root system is exposed but normally protected from drying out throughout the process from nursery to transplanting site.

b) Rootball (ball and burlap). Rootballed trees are lifted from the nursery rows with a ball of field soil surrounding the part of the root system lifted with the tree. This ball is subsequently wrapped in hessian and bound with wire rope.

c) Containerizing. Bare root or rootballed trees are lifted from the nursery field and then potted up into containers, allowing the root system of the young tree to regenerate on the nursery prior to dispatch for transplanting into the landscape. These trees are normally grown in a container for at least one full growing season before being available for sale.

d) Container-growing. Trees are grown in containers for all or most of their time on the nursery and moved from smaller to larger containers as growth necessitates.

Each of the above systems has advantages and disadvantages, some of which are shown in Table D.2.

Table D.2 **Advantages and disadvantages of different nursery production systems** *(1 of 3)*

Production system	Advantages	Disadvantages
Bare root (open ground)	The cost of production is lower compared with other production methods, and this is reflected in the supply cost. Bare root trees are lighter than rootballed, containerized and container-grown equivalents, and are therefore easier and more economical to handle, transport and plant. They are less likely to contain soil-borne disease than trees supplied with soil. This is the best tree production system for identifying and correcting root deformities prior to planting.	The appropriate time for lifting from the nursery field and transplanting into the landscape is limited to the dormant season. Not all species are tolerant of the technique. A significant proportion of fine roots might be damaged. As a general rule, the larger the bare root tree within a given species, the higher the mortality rate, with survivors slow to recover. Field soil conditions can limit times of lifting, with frozen, very wet and very dry soils being unsatisfactory. Handling and care of bare root trees between lifting and planting is critical to achieving good survival rates. Roots need to be kept moist at all times, and where there is a delay between lifting and planting, the roots need to be heeled in.

Table D.2 **Advantages and disadvantages of different nursery production systems** *(2 of 3)*

Production system	Advantages	Disadvantages
Rootball (ball and burlap)	The lifting and transplanting season is extended when compared to bare root trees. Trees that have poor survival percentages when handled bare root can be transplanted successfully. Trees may be lifted from the nursery field ahead of time and stored above ground, if handled correctly, thus extending the period for transplanting beyond the dormant season. Trees can be lifted during the dormant season and stored in the nursery for summer planting. Care between lifting and planting is less critical than for bare root trees, as the roots are kept moist and frost-free within the rootball.	If nursery practice is poor then as much as 95% of the root system can be lost on lifting from the nursery field. Actual lifting from the nursery field is limited to the dormant season for all but a very small number of tolerant species. Handling of large rootballs is labour-intensive, with rootballs being heavy and awkward to transport. If the rootball is broken or allowed to shift during handling and dispatch, the chances of tree survival are reduced. Field soil conditions can limit times of lifting, with frozen, very wet and very dry soils being unsatisfactory. Rootballs are generally more expensive than bare root trees. Successful transplanting of young trees can be adversely affected if the primary root or root flare is too deep as a result of nursery production. This is the worst tree production system for identifying and correcting root deformities prior to planting.
Containerizing	The root system is entire and undamaged. Containerized trees can be planted at any time of the year, although soil conditions in the summer can be a limiting factor. The trees are generally easier to handle than rootballed trees. The trees are generally easier to store than trees from other production systems. Post-transplanting stress and shock is reduced to a minimum, consequently achieving earlier benefits from planting. They generally weigh less than rootballed trees, as the growing media is usually peat-based rather than soil-based.	Additional irrigation might be needed during the post-transplanting maintenance period. The organic soil-less compost used in containerized mixes can shrink if allowed to dry out post-transplanting. This can lead to shrinkage of the compost, which can cause difficulties with lateral root formation into the indigenous soil. There is always the potential for root circling in any container. Irrespective of the container type, if a tree is left in any container for too long, its roots fill the pot, becoming distorted. It has been argued that the container compost media contains none of the beneficial micro-organisms found in soil. They are generally more expensive than bare root or rootballed trees.

Table D.2 **Advantages and disadvantages of different nursery production systems** *(3 of 3)*

Production system	Advantages	Disadvantages
Container-growing	Trees never have to be lifted from the nursery field and are less likely to suffer root damage if handled correctly. Trees are grown in a controlled environment throughout the production process. Irrigation and nutrition can be regularly monitored and easily adjusted throughout the production process. Trees can be planted all year round, although soil conditions in the summer can be a limiting factor.	Trees have to be progressively moved from smaller to larger containers until the final dispatch container is reached. Root circling is potentially more likely to occur than with containerized trees. As the tree is pot-grown throughout its life, there is an opportunity for circling to occur at each stage when the root reaches the sides of the pot. Movement from smaller to larger containers has to be carried out at the optimum time in terms of root development. Poor timing can result in root circling and root deformation. This will result in eventual failure in the landscape. Re-potting into progressively larger containers can result in the root flare becoming incrementally deeper in the container.

D.3.2 Root system

Lateral root development is important as trees with strong tap roots and little lateral root development are less likely to survive after transplanting. Table D.3 shows typical root spreads for a range of young tree heights for bare root stock.

Table D.3 **Root spread for bare root stock**

Young tree height m	Diameter of root spread mm
2.5 to 3.0	450
3.0 to 3.5	550
3.5 upwards	700

Table D.4 shows typical container sizes for a range of young tree sizes.

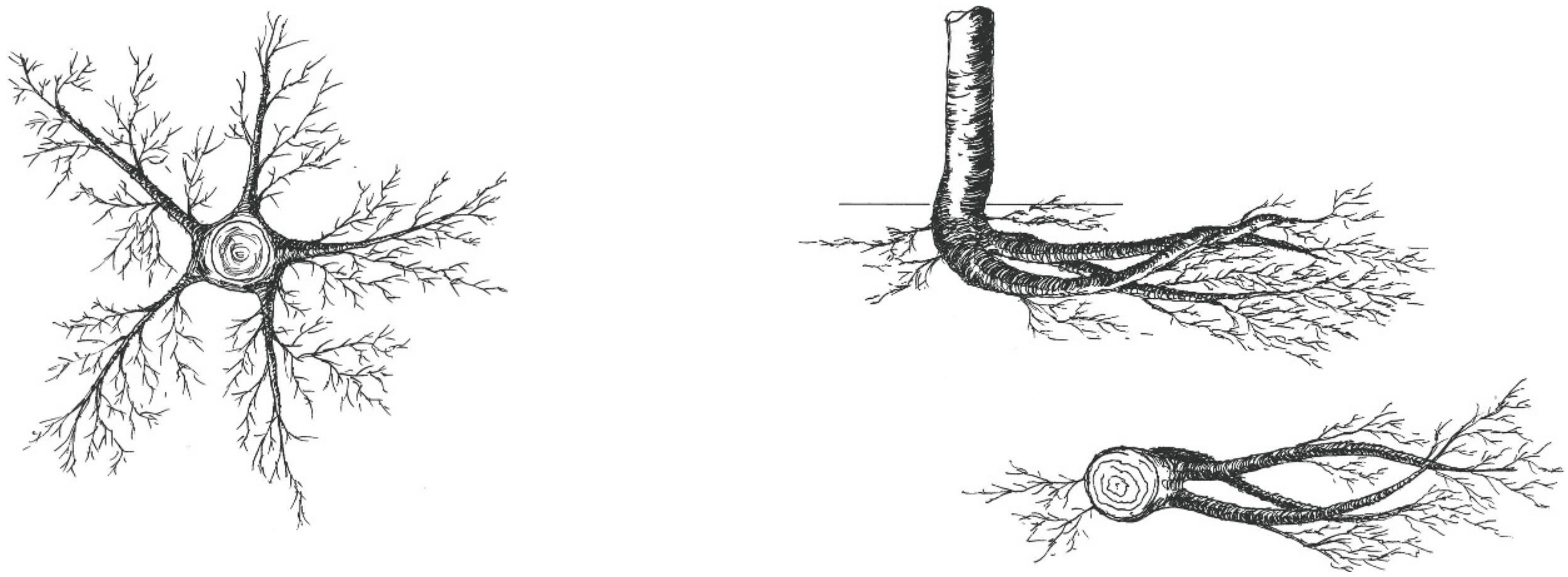
Table D.4 **Container sizes**

Girth of tree measured at 1 m cm	Container size L
8 to 10	25 to 45
10 to 12	45 to 65
12 to 14	45 to 65
14 to 16	45 to 100
16 to 18	100 to 150
18 to 20	100 to 250
20 to 25	150 to 500
25 to 30 and above	500 and above

Typical bare root systems are shown in Figure D.8.

When selecting bare root trees, the vigour as well as the structure of the root system needs to be considered. A simple iodine stain test can be performed to confirm the presence of adequately stored carbohydrate that will be needed for new root growth.

Figure D.8 **Typical bare root systems** *(1 of 2)*

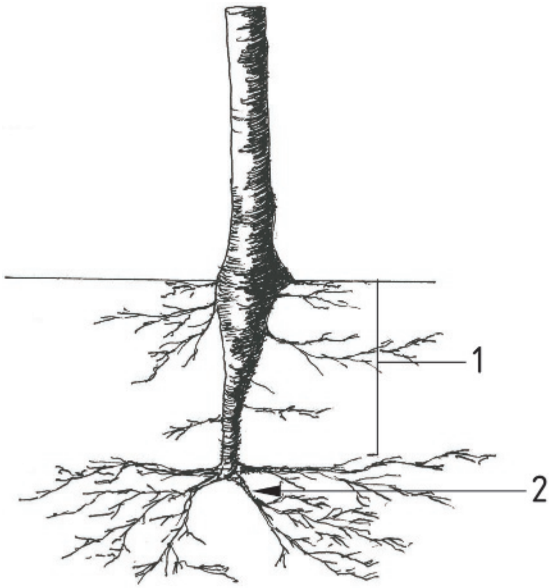


NOTE This is unlikely to produce a balanced root system or stability in the landscape.

a) Well-developed bare root system with evenly spaced lateral roots distributed radially from the main stem

b) One-directional poor bare root system caused by method used to line out young trees in the nursery field

Figure D.8 **Typical bare root systems** *(2 of 2)*



Key

1 Root shank

2 Adventitious root fibre

NOTE 1 This is likely to exacerbate problems associated with deep planting.

