New Approaches to Optimising Environments for Rooting Cuttings

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INTRODUCTION

Achieving high rates of success in rooting leafy cuttings is strongly dependent on the provision of a suitable environment. Improving existing propagation environment technology offers the prospect of bringing new plants to the market by enabling nurseries to propagate cuttings that are currently considered too difficult. There are two obstacles to such progress: the difficulty of identifying the optimum conditions for a particular plant, and the difficulty of describing that environment in a way that others can reproduce reliably in their own facilities. This paper outlines new approaches to overcoming both of these obstacles.

THE BASIC REQUIREMENTS

Detached from the root system that previously supplied it with water, the cutting's most important requirement is for protection from water stress. As the capacity for water uptake through the cut base is small, the emphasis must be on providing an aerial environment which restricts potential transpiration, i.e. the rate at which cuttings with fully open stomata would lose water (Harrison-Murray et al., 1992). Three components of the aerial environment largely determine potential transpiration: humidity, light, and leaf wetting.

Raising the humidity decreases transpiration by reducing the difference in the concentration of water vapour between air inside the leaf and that outside it. If the leaf surface is kept wet then, as the water evaporates, it absorbs energy (the latent heat of evaporation) that would otherwise be available to drive evaporation from inside the leaf (i.e., transpiration).

Light stimulates transpiration because only a small proportion of the light energy absorbed by the leaf is used for photosynthesis, the remaining energy is available to drive evaporation. One result is that transpiration continues even when the relative humidity of the air around the leaves is 100%. But light is essential for photosynthesis and most leafy cuttings must photosynthesise to obtain enough energy to survive and root. Therefore an important part of optimising the environment for cuttings is the striking of an appropriate balance between light, which stimulates transpiration, and the combination of wetting and humidity, which suppresses it.

CONTROLLED PROPAGATION ENVIRONMENTS

Much previous research, using conventional propagation facilities, has demonstrated the practical benefits of using different propagation systems such as polythene tents, mist, and fog and has elucidated the individual benefits of leaf wetting, elevated humidity and shading on the water status and rooting of cuttings (e.g., Grange and Loach, 1983; Harrison-Murray et al., 1988). However, the conditions in such facilities change constantly, making it difficult to define the environments precisely and impossible to reproduce them exactly. As a result, there is still much to be learned about the response of cuttings to their environment, particularly concerning the interactions between different factors.

To avoid these limitations, novel controlled-environment facilities were developed at HRI - East Malling. The novel facilities consist of three walk-in polythene chambers erected inside a large controlled-temperature room, with wetting and humidification provided by carefully positioned Sonicore fog nozzles and light from high pressure sodium lamps. These controlled propagation environments (CPEs) combine reproducibility with the ability to achieve the wet and humid conditions needed for cuttings.

They include a chamber known as the "gradient CPE" or G-CPE in which separate gradients of wetting and light have been established at right angles to each other, creating a matrix of 54 different combinations of light and wetting. The levels of light and wetting cover the range of daily average values likely to be encountered in shaded propagation houses in the U.K. The relative humidity is close to 100% throughout.

ENVIRONMENTAL FINGERPRINTS

With so many different environmental combinations, the numbers of cuttings that can be placed in each is usually only four. Therefore, it is necessary to look for trends in responses to the gradients rather than at the results from individual locations. Three dimensional line graphs have been found to be the most effective way of displaying these trends (see examples in Fig. 1). These 3-D graphs are referred to as "environmental fingerprints".

Figure 1 shows how a fingerprint provides an effective summary of the response of a particular plant to a range of environments and demonstrates the scale of differences between species. The fingerprint for *Cotinus coggygria* 'Royal Purple' shows that it rooted well where heavy wetting was combined with moderate to high light but failed completely at similar light levels with little or no wetting, whereas *Cryptomeria japonica* 'Elegans Compacta' showed the opposite response. However, neither subject rooted well at the lowest light levels tested, irrespective of the amount of wetting.

