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# GROWING EUCALYPTUS IN THE UK: ADAPTATION STRATEGIES AND BIOMASS POTENTIAL

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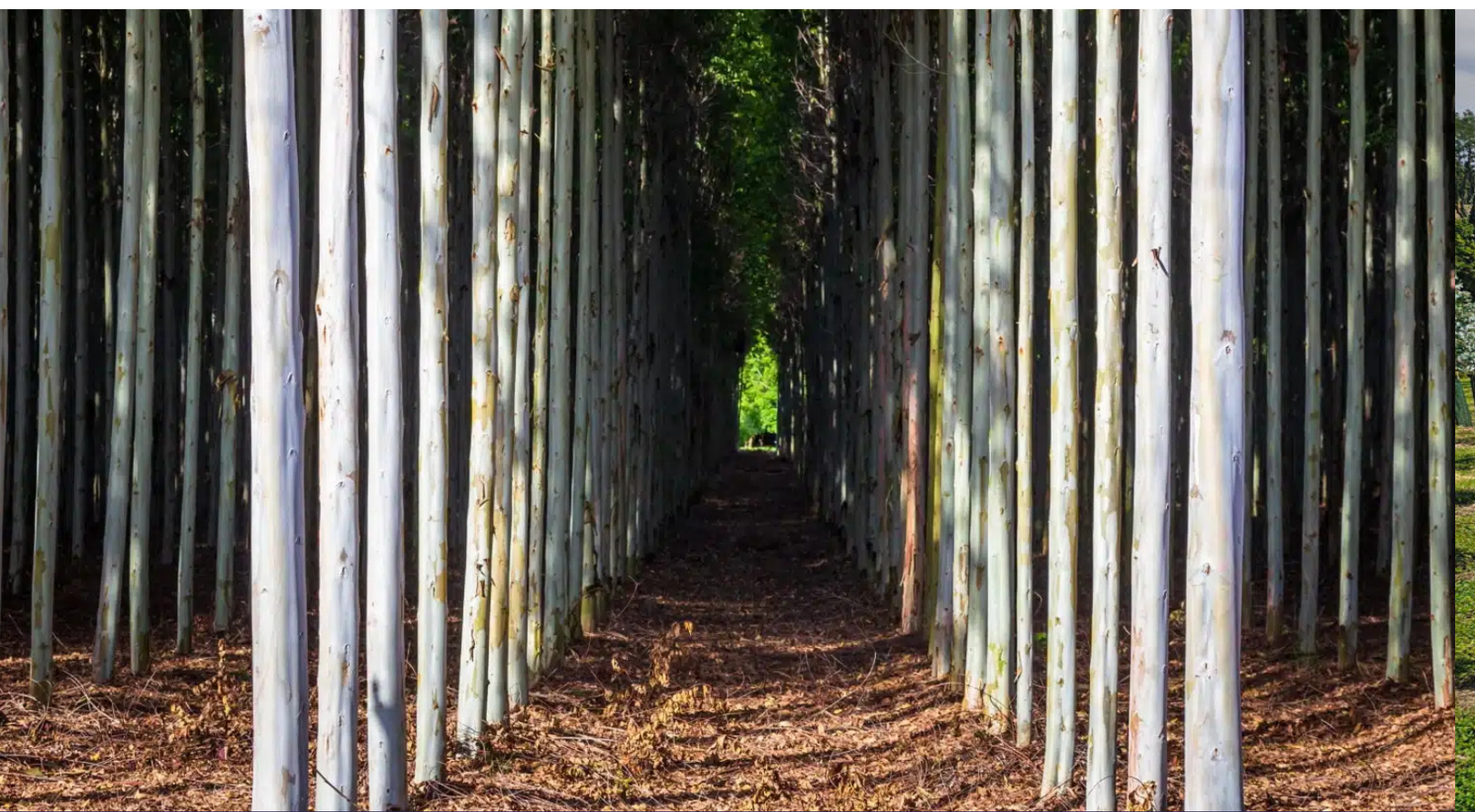
## Take Home Messages

The success of Eucalyptus cultivation in temperate climates like the UK will be most influenced by

- Careful site selection (avoiding frost-prone areas and considering local climatic conditions).
- Choosing suitable (cold tolerant) varieties.
- Best silvicultural practice.
- Climate Change Impact: Farmers and growers should stay informed about climate forecasts and consider the potential challenges and benefits associated with climate change in their cultivation practices.