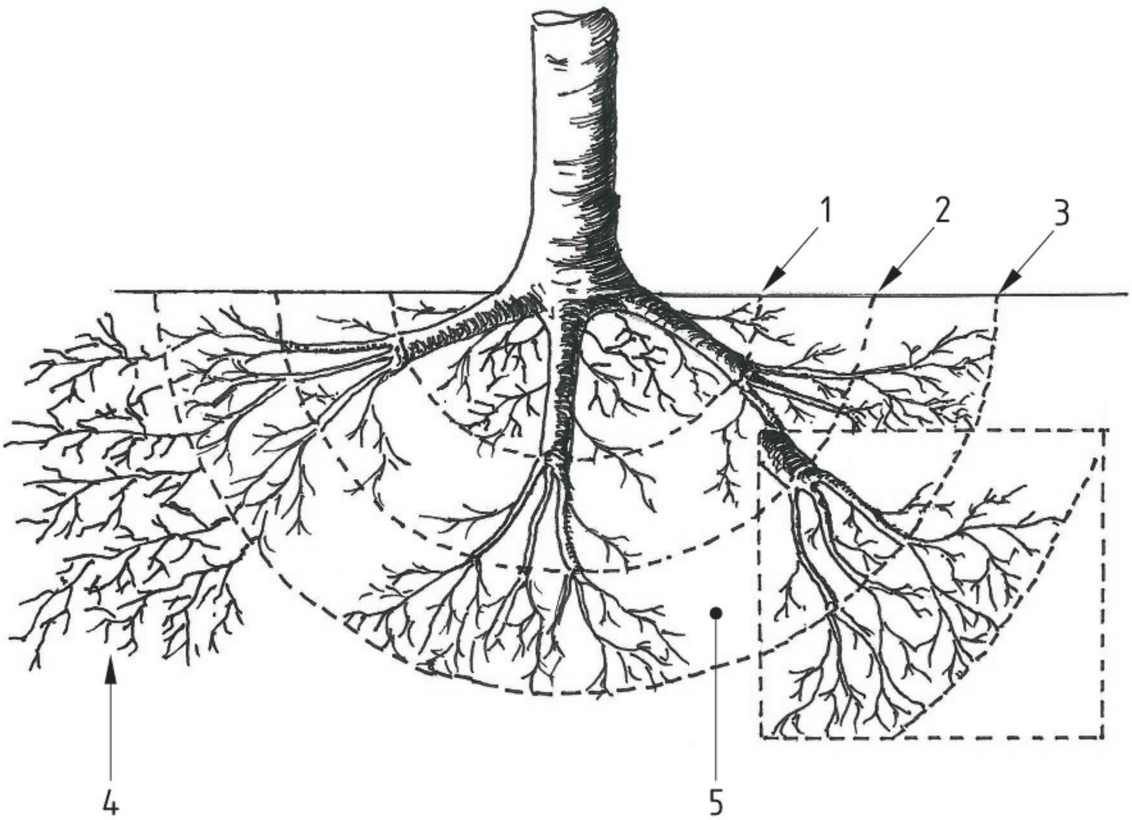
NOTE 2 If the root shank is 100 mm or less, then a deep root system originating from the adventitious roots is unlikely to cause a significant problem. There is also likely to be species variation.

c) Adventitious root fibre caused by undercutting of young trees in the seed bed

D.3.3 Transplanting or undercutting of trees to be rootballed

Transplanting or undercutting treatment increases the amount of fibrous root which is contained in the rootball. The increase in the number and smaller size of cut roots can be significant in achieving better transplanting success. It has been estimated that when such transplanting or undercutting is not practised then as much as 95% of a young tree's root system can be left in the nursery field. The principles involved in transplanting or undercutting are illustrated in Figure D.9. The effects of not undercutting or transplanting are illustrated in Figure D.10.

Figure D.9 **Principles involved in transplanting or undercutting trees to be rootballed**



Key

1 First cut

2 Second cut

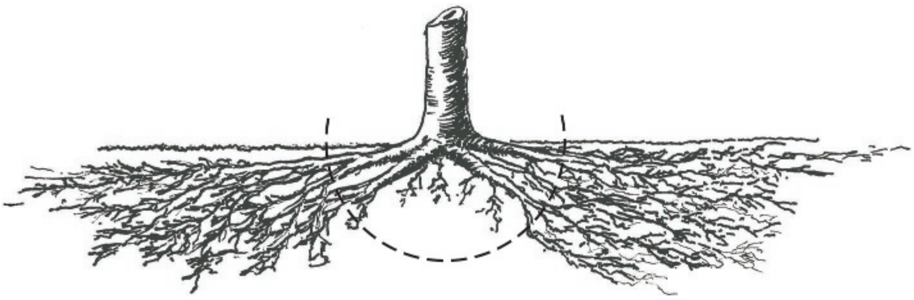
3 Third cut

4 A percentage of the root system is left in the ground

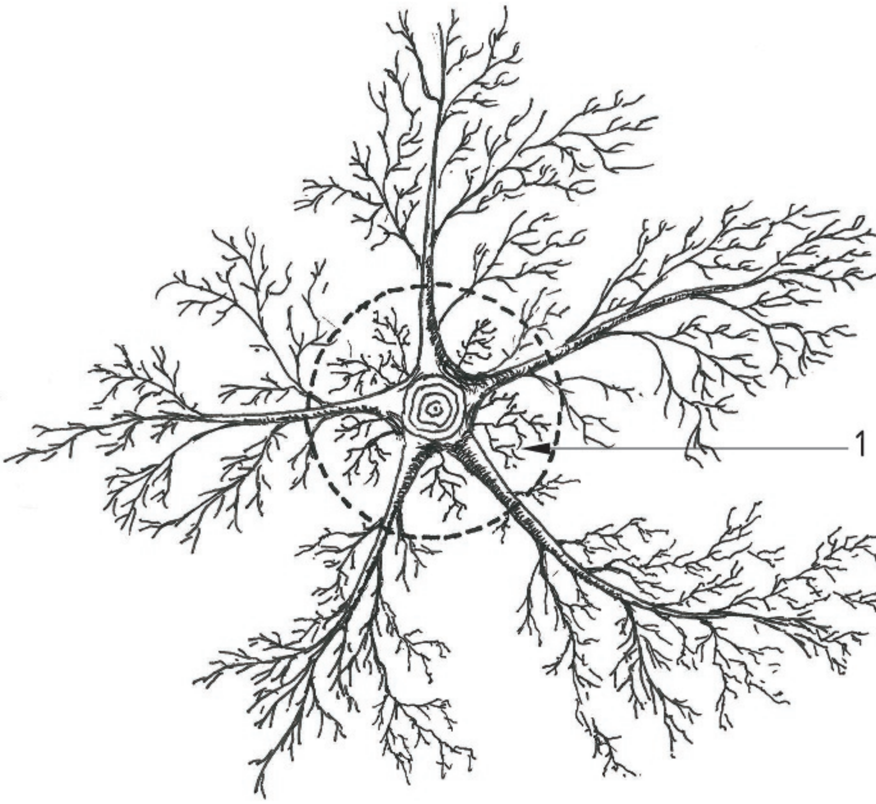
5 Fibrous root development inside ball to be lifted

NOTE The number of undercuts increases with the size of the tree (see Table D.5).

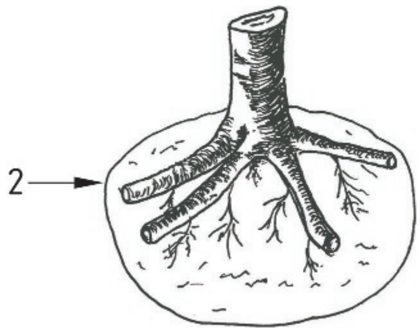
Figure D.10 **Effects of not transplanting or undercutting trees to be rootballed**



a) Up to 95% of fibrous root system can be left in the nursery field (side view)



b) Up to 95% of fibrous root system can be left in the nursery field (cross-section)



c) Stub ends of root inside rootball with little or no fibrous root

Key

1 Approximately 5% of fine roots left within rootball

2 Rootball

NOTE The dotted lines represent the position where a machine would cut on lifting and the roots that would subsequently be left in the ground if the tree had not been transplanted during production.

All rootballs need to be of a size commensurate with the size of tree being supplied from the nursery (see Table D.5).

Table D.5 **Relationship between tree size, size of rootball and number of times transplanted/undercut on the nursery**

Girth of tree measured at 1 m cm	Minimum diameter of rootball mm	Minimum number of times transplanted/undercut on the nursery
8 to 10	300	—
10 to 12	300	—
12 to 14	400	3
14 to 16	450	3
16 to 18	500	3
18 to 20	550	3
20 to 25	600	4
25 to 30	700	4
30 to 35	800	4
35 to 40	900	5
40 to 45	1 000	5
45 to 50	1 200	5
50 to 60	1 300	6

D.3.4 Mounding of soil above root flare

Nursery cultivation in the field can often result in the mounding of soil around the base of young trees. On lifting, this soil is often incorporated into the rootball itself, resulting in the natural root flare of the tree being too deep. This can lead to failure, which might not manifest itself for a number of years after the tree has been transplanted into the landscape. The root flare needs to be clearly visible at the top of the rootball prior to site installation.

If a tree has been buried too deep on the nursery, it is not unusual to find roots confined to the bottom of the rootball. Some adventitious roots might develop on the buried part of the stem but these might not be vigorous enough to support the young tree after transplanting if the main root system fails because of its eventual depth in the landscape soil.

These conditions are illustrated in Figure D.11.

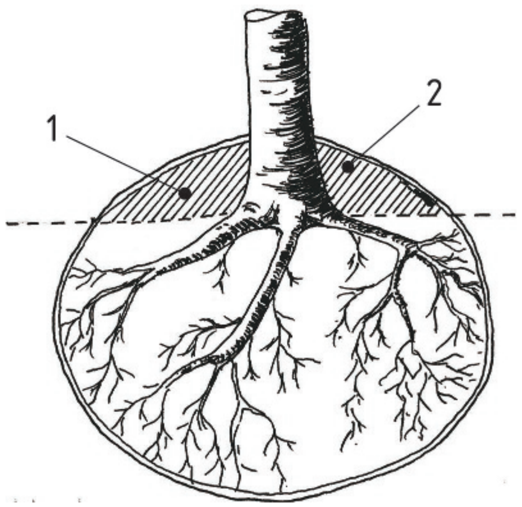
D.3.5 Root circling in containerized trees

Root circling in containers, which if left unchecked leads to root girdling either in the container or later in the landscape, is a well-documented problem where roots have secondary thickened along the side wall of the container, producing a packed distorted root system which prevents lateral root development and reduces stability after transplanting. Roots badly distorted in this fashion can cause eventual self-strangulation and failure in the landscape.

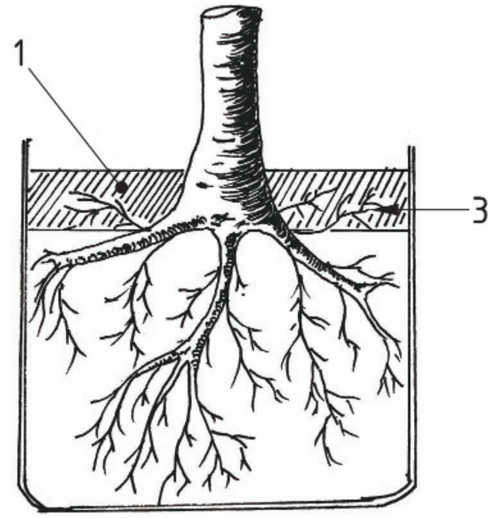
Irrespective of the containerization system which is used, any young tree left in a container for too long will produce circling roots. It is critical that the length of time for which a young tree has been in a container is established by asking the nursery. Figure D.12 illustrates root circling and subsequent root girdling in containers.

As with rootballs, it is possible that during the containerization process the root flare of young trees is buried too deep. In containers, this results in the upward movement of roots into the layer of compost above the root flare with a dense matting of fibre apparent at the container surface. If this fibrous mass is then transplanted into the landscape the result is, as with rootballs, the young tree being planted too deep. It can also result in surface roots girdling the tree above the root flare. The root flare needs to be clearly visible at the container surface.