In work funded by U.K. growers through the Horticultural Development Council, this approach has been extended to a wide range of additional plant subjects. These studies have served to improve production of a number of troublesome subjects and to test the value of morphological characters (e.g., hairy leaves) as indicators of the environmental conditions likely to favour rooting in particular species.

RELATING RESULTS TO CONVENTIONAL FACILITIES

Responses observed in the gradient CPE have paralleled results from conventional facilities, encouraging confidence in the practical value of environmental fingerprints. For example, subjects with fingerprints similar to that for *Cotinus coggygria* can be expected to root well in a wet-fog or enclosed-mist system, whereas a simple polythene tent system would not be adequate. Further work is required to determine whether it is possible to translate more precisely the optima identified in the G-CPE to the fluctuating conditions of conventional propagation systems. The light factor is straightforward but wetting is more difficult, especially as it cannot be considered in isolation from humidity because both contribute to the suppression of transpiration.

A promising approach utilises a novel sensor developed at HRI - East Malling. This

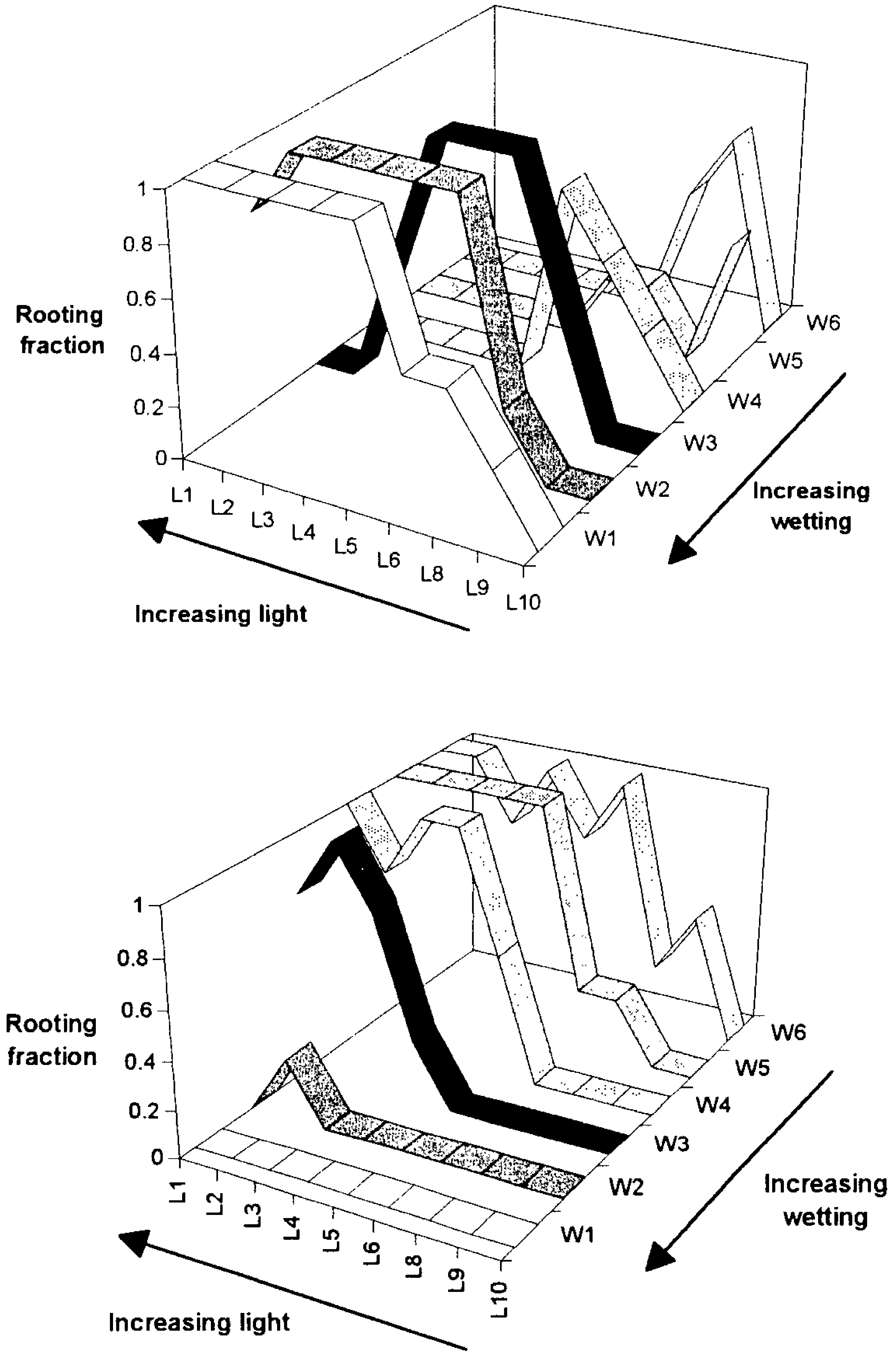

Figure 1."Environmental fingerprints" for *Cotinus coggygria* 'Royal Purple' (upper) and *Cryptomeria japonica* 'Elegans Compacta' (lower). Light levels (photosynthetic photon flux density) increased from 10 to 213 μmol m^{-2} s^{-1} between L10 and L1, while wetting increased from 0 to 400 μm h^{-1} between W6 and W1 (over the 12-h light period).

"evapo-sensor" is sensitive to the combined effects of wetting, humidity, light, temperature and wind on potential transpiration. Using this instrument, separate measurements of light would be less critical because the effect of light on transpiration would be taken into account already. Opportunities for the commercial production and marketing of this evapo-sensor are being evaluated.

PHYSIOLOGICAL STUDIES

The reproducibility of the controlled propagation environments is a great advantage for studies into the physiological processes underlying rooting responses. To date these studies have focused mainly on water relations and photosynthesis, processes intimately connected to the balance of light and moisture. Gas exchange measurements are used to monitor changes in stomatal conductance, photosynthesis, and respiration in contrasting environments, together with measurements of leaf water status and the accumulation and distribution of dry matter.

One objective of these studies is to understand why species differ so much in their tolerance of different environments. For example, when *C. coggygria* 'Royal Purple' was compared with *Weigela* 'Florida Variegata' — a subject which can tolerate conditions in all parts of the gradient CPE — we found that the main reason for weigela's wide tolerance was the high sensitivity of its stomata to leaf water deficit, probably combined with inherently faster rooting.

