Practical Guidance

Native woodland creation

Measures to mitigate drought conditions

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Technical Note

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Introduction

This technical note reviews the current research and practice on measures to mitigate the effects of drought conditions on woodland establishment in the UK. Much of the information is likely to be familiar and repeats what should be regarded as best practice, but some techniques, such as the use of mycorrhizal fungi, water retaining gels, drought hardening and the use of mulches may be unfamiliar or at least not in regular use.

A number of measures might be taken to aid the establishment of trees under drought conditions. These include:

- Ensuring best practice; especially in site preparation, plant handling, planting technique and weed control
- The use of bulky organic mulches to reduce evaporation loss from surface soil layers
- Use of mycorrhizal inoculum to increase drought tolerance of planting stock
- Drought hardening to produce plants physiologically adapted to drought conditions
- Greater use of direct seeding and natural regeneration to avoid transplanting 'shock'
- Water retentive gels and root dips
- Choice of provenance
- Irrigation

The issue

Climate change is leading to changing weather patterns in the UK. The generally expected future pattern is for drier hotter summers, especially in the south east of the UK, and wetter warmer winters (UK Climate impacts programme, http://www.ukcip.org.uk/essentials/climate-trends/, downloaded 18th June 2011). A report from the Met Office in 2010 predicts an increase in the frequency of severe droughts (Met Office, http://www.metoffice.gov.uk/news/releases/archive/2010/droughts-to-increase, downloaded 18th June 2011)

A drought is an extended period of dry weather with little or no rain, causing serious hydrological imbalance i.e. when evaporation and transpiration exceed precipitation. A drought in the UK used to be defined as 15 consecutive days with less than 0.25mm rain on any one day, but this definition was abandoned in the mid-80's. The current definition of an absolute drought in the UK is a period of at least 15 consecutive days on none of which is there more than 0.2 mm of rainfall (Weather online, http://www.weatheronline.co.uk/reports/wxfacts/Drought.htm, downloaded 18th June 2011)

For the purposes of establishing trees, a drought can be regarded as any extended period of dry weather which causes plant damage, in the worst case leading to death.

Soils, water and plants

Rainwater falls on soils and either runs off or infiltrates and percolates through the soil profile. Having a porous soil surface on which rainwater is held for long enough to be absorbed, increases the possibility of groundwater recharge (and reduces the possibility of erosion and pollution of water courses).

In freely draining soils water passes through the soil and that which remains is held by surface tension to soil particles. At this point the soil is said to be at field capacity (FC). As water evaporates from the soil or is taken up by plants and lost by evapotranspiration, a point is reached where no further water can absorbed by plants and they begin to wilt.

The available water capacity (AWC) of a soil is the amount between FC and permanent wilting point (PWP), the point at which plants wilt and cannot recover. AWC varies for different soil types and according to factors such as particle size, soil structure and organic matter content (OMC). Well structured soils with high OMC have, all else being equal, a greater AWC and thus plants reach PWP later than on poorly structured low OMC soils; well structured loams and clay soils will have a higher AWC than sandy soils.

Trees absorb water through their roots, and in particular through fine root hairs. Their ability to absorb water is enhanced by association with soil mycorrhizal fungi (which also confers other benefits such as disease resistance and ability to absorb nutrients). They lose water as a result of evapotranspiration through leaf stomata and also through lenticels on stems and through the cells on the leaf surface.

In conditions of drought plants can respond by increasing water uptake, through channelling more resources into root growth and thus increasing the root to shoot ratio. They can also reduce water loss by closing stomata (although some water loss continues through lenticels and leaf surface cells) and in some cases by shedding leaves.

Mitigating the impacts of drought on newly planted trees requires maximising the soil's AWC water and having plants with the best opportunity to respond to changing conditions.

Using planting best practice

Using planting best practice is intended to establish trees with the minimum of 'check' to growth. In general this means ensuring that plants are able to anchor themselves and absorb the water and nutrients necessary for growth. Best practice should ensure a good root system, with as little damage as possible. This should be regarded as the minimum necessary to ensure trees are able to withstand summer droughts. It is worth reiterating some of the basics elements of best practice and their impact on drought tolerance.

Time of planting

As far as possible planting in early autumn, as soon as plants are available from nurseries, is preferable for most lowland sites. Tree roots continue to grow slowly over the winter months (particularly in years with warm winters) and will arrive in the spring in a better position to extract moisture from the soil as buds burst and the new season growth begins. Spring planted trees will be attempting to put on new root growth at the same time that new leaf growth has started.