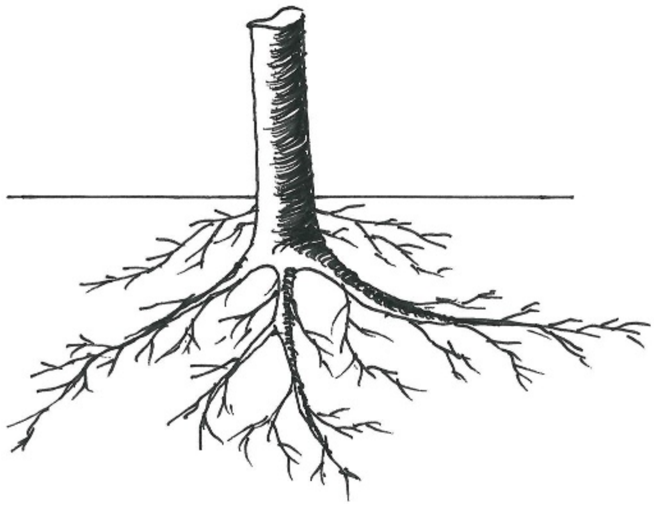
Figure D.11 **Mounding and deep planting**



a) Deep planting in a rootball



b) Deep planting in a container



c) Deep planting in the nursery field

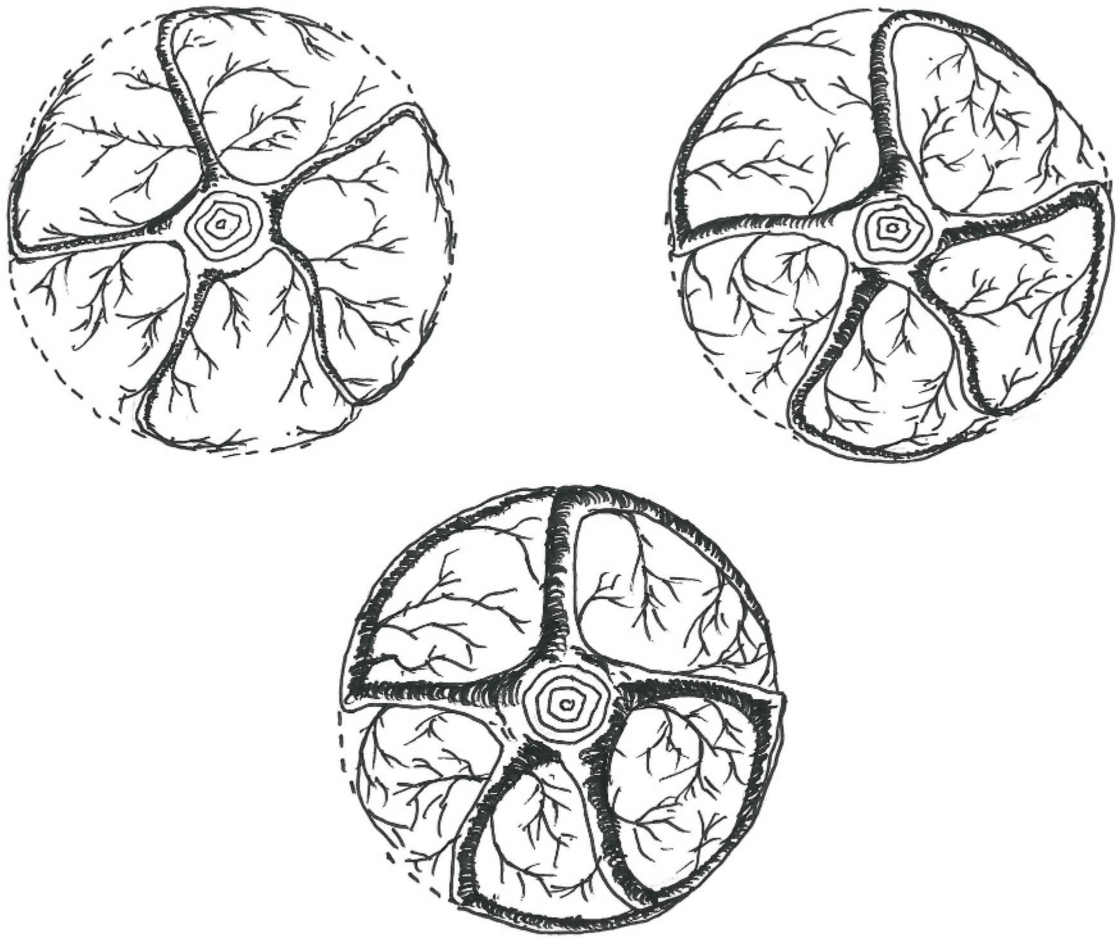
Key

1 Excess soil above the root flare results in planting being too deep

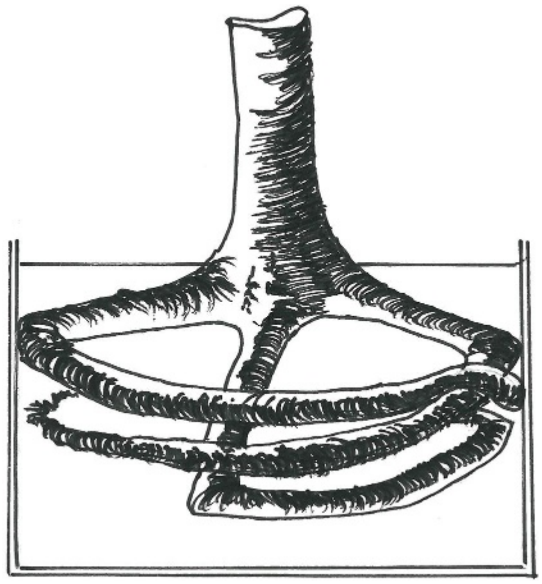
2 Soil mounded during production process results in root flare being buried and lifted as part of the rootball

3 Deep planting in the container results in root flare being buried and adventitious fibrous root growth in compost above root flare

Figure D.12 **Root circling and subsequent root girdling in containers**



a) Progressive root circling and girdling against container wall (related to length of time in container), seen from above

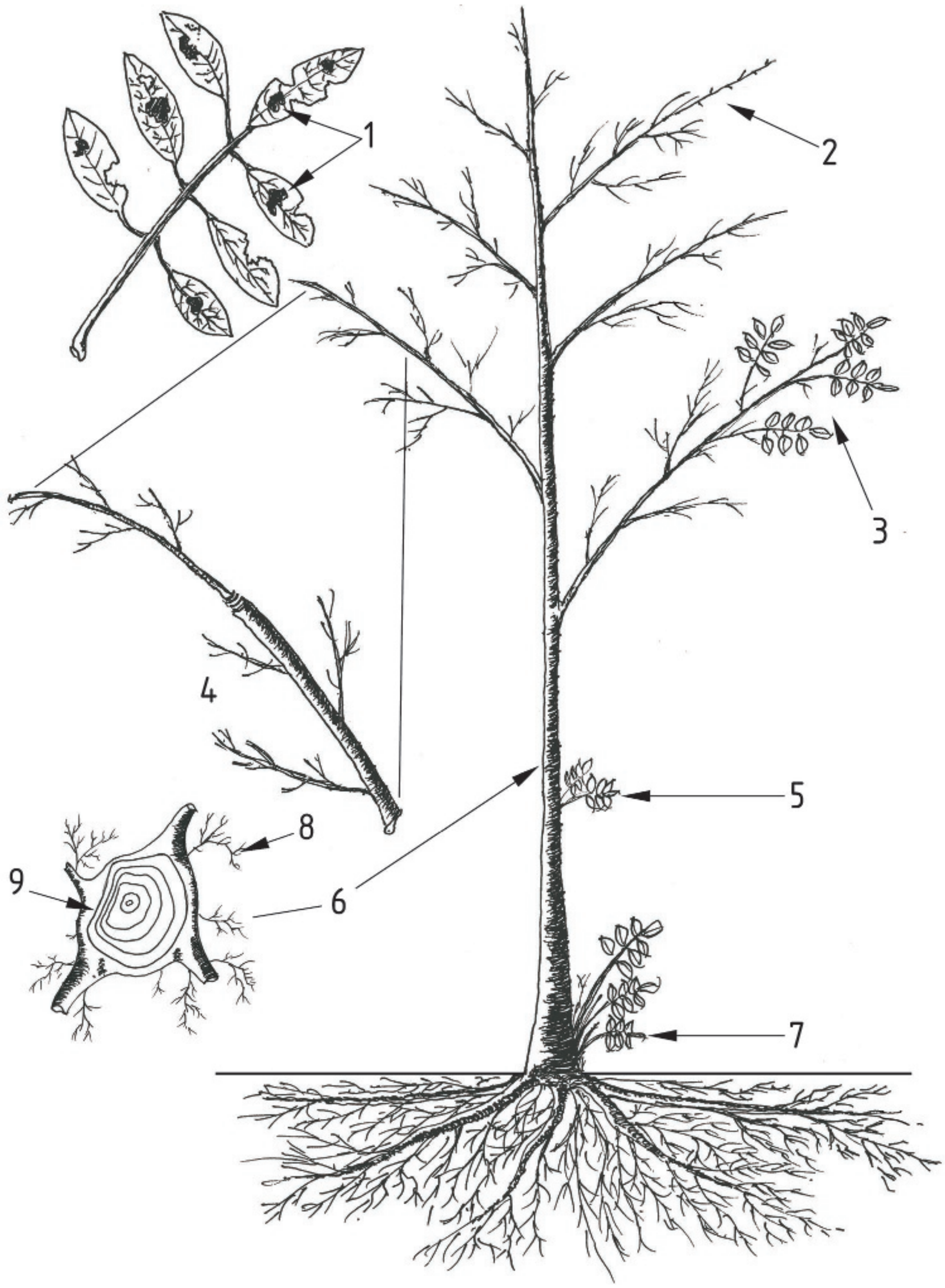


b) Thickening and girdling of primary roots against container wall

D.4 Young tree quality assessment

There are many visual indicators as to a young tree's condition. Some of the most common problems are illustrated in Figure D.13.

Figure D.13 **Visual assessment of poor health in young trees**



Key

1 Leaf lesions or leaf discolouration

2 Dieback in crown

3 Low density and/or small size of foliage

4 Reduced length of extension growth compared to previous years' growth

5 Abnormal adventitious bud development on main stem

6 Abnormal flattening at main stem, which can indicate vascular dysfunction

7 Epicormic growth from rootstock

8 Root fibre

9 Abnormal flattening at main stem indicating vascular dysfunction, in cross-section

The physiological condition of nursery trees is important. There are non-destructive and non-invasive methods available to test the physiological health of young trees both at the nursery and subsequently in the landscape, including the following.

a) Chlorophyll fluorescence. This is a rapid non-destructive diagnostic system of detecting and quantifying physiological injury in tree leaves and needles. It can be used to detect reductions in tree vitality prior to visible signs of deterioration.

b) Leaf chlorophyll content. The exact knowledge of foliar chlorophyll provides a robust and accurate estimation of tree vitality by quickly and accurately estimating leaf chlorophyll concentrations.

c) Annual growth measurements. Both stem girth and extension growth can be measured annually.

D.5 Procurement

When procuring young trees for any planting scheme, it is important to allow ample time in the planning process, especially where particular specifications or species choices are required.

Nurseries hold a limited stock range, but almost any specification can be met if adequate time is allowed. Reliance on the availability of tree stock at the time when that stock is required can result in design or other requirements having to be compromised.

It is sensible to involve a nursery or nurseries in the procurement process at the design stage, to ensure that all design and/or other requirements can be met in full.

Annex E (informative) Further guidance on handling and storage

E.1 Lifting on the nursery

Bare root and rootballed trees are lifted during the dormant season. It is essential that young trees are not lifted until the storage of carbohydrates has been maximized.

Research has indicated that trees lifted from the nursery in the early autumn have a lower stress tolerance when compared to trees lifted later. Trees need to have developed sufficient hardiness before being lifted, and the ideal lifting date varies among species. In nurseries the ideal physiological lifting date can be in conflict with the time required to manage harvests.