## Eucalyptus production in the UK

Eucalyptus is an evergreen tree species originating from Australia. It has been identified as having great potential[1] for short rotation forestry (SRF)[2] or coppicing (SRC) in the UK due to its fast growth rate and high biomass yield, which can exceed that of native UK species. When planted in favourable locations the growth rate can be 2–3 m per year, with harvesting possible from years 4–6 onward.

## Production in the UK

Eucalyptus has adapted to grow under a wide range of climates and challenging environmental conditions. As with the majority of trees native to Australia, eucalypts are evergreen, meaning that they can grow at any time of the year as conditions permit. This contrasts with deciduous species, which lose leaves to lie dormant[3] during the colder winter months.

It is therefore essential that suitable species are selected for UK growing conditions.

This article explains cold adaptation in Eucalyptus and shows how understanding the underpinning mechanisms can help growers decide where to plant Eucalyptus and how best to manage it.

Growers in the UK have experienced tree death during extreme cold snaps in the UK. Research carried out to explore frost damage in Eucalyptus in Cumbria[4] suggested that there is a combination of environmental factors[5] that affect Eucalyptus including;

- Cell damage by frosting.
- Reduction in photosynthesis ability – photoinhibition.
- Dehydration and decreased water uptake by roots.

## Cold temperature adaptation in Eucalyptus

### Dormancy

Dormancy in woody plants[6] is a period of a non-growing state to withstand low temperatures. There are two main types of dormancies expressed in trees of temperate climates. These forms are endodormancy and ecodormancy.

- Endodormancy[7] is an internal physiological process crucial for the survival of deciduous plants by inhibiting growth. This includes leaf fall and therefore a halt in photosynthesis and growth above ground.
- Ecodormancy[7] occurs during abiotic (external) stress periods, such as cold temperatures or drought.

Eucalyptus trees are not thought to have adopted the endodormancy mechanism[8] but do exhibit ecodormancy. As they are evergreen, photosynthesis, transpiration and growth still take place during colder months as long as there is adequate light levels and available water. This will contribute to the elevated growth rates when compared to deciduous trees.

### Ecodormancy - cold acclimatisation

The Eucalyptus species use a range of mechanisms to withstand periods of abiotic (environmental) stresses. One such adaptation is cold acclimatisation[9], often called hardening. Hardening is a series of processes[10] that happen when the trees are subject to abiotic stresses, such as a reduction in temperature or photoperiod. These processes cause the tree to produce antifreeze proteins and accumulate soluble sugars that inhibit ice crystal development, helping to stabilise cells. In Eucalyptus, the variety will determine the type and onset of hardening initiation.

A study on cold stress responses[11] reported a range in time for the hardening response to

take place. After progressive drops in night-time temperatures to 4°C, these physiological changes were triggered from as early as 10 days in some varieties and up to 7 weeks in others.

Lack of cold acclimatisation can result in frost cracks and bark loss (Fig 2) caused by the freezing , expanding, and rupturing of cells involved in nutrient and water transport. The subsequent disruption of water and nutrient flow causes dehydration, nutrient depletion, and possible death to the tree. It should be noted that stress-induced bark loss is different to that of bark shedding[12], which is a normal part of Eucalyptus growth.