It may also be the case that spring planted bare-root trees spend a longer time lifted from the ground and held in cold storage on the nursery than those which are delivered in the autumn.

Whilst nurseries clearly take every measure to reduce harm to trees, the possibilities of desiccation may be greater.

Species/provenance choice

Whilst the use of non-native broadleaved species has been suggested as an adaptive measure for UK forestry, this note looks only at native tree species. Nonetheless species selection is an important consideration in mitigating the possible impact of drought. Beech in particular has been identified as susceptible to drought, both during establishment and subsequently. Increased frequency of drought in those parts of the country generally regarded as the native range of beech may mean other species, such as penduculate oak *Quercus petraea*, are better suited.

Broadmeadow et al (2005) investigated the use of climate matching for provenance selection for ash and beech, under future climate change scenarios. This identifies summer drought as the main constraint to species selection and timber production. In particular it highlights Beech as a species which, even if successfully established, may have problems from drought in the coming decades in southern Britain.

The use of provenances from further south in Europe may offer the possibility of trees better able to grow under future climate scenarios, but runs the risk of poor establishment due to poor adaptation to current climatic conditions (e.g. frost damage as a result of early flushing).

Choice of planting stock

In general smaller planting stock with a higher ratio of root to shoot, improves survival. Ideally, bare rooted plants should be no greater than 30/45 cm and where possible should be pruned to increase the root/shoot ratio (species such as willow, hawthorn and other shrubs).

Cell grown plants reduce root disturbance and offer an extended planting season, in particular allowing earlier planting and the potential for more root growth over the relatively wet period of the year from early autumn to early spring. Careful plant handling and ensuring cells do not dry out is essential if the benefits of using cell grown stock are to be realised.

Plant handling

Whether plants are bare-rooted or cell grown careful plant handling is critical to subsequent survival rates (Forest Research 2002). Making certain plants are kept in co-extruded bags, not thrown around or crushed, with the roots prevented from drying out, ensures that roots suffer as little damage as possible and are able to establish quickly and exploit available water.

Cultivation and method of planting

Wet winters may exacerbate summer droughts when waterlogged soils lead to root development being confined to the upper layers of the soil profile. Sub-soiling and other cultivation to break 'plough pans' to avoid water-logging of the upper soil profile and aid root development, will make trees better able to deal with summer droughts.

It is suggested that the use of a planting machine or 'distance scribe' can initiate the development of cracks particularly in clay soils. In a dry summer, planting stock can become suspended in an open fissure and subsequently die of desiccation. Cracking can also be initiated where there is compaction, such as tractor wheel lines, which may then develop into fissures (Eric Porter, personal comment).

On heavy soils marking planting positions using herbicide can reduce the incidence of cracking on planting lines. It is suggested that where it is necessary to use a scribe or subsoil tine then planting should be done between the subsoil lines. The Forestry Commission also suggests cultivation of lowland clays as a way of avoiding the risk of tree planting notches opening up in summer droughts. Cultivation should be undertaken in the autumn when clay soils are still friable (Willoughby and Moffat, 1996).

Although cultivation of lowland soils can increase survival rates as compared to unprepared grassland, the negative impact of increased weed growth may be considered to outweigh the benefits.

When planting into uncultivated soil, plants should not be slit planted. Use of an 'L', 'T', or 'V' notches increases the opportunity for root development (Scottish Agricultural College, 2007). Pit planting improves further the development of roots and reduces the possibility of planting slits opening is dry summers; however it is more costly than other methods of planting.

Weed control

Good weed control to maintain a weed free spot or strip around trees is a key to successful establishment. This is largely due to reduction of competition for water (Sellers, 2006). Mechanical removal of weeds (hoeing) will only be applicable on very small schemes and is labour intensive. Application of a suitable herbicide or use of a mulch to suppress weed growth is more practical options for most planting schemes.

Mulching

Mulches can take the form of;

- mulching mats or sheets of black polythene or woven synthetic fabric,
- hessian, coir or other natural materials
- bulky organic materials such as mushroom compost or straw

In addition to contributing to reduction in water stress through the control of weeds, mulches encourage root development in the upper layers of soil, thus increasing the capacity of plants to make use of available water. Bulky organic mulches may also offer additional water retention through an increase in soil OMC.