The harvesting techniques used to lift trees from nursery fields need to be understood. The lifting of trees from a particular field can extend over three or four seasons. Trees lifted at the end of this cropping cycle need to be evaluated carefully to assess potential damage or reductions in quality caused by earlier liftings.

The fibrous root system of some species can be irreparably damaged in as little as 15 min if exposed and unprotected during the lifting process.

The production of rootballs where the soil ball can be lifted intact is difficult when ground conditions are unfavourable. The correct preparation of rootballs is difficult on light soils. Heavier nursery soils are the most suitable for the preparation of rootballs, since the ball is less likely to break.

E.2 Movement on the nursery after lifting and before dispatch

Research has indicated that during cold storage, carbohydrate reserves accumulated during the previous growing season are depleted due to respiration. This can impact on canopy expansion in the spring.

The method of storage of rootballs is critical. They are heavy and difficult to handle. Stacking can lead to additional movement as the trees are selected for transplanting. Additional movement increases the chances of the rootball being fragmented and the root system damaged.

Containerized or container-grown trees are lifted for dispatch directly from their growing lines. Most containerized or container-grown trees are produced in organic composts, whether peat-based or peat-free. These composts dry out very quickly, and desiccation is likely if they are not irrigated and are allowed to dry out. There is also the possibility of compost shrinkage in the container. Additionally, organic composts are difficult to successfully re-wet once drying out has occurred.

Where lifted trees have to be moved, all damage is significant, but is exacerbated in certain species where excessive movement and subsequent damage occurs in the spring. In ring porous species, cavitation can be as high as 90% after the first hard frost. With these species, new xylem has to be formed in spring to restore hydraulic conductivity. Research has indicated that the rough handling of ring porous nursery trees in early spring damages developing xylem and compromises hydraulic conductivity and, consequently, survival and transplanting success. Diffuse porous species are less susceptible than ring porous species to cavitation.

Annex F (informative) Further guidance on planting

F.1 Considerations below ground

F.1.1 Tree pit design

There is no simple off-the-shelf tree planting pit design which will suit all purposes at all times. There are numerous drawings of tree pit design, some academic, some linked to the marketing of a particular product or products and some a combination of both. In principle, sensible tree pit design begins with the intention of doing as little as possible other than digging a pit, planting the tree, and using the existing soil, separated as subsoil and topsoil, as backfill.

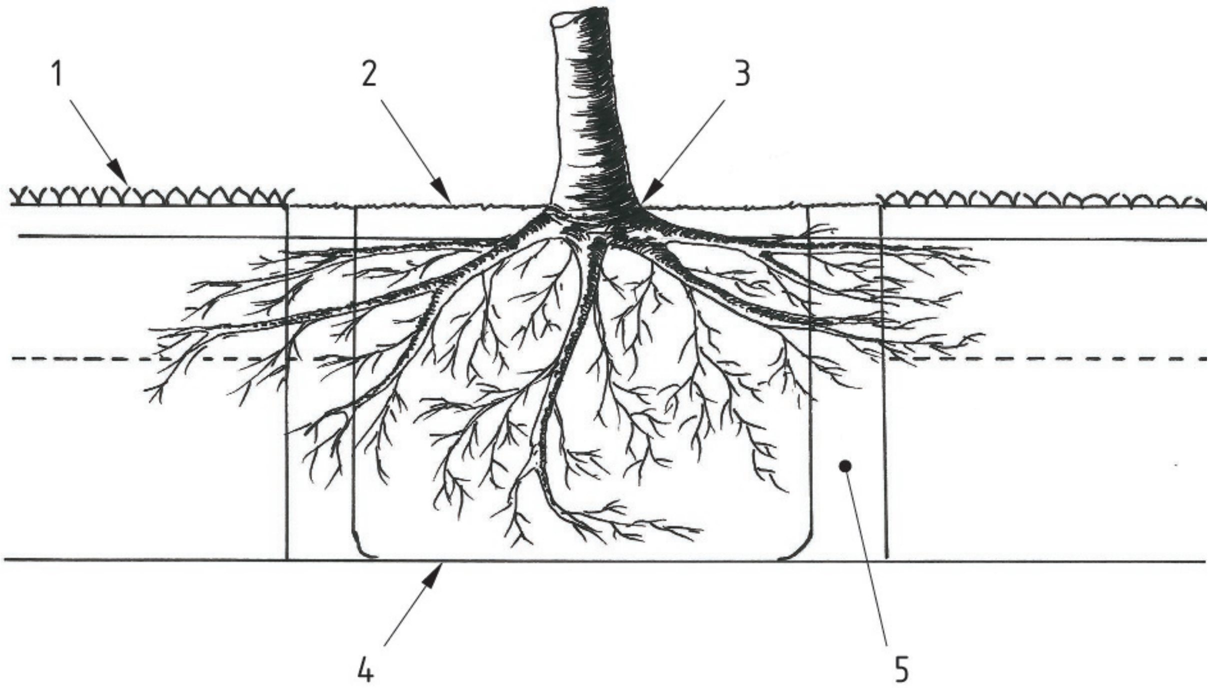
Each additional level of complexity added to the basic pit design can be related to the amelioration of a particular constraint. Before pit design is started, it is also necessary to differentiate between those pieces of equipment which are of little value and those which contribute to the successful transplanting of a young tree into the landscape. It is the tree which will provide the longevity and benefits, and not the many, often decorative, elements which complicate tree pit design.

Examples of tree pit designs are shown in Figure F.1 to Figure F.5. None of these figures are intended to be complete or to scale. They illustrate varying complexities of tree pit design and some of the modifications that can be made. Simple tree pit design is a good starting point, with modifications made in response to site and design constraints.

It has long been common practice to disturb or break up the bottom of a tree pit prior to planting, often working in organic material either to aid drainage or for future root development. The application of organic products such as humates and plant extracts at planting have been shown to have only limited benefit to root or shoot growth of trees, and the addition of a gravel sump to aid drainage has been found to be detrimental. Given that most early root development is in the top 200 mm to 300 mm where soil conditions are optimum for root growth, it is considered unnecessary and potentially detrimental to disturb the soil at the base of the planting pit. Soil settlement following planting disturbance can exacerbate problems associated with deep planting.

When the entire planting pit has been filled with backfill soil, it can be expected that this soil will settle by up to 10%. This natural settling needs to be taken into account when planting depth is determined.

Figure F.1 **Tree pit design: Planting in grass**



Key

1 Grass sward

2 Tree pit surface as large as possible, with organic mulch layer

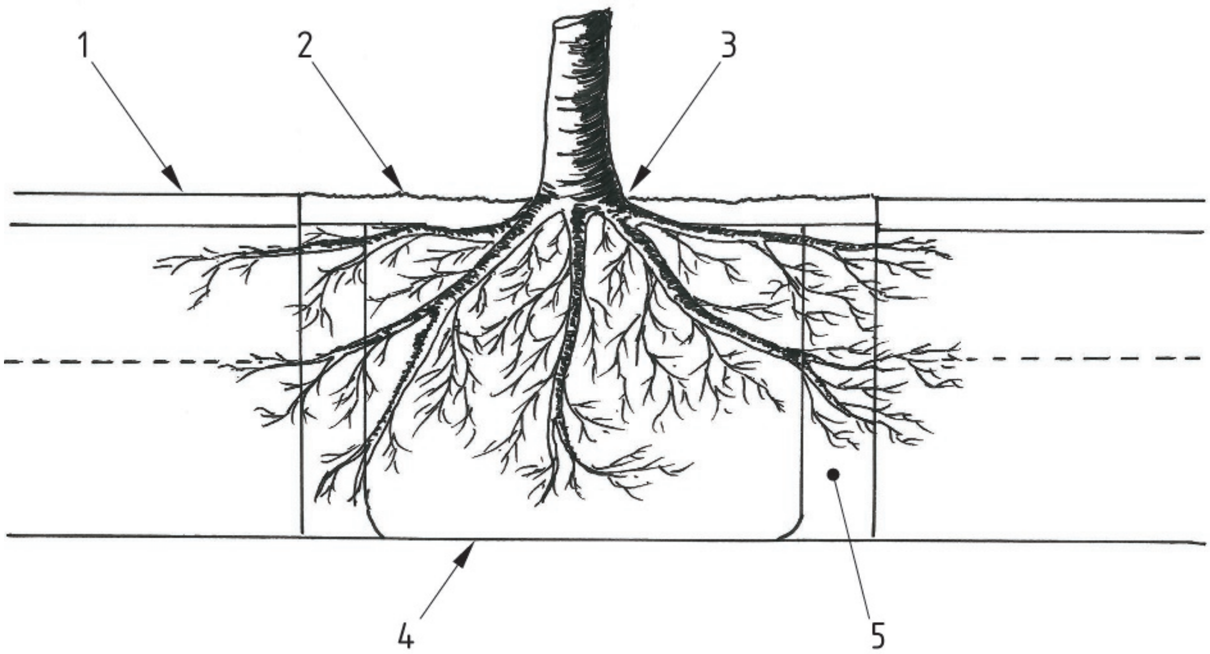
3 Root flare

4 Base of tree pit undisturbed unless drainage problems are apparent

5 Backfill replicating existing topsoil/subsoil profile

NOTE This is an example of tree pit design where there are no site constraints (support systems have been left out).

Figure F.2 **Tree pit design: Planting in hard surfaces**



Key

1 Hard surface

2 Tree pit surface area as large as possible, with organic mulch layer

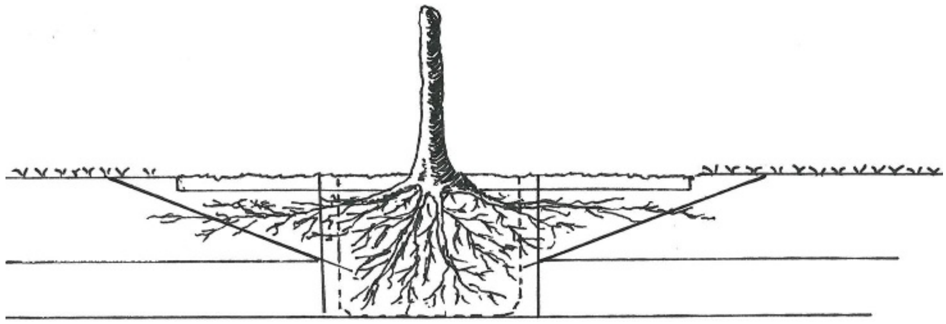
3 Root flare

4 Base of tree pit undisturbed unless drainage problems are apparent

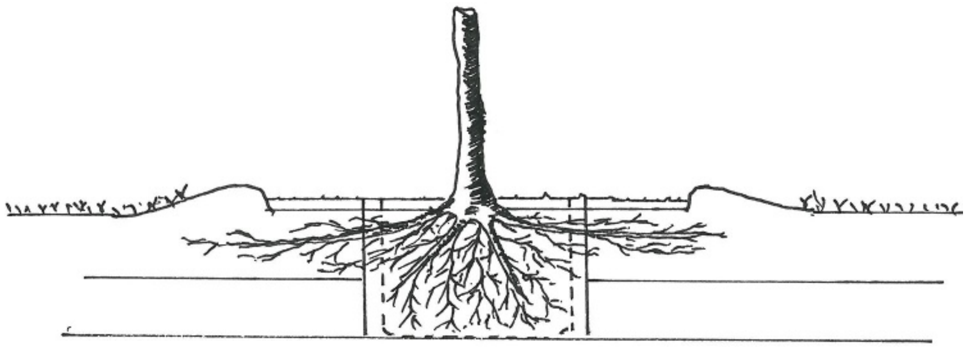
5 Backfill replicating existing topsoil/subsoil profile

NOTE This is an example of tree pit design where there are no site constraints (support systems have been left out).