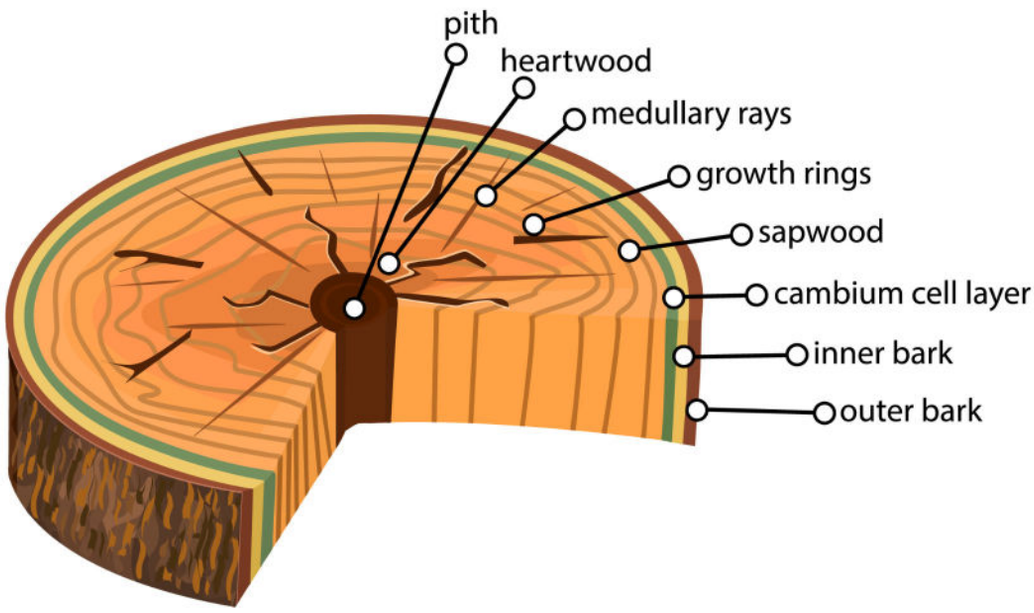



Fig 1. A generalised cross section of a woody plant structure

Fig 2. White arrows indicating frost splits in 3-4 year old Eucalyptus near Llangeitho, West Wales (2023)

## Tree variety and establishment

In a study, carried out in Cumbria[4], exploring Eucalyptus death due to cold weather, it was found that shorter trees, of less than 131 cm, suffered significantly more frost damage to the foliage and stems than trees of heights between 131 and 175 cm.

The varieties studied were, *E. gunnii* and *E. nitens*. The *E. gunnii*, noted for being frost hardy had a survival rate of 35%, whereas *E. nitens*, considered to have one of the lowest frost tolerances, had less than 2% survival rate. These assessments were conducted in the following spring when the trees had had the opportunity to regenerate from the epicormic buds at the base of the trees.

The larger trees had greater sap reserves, and their sensitive growing tips were above the height of early radiation (ground frosts). In addition, the larger trees are better able to carry out the hardening process to aid frost protection.

The study concluded that, although the cold temperatures were regarded as a once in a 30-year experience, the *E. gunnii* were better adapted than *E. nitens* for biomass production in the UK.

To reduce damage to newly planted trees, therefore, best practice recommends ensuring seedlings are given the greatest opportunity for rapid and effective establishment. This includes weed control and adequate nutrition before the onset of winter.

## Photoinhibition

Eucalyptus, carrying leaves through the winter, will continue to photosynthesise. When under stress, for example when the sunlight is strong but the temperatures are low and water is restricted, the tree is able to release a substance called anthocyanin[13]. This is a pigment which is thought to act to reduce the light absorption to chlorophyll. This is known as photoinhibition[14] and will screen the chlorophyll, helping to reduce the rate of photosynthesis and transpiration, therefore reducing leaf damage during these stressful periods. .

If hardening doesn't take place, eucalypts can drop their leaves, called photobleaching[15], as a mechanism to reduce tree damage. If light levels are above that can be used effectively, then the formation of chemicals that will oxidise proteins and membranes cause cell bleaching and death. The excess light, reduced temperatures and dehydration disrupt the production of glucose, reducing the plant's ability to maintain cell function and repair.

These cells are more likely to succumb to frost damage and die.

The timely release of anthocyanins can help to shield chloroplast from excess sunlight and help preserve leaf tissue.