As soils dry there is no substantial movement of water between the lower layers of the soil horizon and the surface layers and so the impact of mulches is limited to the surface soil layer. However it is suggested that bulky organic mulches can reduce evaporation from the soil surface by 70% (University of New Hampshire, 2002), and may result in a water saving equivalent to around 0.75 inches of rainfall. This may be a critical amount in a dry summer.

Bulky organic mulches have the additional benefit of increasing water infiltration as compared to bare soils, particularly following periods of drought or during periods of high rainfall intensity. They may also increase the soil's AWC.

Trials in Kent on mulching of top fruit have used composted waste alongside straw mulch in the early establishment of plums (WRAP 2006) with similar trials during the establishment of apple trees (WRAP 2006a). The coarse mulch was applied in bands along rows using a side discharge spreader at a rate of around 4 tonnes per 100 metres row. The cost was said to be comparable with the use of straw (although it should be remembered that this is an orchard situation with continual bands of mulch). In both trials the compost improved water conservation and reduced water stress, and was more effective in weed suppression that straw.

Mulching has been trialed at Victory Wood in Kent as part of the objective to reduce pesticide use; this included the use of "Hybrid Jute" mulch mats (2005/6 planting season), and an area of straw mulch (about 1000 tree positions) using two wads or slices of approximately 6-7" taken from the bale and placed either side of the tree.

Although not a replicated trial, the observations following the 2006 summer drought suggest that even where mats were used there were losses of around 40%, but with better survival rates where straw was used; the straw mulch appeared to retained moisture around the plants, whereas under the mats the soil appeared dry (Clive Stewart, personal comment).

During the 2006/7 planting season all new planting at Victory wood was straw mulched. Despite a dry spring and clay soil cracking open, survival rates of 95% look likely; however, the summer was exceptionally wet. Straw mulches have proved cost effective and relatively easy to use.

Mulches appear to offer considerable benefits to woodland establishment.

Mycorrhizal fungi

Most plants form a root association with mycorrhizal fungi. Tree species associate with both ectomycorrhizae, EM, (Scots pine, birch, oak, hazel), and endomycorrhizae or arbuscular mycorrhizae, AM (ash, rowan, gean, aspen, elder). Plants with a healthy mycorrhizal association are better able to stand drought and heat stresses and may also get additional protection from pathogenic fungi (Ardle 2003). In addition to increasing absorption, mycorrhizal hyphae reach further into the soil than roots.

Most trees arriving from a nursery have poor mycorrhizal associations and such fungi are also likely to be lacking from most woodland creation sites and clearfell woodland sites which have been left for more than a year. Although trees will form mycorrhizal associations within a few years through airborne spores, this misses the critical establishment phase of the tree and early survival in the case of low summer rainfall.

Kent County Council used a mycorrhizal inoculum on a mixed broadleaved planting site on ex-agricultural land. Mortality on the untreated control area was 30% compared to 1% in the treated area A trial by Christchurch College Canterbury at Bettshanger Colliery showed that inoculated birch plants had a mortality rate of 3% compared with 60% for untreated plants.

Measurements in the eastern United States of xylem pressure potential and soil water potential in *Betula lenta* inoculated with ectomycorrhizae showed enhanced water uptake during two periods of simulated drought and in the subsequent recovery periods. Trials in semi-arid areas of Kenya showed significant increase in tree survival with the use of mycorrhizal inoculation (Wilson et al 1991).

Tree plant roots can be dipped in a mycorrhizal inoculum at a cost of around 5p per plant. Given the potential reduction in plant mortality, reduced beating-up rates, reduced aftercare period etc., this appears to be a treatment worthy of consideration.

Drought Hardening

When subjected to periods of drought, plants undergo physiological changes as outlined above. In particular they increase the root to shoot ratio and reduce relative leaf size. Drought Hardening is the use of preconditioning to make plants better adapted to and more tolerant of drought following planting. Such techniques have been used with success in drier areas of the world (Guarnasceli *et al* 2006, Sachs 1993).

In the UK many nurseries use field irrigation. This is likely to have the opposite effect of drought hardening, i.e. reduce the root to shoot ratio and make plants more susceptible to drought conditions during early establishment. In may be that, in discussion with plant nurseries, omitting irrigation in the year prior to planting could be trialled to see if it increases plant survival.

Water harvesting

In the drier states of the USA a firm soil 'lip' of 1-2 m diameter is formed around the base of newly planted trees to contain water and make the most of rainfall. Similar techniques, including bunding and cultivation across the contour, are used in other semi-arid areas to arrest the movement of runoff water and increase the opportunity for infiltration.