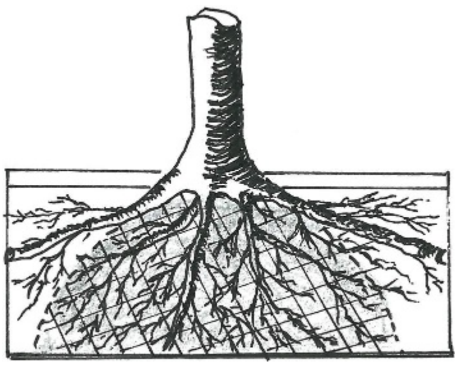
Figure F.3 **Tree pit design: Options for planting pit where site constraints are non-existent or minimal**



a) Sloping side to tree pit increases amount of worked topsoil for lateral root expansion

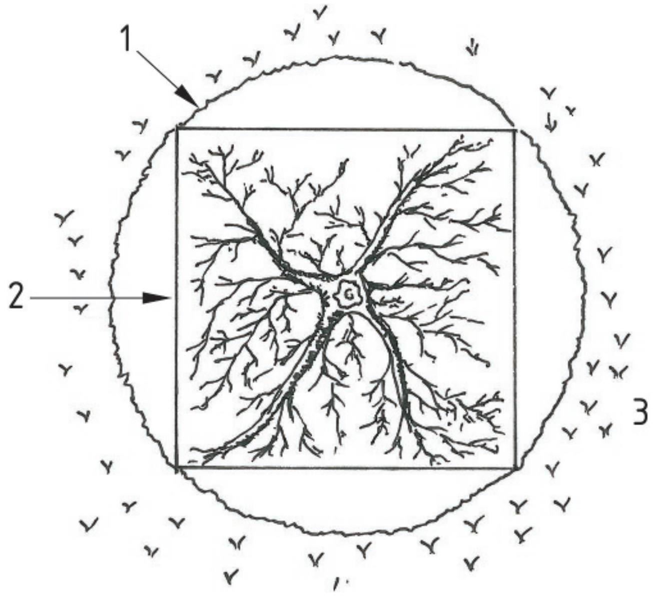


b) Mounded sides to tree pit create reservoir to hold water to percolate through pit horizon



c) Mounding under bare root trees provides support against shrinkage and ensures correct planting depth

Figure F.4 **Tree pit design: Pit with square sides inside circular area excavated in grass**



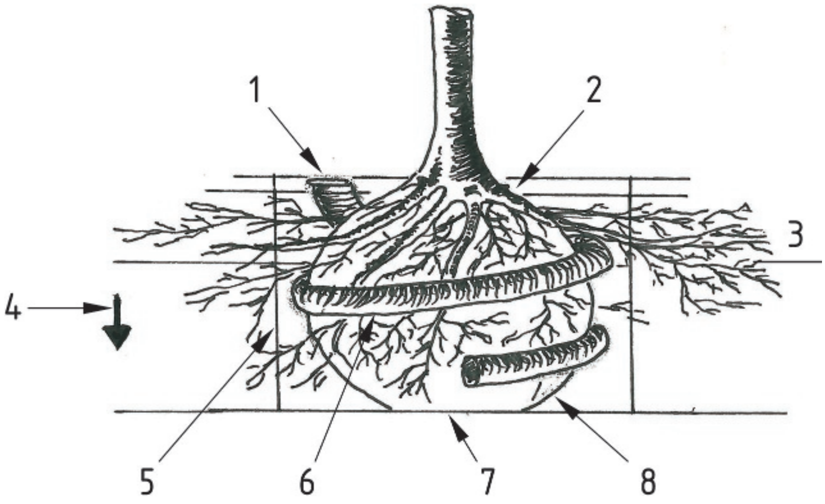
Key

1 Excavated area in grass for organic mulch

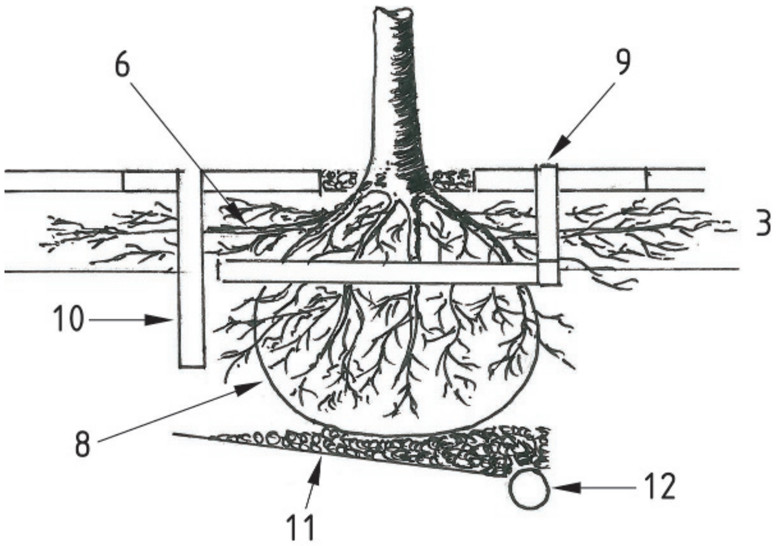
2 Square sides to planting pit can discourage roots from circling

3 Grass

Figure F.5 **Tree pit design: Tree pit modifications in response to site constraints and design necessities**



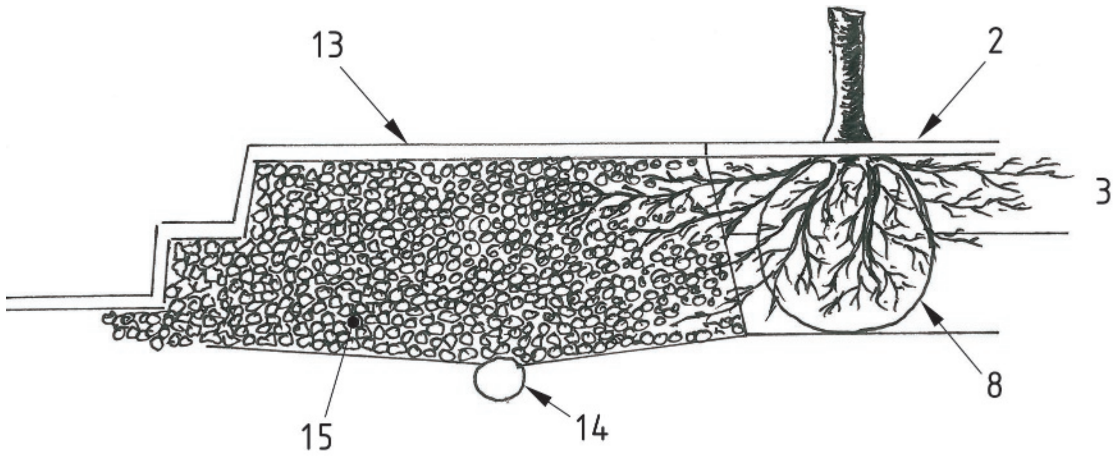
a) Wraparound perforated tubing for watering



b) Irrigation and air vent/drainage pipes

Key

1 Water entry point
2 Mulch layer
3 Topsoil
4 Flow of water
5 Side wall of pit
6 Height of tubing can take water away from topsoil area and surface watering might be necessary
7 Undisturbed tree pit base
8 Original rootball or container
9 Irrigation pipe
10 Air vent
11 Slope to facilitate drainage
12 Drainage pipe
13 Hard surface
14 Slope and drainage pipe
15 Structural soil



c) Load-bearing structural soil

NOTE 1 Approximately 500 mm³ of structural soil provides 100 mm³ of soil.

*NOTE 2 These drawings do not show the tree pit/native soil interface as being lined with a geotextile membrane (see **10.2.4**).*

F.1.2 Soil volume

It is widely accepted that the volume of soil available for young tree development is an important limiting factor in them achieving longevity in the landscape. There are various methods available for estimating adequate soil volume, but none are perfect and all require careful assessment of the specific circumstances.

A common way of calculating the soil volume necessary to support a tree is to use the estimated nutritional or water requirements, based on the eventual crown projection of the tree, with leaf area and local rainfall patterns to determine the water use of the whole tree. This information is then coupled with the known water-holding capacity of the soil type to calculate the soil volume necessary to meet the water requirements of the tree. However, this can only provide a guideline, which is at best an estimate. The differing water-use strategies of different tree species, the varying characteristics of soil types, the multiplicity of variants affecting water release patterns and the peculiarities of local climatic conditions are all factors that can have an impact on long-term tree survival.

New trees can still be planted where soil volumes are limited, but it needs to be done in the knowledge that they might not reach their full genetic potential. The chances of success in such conditions can be greatly improved by the provision of access routes to nearby native soil to allow roots to eventually find the soil resources necessary to support the tree into maturity. However, if soil volumes are restricted and there is no potential for future access to native soil, the life expectancy of newly planted trees can be greatly reduced, and managed replanting might be necessary.

F.1.3 Load-bearing surfaces

Where it is necessary to provide a load-bearing surface, structural soils and soil cells are two of the commonest options. In general terms, structural soil is a feasible approach to supporting surfacing above a rooting volume where it is not the only soil volume available to the tree. A typical situation would be a parking area adjacent to unpaved landscape areas, where tree roots can grow beneath the hard surfacing, but also have the opportunity to exploit the adjacent native soil. Soil cells are more appropriate for areas of more intense urbanization where the opportunities for roots to exploit native soil are much more limited. Both approaches perform best where specific provision is made to ensure that rainwater is directed into the rooting volume and roots have access to the native soil beyond the installation.

The first load-bearing soil was extensively trialled in Amsterdam and was named after that city. This is a coarse sand mix carefully constructed to a specific density with aeration provided through spaces in the surface material placed over the soil. This system has proved to be effective in providing vigorous trees and stable pavements for many years. Some problems have been reported with pH as planting schemes mature. There is also evidence that some soil mixes might not have good water retention characteristics in extreme drought conditions, and this can adversely affect trees that solely rely on the installed soil volume.

Other structural soil systems developed in Europe and the USA have been created on-site using various grades of stone and soil mixes to produce a network of connected spaces. Compaction to 0.185 g/mm^3 and greater does not seem to reduce macropores or restrict root penetration into the soil. Typically, a stone soil mix can hold 7% to 11% moisture by volume, which is similar to a sandy loam with high infiltration, drainage and aeration.

Research has indicated that soil/stone mixes can support better root growth than compacted soils or road base materials, but that growth is limited by the net soil volume rather than the total volume of the soil/stone mix. Other research has indicated that trees planted in non-compacted soils or pavements suspended by underground cellular systems outperform those planted in structural soil mixes. Soil/stone mixes can be a useful compromise where high quality non-compacted soils cannot be used.

Underground cellular systems are designed to provide necessary load-bearing capacity via rigid structures surrounding a void that is filled with soil to provide the substrate for root growth. Such an approach is particularly valuable in an urban context because rainwater can be directed into the cells, which mimics very closely the water flow buffering characteristics of natural soil. This means that they have the dual function of supporting tree growth and providing a sustainable urban drainage function within the same below-ground volume.