It is suggested that recovery from this photoinhibition[4] is possible especially where trees have gone through a hardening process and that the low temperatures and dehydration do not persist.

## Roots

The impact of frozen ground on root activity should also be considered. The function of the root[16], in addition to anchoring, vegetative reproduction and food storage, is to absorb water and minerals from the ground

The fine roots move water across the membranes using osmosis, however, the uptake of minerals is achieved by active transport[17]. This active transport requires an energy source to take place. If translocation is restricted by cold weather, root respiration rates[18] will increase and utilise non-structural carbohydrates such as sugars. Prolonged periods of this will deplete energy storage capacity from roots.

During periods of below ground frost, it is mainly the fine root hairs[19] that are killed or damaged. These fine roots will only tolerate moderate freezing[5] down to - 5°C. It is known that, as in severe summer droughts, water stress by freezing can have long term effects on future growth[20] potential.

Wet soils are known to take longer[21] to warm up during the spring and stay warm during the winter. Increasing soil temperature is linked with increasing soil microbiological activity, which is key for healthy plant growth. Wet and waterlogged soils also have less available oxygen required for respiration by the roots.

Figure 3. Root death and desiccation at a site in Llangeitho West Wales (2023)

Studies carried out in Eucalyptus native regions[22] found that water logged soils reduced the tree's ability to become hardened to cold weather. Such conditions will clearly hamper root function and future growth of the tree. Figure 3 illustrates the root death and desiccation suspected of contributing to the death of the tree.

Adapting to these conditions, the root system of Eucalyptus have been shown to prepare in a similar method to that of above ground structures. They increase the concentrations of sugars in cell membrane as a form of antifreeze protection.

## Mulching for temperature and moisture regulation

The application of a layer of mulch[23] – material spread around or over plant – has been shown to regulate moisture levels, protect the soil surface from extremes of temperature and help to control weed cover whilst establishing plants. Mulching can be considered an important element of sustainable production[24], and there are range of organic and inorganic mulches[23] to be considered.

## Regeneration

Adventitious or epicormic shoots are triggered in response to serious abiotic stress[25] damage, such as frost, fire or grazing. Foliage at the base of dead or affected trees can be seen to develop. These are adventitious shoots that stem from the epicormic buds[26]. These buds, found at the base of the tree, are triggered in response to abiotic stress. Epicormic buds will establish if they have access to a store of carbohydrates and a supply of water and nutrients from an established root system. This is a resilience trait[27] response that allows the restoration of new shoots and photosynthetic capacity in the case of serious damage to the foliage and trunk.

Figure 4. Epicormic stump regrowth at Llangeitho West Wales 2023 )

Although much of the research into

this type of regeneration is after fires, frost and insect damage are also forms of stress[26]. Figure 4 shows these shoots with juvenile leaves forming at the base of a frost affected Eucalyptus tree.

An effective silvicultural practice would be to cut affected trees down to the stump (stumping) as practiced in coppicing. If the stump has the cambial layer intact (Fig 1), it will allow the unaffected root system to respond with stem adventitious shoot development. Studies in Tasmania and China[28] showed that even decapitation (or coppicing) of young damaged trees allowed good regrowth, and didn't affect future production. It did, however, lead to multiple stem regrowth, so selecting a suitable leader (main) stem was important.

This ability is also an advantage after harvest management such as coppicing or short rotation forestry felling. The tree will continue to produce biomass for future harvests[29] stemming from an established root base, therefore negating the need for replanting.

## Considerations for optimising Eucalyptus production in the UK

### Improved site selection

There are a number of useful tools to aid the site selection for Eucalyptus plantations.

Being able to avoid areas such as cold pools or frost pockets or hollows[30] where the likelihood of frost is greater would be beneficial.

The map in Figure 5, for example was compiled on behalf of National Resources Wales (NRW) to map the high exposure areas with the aim of helping to determine crop suitability. The map indicates areas within Wales[31] where frost pockets are likely.