Whilst the use of water retaining micro-catchments around each tree is likely to be too labour intensive for most woodland creation sites, anything which reduces runoff and enhances infiltration, will increase water recharge to the soil. This includes vegetation between planting stations, and the use of mulches around planted trees.

Use of water-retaining polymers

Although the use of water retaining polymers is recommended by a number of local authorities and water companies as part of the measures gardeners can take to reduce water use, there appears to be little research evidence to support its use at a filed scale; most current use of polymers is as an additive to compost for container grown plants.

The water retaining polymer generally used is sodium polyacrylate. The potential benefits of using water retentive polymers at planting has been demonstrated in laboratory tests and container trials carried out by the Forestry Commission and Liverpool University. However, it was concluded that polymers were unlikely to benefit newly planted trees in terms of survival during long periods of drought (Hodge 1991).

Trials in Kenya which used by mycorrhizal inoculum and water retaining polymers found increased tree survival with the use of inoculum, but detrimental effects as a result of the use of polymers (Wilson *et al* 1991). However, their use in Sudan with transplanted Eucalyptus seedlings led to an increase in survival (Callaghan 1989).

Overall, there is little to support the use of water retaining polymers for field use.

Anti-transpirants

Anti-transpirants work by forming an impermeable layer on the leaves of plants and blocking stomata. There is little research evidence that, at a field scale, this can increase survival during periods of drought 9Dewayne and Burbage 1986).

Irrigation

Whilst, in theory, it would be possible to irrigate new planting sites, there are practical and environmental reasons why this might not be regarded as acceptable. Obtaining abstraction licences for field irrigation together with the cost of equipment and water, and the need to attend and manage irrigation equipment, would add substantially to the costs of site establishment.

Water bowsers can be used to apply water individually to trees, but the cost of use is likely to be prohibitive on all but small schemes. In addition watering plants prevents them from making the physiological adaptations which would promote subsequent drought tolerance and thus may be counter-productive.

Furthermore it would be difficult to justify the use of scarce water resources during periods of drought, and might expose us to reputational risk.

Use of natural regeneration and direct seeding

The issues which arise in considering natural regeneration and direct seeding extend beyond drought tolerance and include determination of species mix, weed control, time to establishment, and expectations of funding partners and local people.

In situations where either of these techniques is acceptable or desirable, it might be expected that young trees will be physiologically better adapted to withstand drought during the initial years, as the root/shoot ratio and other adaptations will develop *in situ*. However against this might be difficulty in ensuring weed control, which is likely to be vigorous on lowland ex-agricultural soils. Protecting (using tree shelters) and weeding or mulching, selected early regeneration might be one way to ensure weed competition is controlled and sufficient stocking can be achieved.

As with tree planting, direct seeding should ideally be undertaken in the between October and the end of December, as the seed will germinate earlier and is more likely to be tolerant of spring drought (Willoughby *et al* 2004).

Conclusion

Based on the evidence the following are suggested;

1. **Reinforce and monitor best practice** – failure to implement best practice in terms of plant handling, planting and aftercare will negate other measures. Existing best practice should ensure that tree roots suffer as little damage as possible and that plants are not subject to heat stress or drying out during handling or planting. Greater emphasis might be placed on planting before the end of December (particularly in the lowlands).
2. **Use of mulches** – consideration should be given to an increase in the use of mulches for weed control given the additional benefits of water retention.
3. **Mycorrhizal fungi** – there appears to be evidence that inoculation with mycorrhizal fungi can increase transplant survival. Current inoculum for UK use is based on lowland conditions but may be transferable to upland planting.
4. **Drought hardening** – preconditioning plants in the year before transplanting may aid survival.
5. **Water harvesting** – the use of micro-catchments around individual trees may be too expensive on larger planting sites. However measures to reduce runoff and increase infiltration (cultivation across the contour, establishment of inter-tree vegetation and use of mulches, will increase the water supply to plants.
6. **Water-retaining polymers and Antitranspirants** – there is little evidence that these can aid establishment at a field scale, and so their use is not recommended.
7. **Irrigation** – the use of field irrigation and water bowsers is likely to be costly and controversial in times of water shortage. In addition it may reduce the adaptation of plants to subsequent dry periods.
8. **Natural regeneration and direct seeding** – all else being equal plants established from seed are likely to be better adapted to drought than transplanted trees. Other factors need to be considered in determining whether to use these methods.

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