The product and installation costs of underground cellular systems are generally greater than standard planting or the use of structural soil, and so they are not practical for all situations. They do offer a feasible means of growing trees in otherwise almost impossibly hostile locations, but there is some uncertainty over the long-term performance because there are no examples of trees that have successfully matured over a long period of time. Anecdotal evidence from recent installations is indicating that careful consideration needs to be given to drainage to get the best results. An important aspect of the design is to direct rainwater into the cells to provide a reservoir for the tree in dry spells, but equally, drainage needs to be sufficient to prevent waterlogging when it is excessively wet. It also seems likely that the use of geotextiles to surround the cell installation needs to be carefully assessed. Membranes that are a barrier to root growth beyond the planting pit prevent trees exploiting adjacent native soil and can adversely affect long term survival.

F.1.4 Root barriers and deflectors

Root barriers are intended to physically prevent roots entering a specific soil volume, whereas root deflectors divert the direction of root growth. Both approaches are valuable where roots can cause damage to pavements or other elements of the built environment. They can be fabricated in many materials, including concrete, plastic, metal screening and geotextile membranes.

Root deflectors are barriers that are profiled to encourage roots to grow downwards where aerobic soil conditions allow. Once roots have reached the bottom of the barrier they often grow beneath and then grow upwards towards more suitable soil conditions nearer the surface.

The depth of root growth is very much dependent on soil conditions and tree species, and so a careful assessment of the local circumstances is essential when considering the dimensions of the product. It is important that the lip of the barrier is above the soil surface as roots will grow across the top.

There is no evidence to suggest that a root barrier used along one or two sides of the area where the root system is to develop will adversely affect tree stability or stem development.

Root barriers used around the whole tree and to a depth where roots cannot grow have the effect of containerizing the tree.

F.1.5 Mycorrhizae

Mycorrhizae are highly specialized root-inhabiting fungi which form beneficial relationships with the fine feeder roots of plants. Mycorrhizae are active living components of the soil, and have some properties like those of roots and some like those of micro-organisms. There are no reports in the scientific literature of any species of forest tree in its natural habitat not having either mycorrhizal or actinorhizal association.

Mycorrhizal colonization is complex. There are essentially three types of mycorrhizae, but it is beyond the scope of this standard to explore the differences in any detail.

The benefits of mycorrhizal associations are well documented and include a tree's fertility requirement, its ability to absorb minerals and nitrogen from the soil, its rooting habit, and the amount of available fertility in the soil. However, there is little literature to support the value of adding commercial mycorrhizal cocktails to the backfill soil used for young tree planting.

F.1.6 Below-ground irrigation aids

There are several irrigation aids available that can be inserted below ground at the time of planting.

Below-ground irrigation systems take the form of perforated tubing wrapped around the root ball or container in the tree pit, with water delivered through an entry point which sits above the soil surface. This might or might not be capped, depending on the system being used.

Below-ground systems have the advantage of delivering a known quantity of water, avoiding the risk of run-off, but it is difficult to monitor whether the actual amount has been applied once irrigation has been carried out. It is also likely that the roots above the pipe will remain dry, and overhead watering might be necessary to correct this deficit.

Where the system is not capped, the tubing can become clogged with debris over time and the perforations in the tubing become blocked, making water movement difficult, if not impossible.

F.2 Considerations above ground

F.2.1 Supporting young trees

There are many methods of supporting young trees after transplanting. In some instances young trees do not need supporting, and any support system used has implications for the future development of the tree itself (see Figure F.6) and the subsequent maintenance necessary.

The choice of support system used depends on many factors, including identified site constraints, the nursery production system and the size of tree planted. The support system itself might also be used to offer other advantages such as protection of the tree and an attachment point for irrigation delivery systems.

The purpose of supporting young trees after transplanting is to allow lateral or anchor roots to develop without excessive movement.

Some of the methods used widely to support young trees are:

a) angled stake;

b) upright single stake;

c) double stake and bridge;

d) four stakes and bridge;

e) wired guying;

f) weighted underground guying;

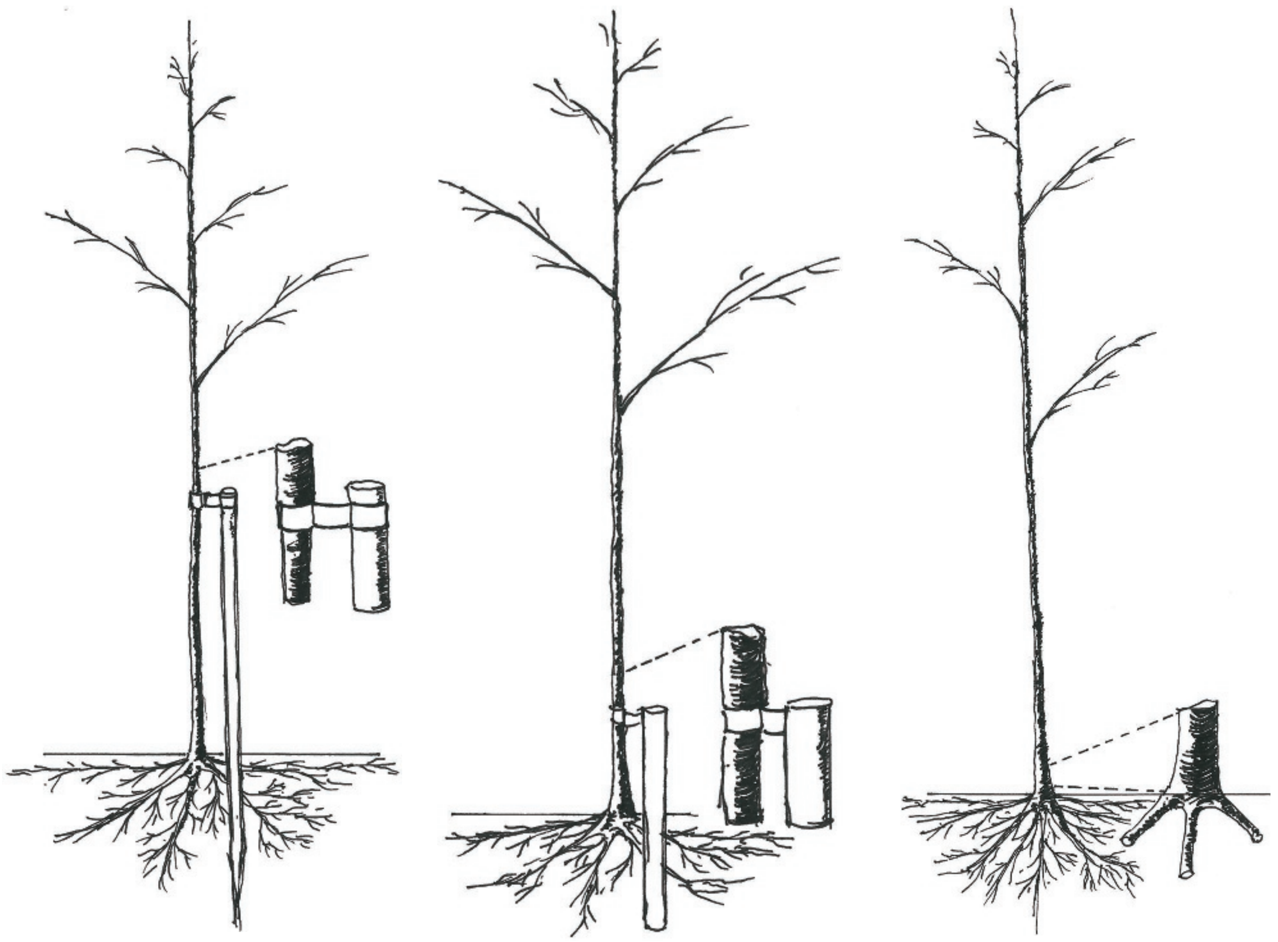
g) anchored underground guying.

Methods a) to e) involve all or part of the support system being visible above ground. All involve connecting the tree to the support system in some way while allowing a degree of stem movement. All involve regular maintenance to ensure that no damage occurs to the main stem of the tree.

Where a staking system is used, the lower the position of tie in relationship to the main stem, the lower the lateral movement of that stem. This movement encourages stem thickening at the fulcrum point. It is advantageous for stem thickening to occur as low down the main stem as possible, reinforcing the development of the stem taper above the tree's natural root flare (see Figure F.6).

With methods f) and g), the support system is below ground and not visible. There are numerous methods available and these need to be installed according to the manufacturer's instructions and maintained accordingly.

Figure F.6 **Impact of stake and tie height on position of stem thickening caused by lateral movement**



a) Lateral movement of main stem is above tie – this creates the potential for greater stem thickening above the tie than below

b) Again, movement is above tie but lower down the tree

c) Without tie, tree experiences full movement with thickening at base of stem

Key

– – – Area of movement

F.2.2 Mulching

The benefits of mulches are well documented. They include minimizing the fluctuations in soil temperature and soil moisture, weed suppression, soil nutritional enrichment, the prevention of soil erosion from heavy rains, regulation of pH and cation exchange capacity, pathogen suppression, increasing soil microbial activity, improving aeration and mitigating compaction.

Mulches are most effective when they are 50 mm to 100 mm in depth and applied from the drip line almost up to the base of the stem. (Mulch placed against the stem is likely to retain moisture, which can result in disease.) If this is not practical, typical minimum mulch circle radii would be 0.3 m for small trees, 1 m for medium trees and 3 m for large trees.

Research has indicated that pure mulches, i.e. those derived from single tree species, can have a substantial positive effect on tree survival rate. Pure mulches from *Prunus* (cherry) and *Crataegus* (hawthorn) have been shown to be suitable.

F.2.3 Permeable and impermeable surfacing for tree pits

Each surfacing material has a number of advantages and disadvantages, some of which are shown in Table F.1.

F.2.4 Above-ground irrigation aids

There are several types of above-ground irrigation aid available. These allow a known quantity of water to be applied to the tree, avoiding the risk of run-off.

With above-ground systems, it is easy to monitor the amount of water actually being applied and this is delivered gradually allowing water to percolate through the pit horizon. However, above-ground systems can be vulnerable to vandalism.

F.2.5 Tree protection

When using grids, grilles, guards and other forms of tree protection, it is the tree which is the important feature and the one which will provide the greatest longevity in the landscape.

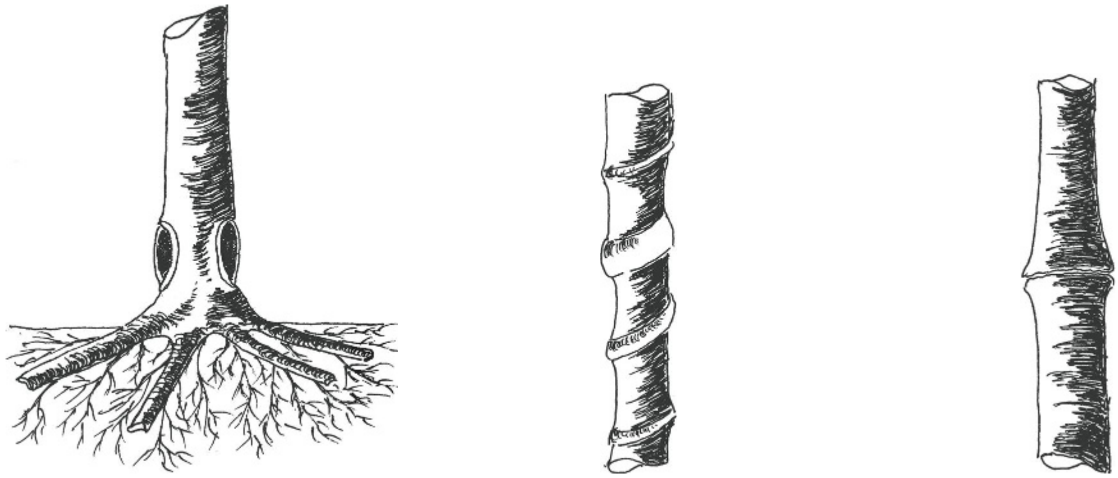
The choice of tree protection is site-specific and relates to both site constraints and the aesthetics of the design concept, but the protection is always a temporary feature, installed to protect the tree when it is planted but then removed once the tree is established. In many instances, failure to remove tree protection is the cause of the damage or failure of the young tree it was installed to protect.