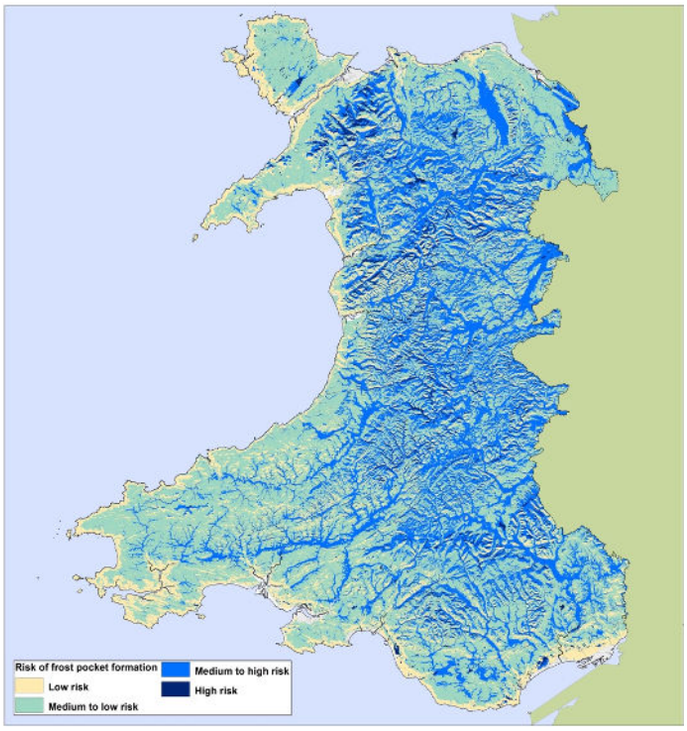



Figure 5. Map showing likely formation of frost pockets (Environment systems)

The Forest Research also have a service called Ecological Site Classification

(ESC)[32]. This is a web-based decision support system to help forest managers and planners select tree species that are ecologically suited to particular sites across the UK. The Forest Research Council suggest selecting a suitable species rather trying to modify the site.

## Varietal Selection

Eucalyptus species and provenance must be selected and matched appropriately on a site-by-site basis. Overcoming the challenges of growing Eucalyptus in the UK requires the need for careful site selection, water availability, likelihood of unseasonal frosts, soil type, light levels, agronomy, silviculture, and variety choice considering local climatic conditions. Suggested recommended varieties for the various regions of the UK can be found at Biomass Connect[33] or at Envirocrops[34].

## Regulatory Considerations

Although Eucalyptus is not native to the UK, it is not considered invasive because our temperate climate doesn't allow natural germination. The wildlife and countryside Act 1981[35] does not allow non-native species to be introduced into wild areas. However, Eucalyptus is permitted to be planted in "non-wild" areas, including agricultural, horticultural and forestry premises. It would be prudent check with the devolved government if you are required to carry out an Environmental Impact Assessment (EIA)[36].

# Conclusion

Adaptation of Eucalyptus trees to temperate climates involves understanding their responses to cold stress and implementing appropriate management practices. Land managers can enhance Eucalyptus resilience through site selection, varietal choice, and adopting strategies such as mulching and coppicing. As the climate changes, staying informed and incorporating adaptive measures will help ensure successful Eucalyptus cultivation in temperate regions like the UK.

## Endnotes/Hyperlinks

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11: https://link.springer.com/article/10.1007/s00468-022-02355-4

12: https://apps.lucidcentral.org/euclid/text/intro/learn.htm

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14: https://www.sciencedirect.com/topics/earth-and-planetary-sciences/photoinhibition

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24: https://link.springer.com/chapter/10.1007/978-981-19-6410-7_20

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27: https://besjournals.onlinelibrary.wiley.com/doi/10.1111/1365-2745.13227

28: https://www.sciencedirect.com/science/article/pii/S0378112716304418

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35: https://www.legislation.gov.uk/ukpga/1981/69

36: https://www.gov.uk/guidance/environmental-impact-assessments-for-woodland

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