Types of damage caused by failure to remove tree protection are illustrated in Figure F.7.

Table F.1 **Advantages and disadvantages of different tree pit surfacing materials**

Tree pit surface type	Advantages	Disadvantages
Bare earth Completely natural	No additional material cost incurred Aeration and permeability for water Amelioration/mulches can be easily applied to surface Bases can be planted	Vulnerable to compaction and capping Difficult to maintain Weeds can seed and establish on the surface
Loose aggregate Rounded or granular material	Decorative Can be used to fill voids in tree grilles so less of a detritus trap Can be used as a complete tree pit surface treatment Aeration and permeability for water Resistant to compaction	Difficult for pedestrians Difficult to maintain Liable to scatter
Self-binding bound gravel Crushed aggregate material with fines	Neat and decorative Low maintenance Hard wearing Firm surface	Specialist installation Gas and water permeability can be reduced Compacted base and surface layers can cause root damage Weeds can seed and establish on the surface Increased maintenance Roots can cause cracking to surface in time
Permeable resin-bound aggregate Bound systems aggregate or other materials are mixed with a polymer or epoxy resins	Neat and decorative Low maintenance Hard wearing Structurally stable surface Permeable Easily cleaned	Highly specialized installation Installation is weather-dependent Gas and water permeability can be reduced if aggregate too small Compacted base and surface layers can cause root damage Anti-slip treatment required Can cause damage to tree by constricting stem growth

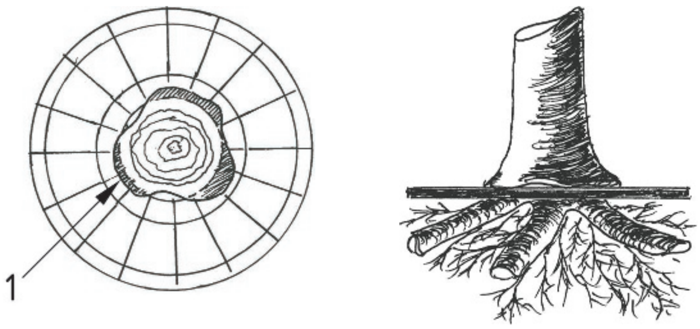
Figure F.7 **Types of damage caused by failure to remove tree protection**



a) Strimmer/mower damage, easily avoided by extending area of mulch

b) Stem constriction caused by failure to remove tubular rabbit guards

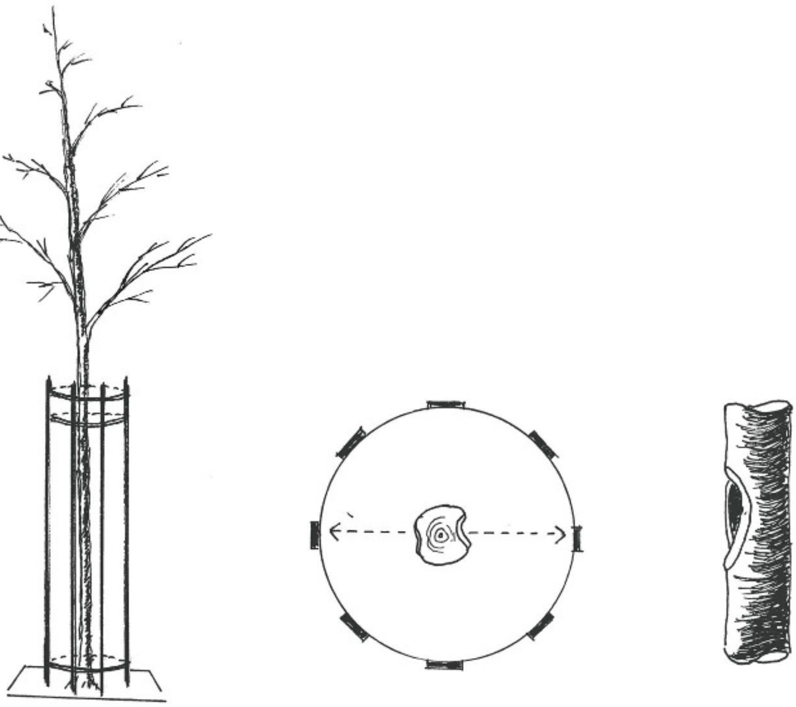
c) Stem damage caused by wire from supporting stakes



Key

1 Hatched area indicates growth across metal grid

d) Young tree grows over metal grille left in place for too long



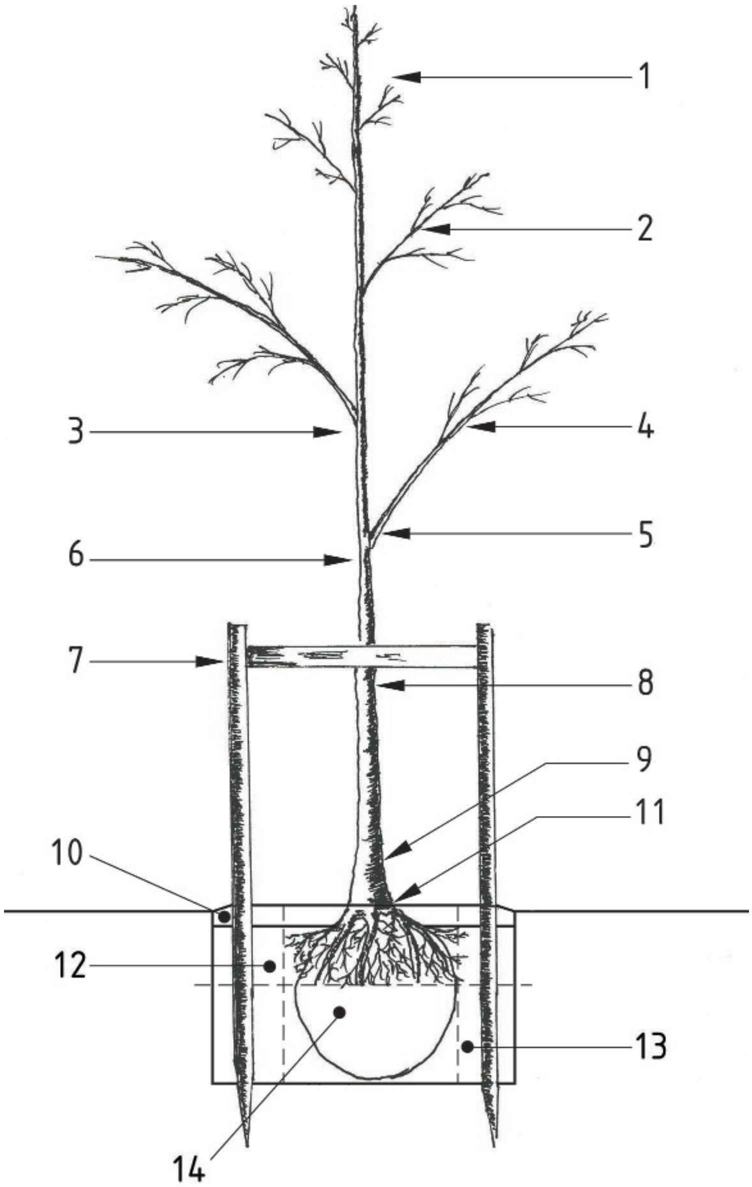
e) Movement of tree inside metal guard causes damage to stem bark

F.3 Planting the tree

F.3.1 General

The key factors involved in tree planting are illustrated in Figure F.8.

Figure F.8 **Factors involved in tree planting**



Key

1 Straight leader
2 Formative pruning, as necessary
3 Size
4 Lateral branch subordination, as necessary
5 Branch union with no included bark
6 Height/stem diameter ratio
7 Support
8 Clear stem
9 Bud/graft union
10 Mulch
11 Root flare
12 Irrigation
13 Soil volume
14 Type and condition of root system

F.3.2 Planting depth

It has been established since the early 1980s that one of the most common causes of failure of trees transplanted from the nursery is that they are planted too deep. This deep planting can occur just at the planting site or can exacerbate deep root problems incurred during nursery production. Failure is often not immediate but can occur a number of years after transplanting.

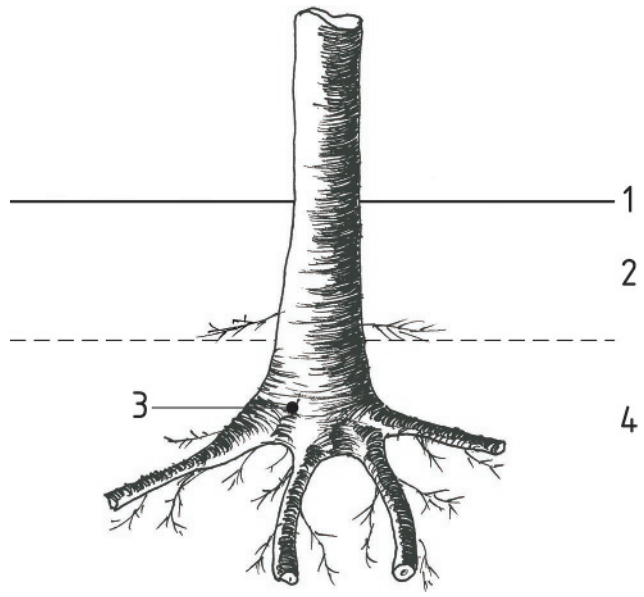
F.3.3 Root flare

The production processes of both rootballs and container-grown trees can result in trees being dispatched from the nursery with the root flare already too deep. This is then exacerbated by over-deep planting. Studies in the USA have shown that up to two thirds of the uppermost structural roots of street and park trees were more than 75 mm below the soil surface, which illustrates that this is a common problem.

In rootball production, constant cultivation in the nursery field can cause mounding around the base of individual trees. This mounding and subsequent burying of the root flare is then lifted as part of the soil ball and dispatched with the mounding intact.

Deep roots are illustrated in Figure F.9.

Figure F.9 **Deep roots**



Key

1	Soil level after planting
2	Aerobic conditions
3	Buried root flare
4	Poor aerobic conditions causing root inhibition and death
– – –	Dividing line between aerobic and anaerobic soil conditions, which varies from site to site

F.3.4 Rootballs

The removal, where feasible without root ball disturbance, of wire baskets, hessian and twine used in the rootballing process ensures that that future root development is not inhibited, once the tree is positioned in the planting pit. When left in place, hessian and twine can remain strong for several years and this is long enough to cause serious constriction in the basal stem area. Wire baskets can last for as long as 30 years after transplanting. Where a wire basket is left in place, the top of the root flare usually grows into one of the horizontal upper wires and roots become girdled as they develop. This causes the transport of water to the stem and carbohydrates to the rest of the root system to become restricted.

F.3.5 Orientation

Trees need to be orientated for the best crown development. It might be found that due to the nature of growing trees on nursery lines crowns develop asymmetrically. In certain circumstances this can be utilized, e.g. in street environments, so that the orientation of the tree's canopy and branch structure is parallel with the road.

Annex G (informative) Further guidance on post-planting management and maintenance

G.1 General

Even when the recommendations given in this standard are followed, failure to achieve longevity in the landscape can still occur. Post-planting management and maintenance is critical. Landscapes, particularly urban landscapes, are littered with young trees, which, although alive, do not grow. Trees in this condition never realize their genetic potential or deliver the benefits for which they were planted. The young nursery tree, once transplanted, has only partially completed its development. It has been carefully nurtured on the nursery and this nurturing needs to continue for several years after transplanting before the tree can be considered fully independent.

G.2 Irrigation

There is no single formula which will provide an answer to the question of how often to irrigate and what volumes of water to apply on any single occasion.

The amount and frequency of irrigation is dependent on several factors, all of which are interrelated and all of which are highly variable. These include:

- amount of rainfall;
- permeability of surfacing;
- daily temperatures and wind conditions;
- moisture-holding capacity of the soil;
- drainage;
- size and species of tree planted;
- nursery production system.

It is important to remember that root growth stops in most species when the soil moisture is reduced to 14% on an oven dry weight basis. Root suberization is accelerated in dry soil and the full capacity for water uptake is not achieved until new root tips are produced. On re-watering, even if immediately after the cessation of root elongation, roots might not begin to grow for at least a week. The resumption of root growth can be delayed for as much as 5 weeks if water is withheld for longer periods. If a soil becomes too dry then some of the smaller roots might die.

Each soil has the capacity to hold water as well as to release it for tree use. The capacity to release water is different from a soil's capacity to hold volumes of water. Therefore both volumetric and matric (capacity to release water) potentials of a soil need to be understood when calculating irrigation needs. The matric potential is determined by characteristics such as texture, parent material and organic content. The matric potential of a soil can be measured using a tensiometer. It is advisable wherever practical to measure the matric potential of a given soil prior to calculating irrigation needs.

Matric potential results in significant differences in soil water availability even when soil volumetric content is consistent across different soil types. A sandy soil with a volumetric content of 5% contains water which is available to the tree, whereas a loam-based soil with an equivalent volumetric content contains no available water. Assessing the volumetric content alone is therefore of limited value.

Different soils hold different amounts of water at field capacity and wilting point. Sandy soils have many macropores and few micropores so the available water between field capacity and wilting point is small. Clay and silty soils, especially when compacted, have many micropores and few macropores. These micropores are often too small for roots to access the water. Available water is limited and wilting point is reached even though the soil might contain significant amounts of water.

Table G.1 indicates the available water in different soil types at field capacity.

Table G.1 **Available water in different soil types at field capacity**

Soil type	Total % available water at field capacity
Coarse sand	5
Fine sand	15
Loamy sand	17
Sandy loam	20
Sandy clay loam	16
Loam	32
Silt loam	35
Silty clay loam	20
Clay loam	18
Silty clay	22
Clay	20
Peat	50

Application of water volumes in excess of field capacity results, at best, in significant amounts of water being wasted as it cannot be held in the soil. This excess water is lost as drainage water or, in worst case scenarios, results in an anaerobic waterlogged zone at the base of the tree pit where root activity is limited or non-existent.

It is more important to irrigate transplanted trees frequently than to apply large volumes of water infrequently, as a single application of a large volume of water does not compensate for irrigating infrequently. Research has indicated that watering every other day with 4 L to 8 L of water for every 250 mm of stem diameter just above the root flare might provide the most even soil moisture for roots but this might be impractical to deliver.

Research has also indicated that in most climates, trees probably need to be watered about twice each week with 20 L of water adequate to keep an 800 mm diameter rootball well irrigated, and that 40 L of water or less thoroughly moistens a soil ball of 500 mm to 600 mm. The assessment of irrigation need can be assisted by the use of a simple soil moisture meter. Sampling can be a useful exercise when large numbers of newly planted trees are being managed and irrigation needs are being assessed.

It can take up to 4 to 5 months for enough roots to grow beyond the soil ball to take advantage of the water available in the surrounding soil following transplanting. During this period the tree is almost entirely dependent on the water contained in the soil ball.

The period over which irrigation is required is likely to be at least two full growing seasons.

As the root system develops, the frequency of irrigation can be reduced. Root development can be between 1 m and 4 m each year depending on site conditions. Where it is possible for enlarged areas to be irrigated commensurate with root spread and development, a depth of 300 mm is ideal. For soils with good water holding capacity this is the equivalent, per application, of 40 L/m^2 of soil surface area.

G.3 Formative pruning

Nursery pruning is an integral part of the production process, but the branch structure created is usually temporary. Formative pruning is therefore an essential part of the post-planting management and maintenance of transplanted trees.

There is anecdotal evidence to suggest that there are three significant problems which can occur if transplanted trees are not placed on a formative pruning programme.

a) Co-dominant stems can develop, which increases failure potential and risk.

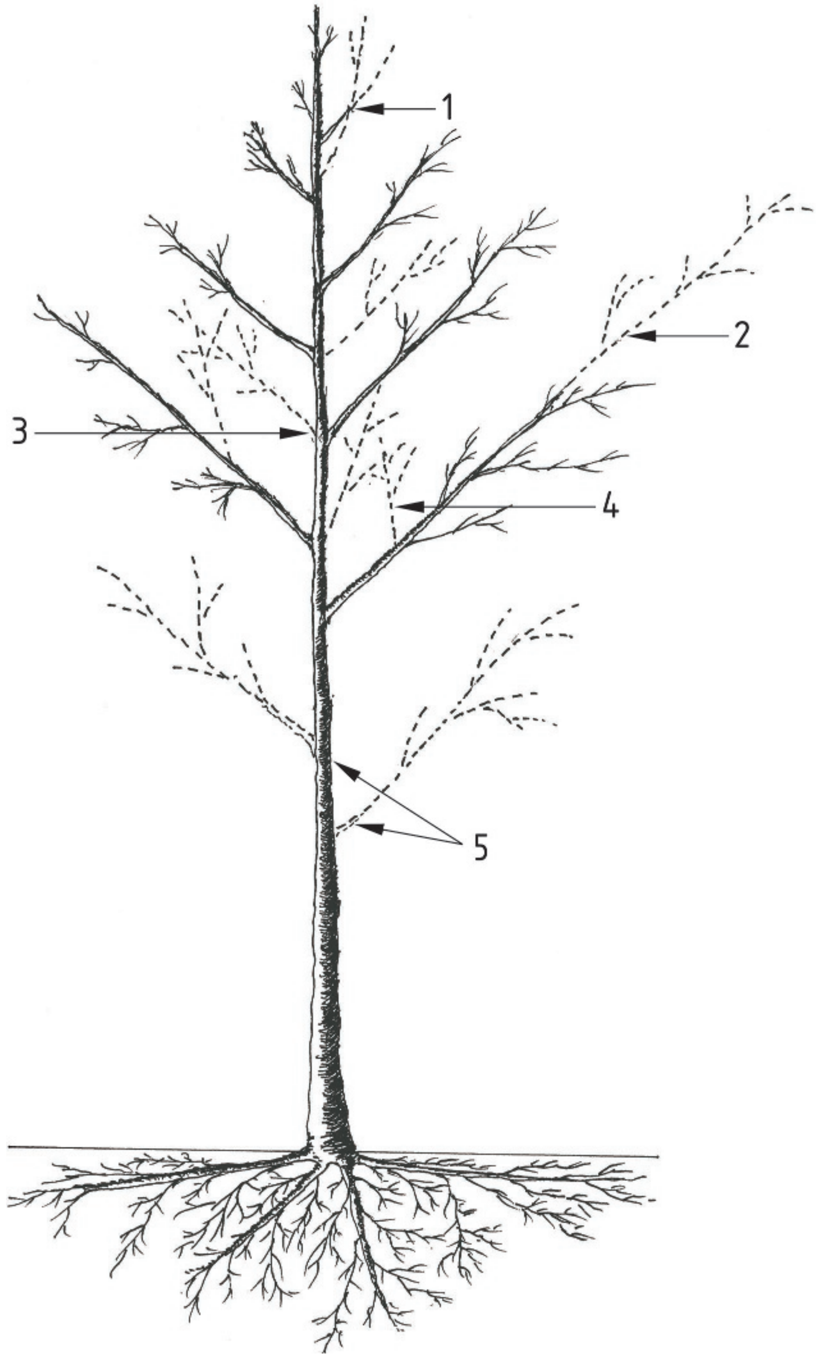
b) Aggressive branches develop low on the stem, droop and require removal, resulting in larger pruning wounds.

c) Vigorous branches develop low on the stem, grow too long and break.

Many trees develop these defects without formative pruning. All of these problems can result in physiological stresses and can shorten tree life and place people and property at risk.

Some formative pruning techniques are illustrated in Figure G.1.

Figure G.1 **Formative pruning techniques** *(1 of 2)*



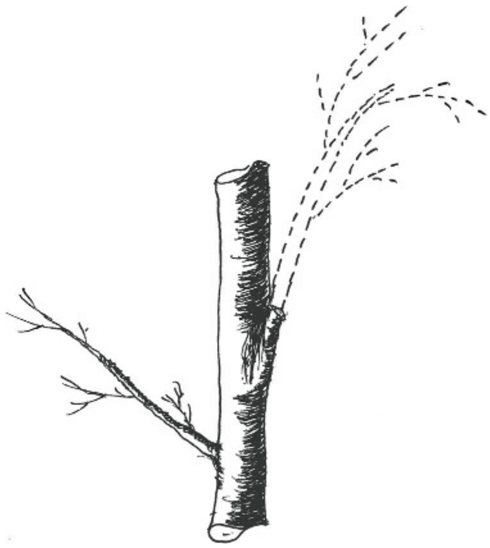
a) Overall formative pruning

Key

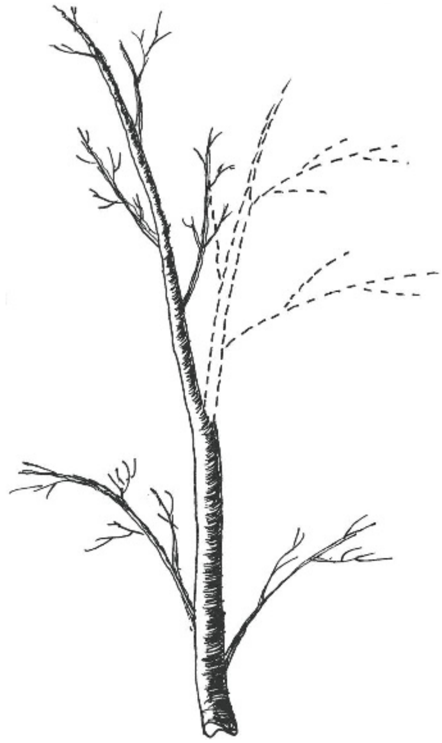
1	Co-dominant leader to be removed
2	Over-vigorous laterals to be subordinated
3	Opposite branches removed
4	Upright growth into crown to be removed
5	Lower branches from nursery kept subordinated as will not form part of final scaffold
	Likely extension growth following pruning

Figure G.1 **Formative pruning techniques** *(2 of 2)*

b) Lateral branches subordinated to retain size at no more than 50% diameter of main stem at point of attachment



c) Included branch unions or weak forks to be pruned out



d) Co-dominant leaders to be pruned out or subordinated to the main leader

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