A second objective is to understand the involvement of the carbon balance in

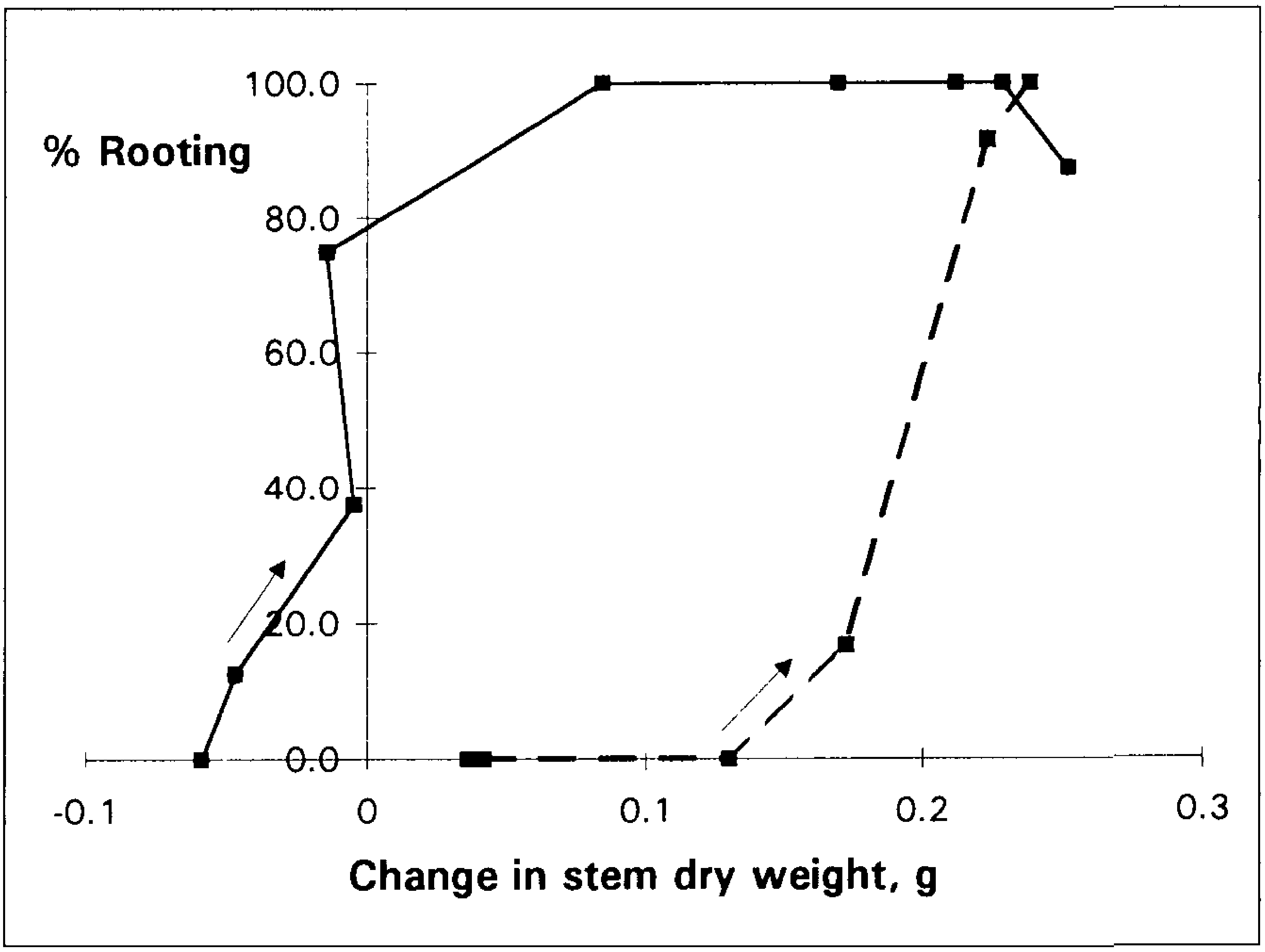

Figure 2. Two different relationships between rooting percentage and the change in stem dry weight of *Cotinus coggygria* 'Royal Purple' cuttings observed in the G-CPE. The data relate to cuttings at different light levels in the heavily wetted zone (solid line) and different wetting levels in the high light zone (broken line). Arrows indicate increasing light and wetting respectively.

rooting responses. For example, stomatal closure conserves water but it also restricts the uptake of CO_2 for photosynthesis and might thus be responsible for some of the inhibition of rooting caused by water stress. The restriction of photosynthesis could starve the cuttings of the source of carbon they need to produce roots.

For example, rooting of *C. coggygria* 'Royal Purple' declined both at the wet end of the gradient-CPE when light levels were low and at high light levels when wetting was reduced. Weight measurements indicated that the accumulation of dry matter by the cuttings was central to the response to light but not the response to water deficit. When high wetting was coupled with low light the reduction in rooting coincided with a loss in dry matter as starving plants began to draw on carbohydrate reserves just to survive. But this was not so at high light levels as wetting was reduced (Fig. 2). Even where cuttings wilted severely and stomata closed almost completely, they continued to accumulate dry matter, albeit at a much reduced rate. Similar results were obtained in experiments with *Syringa vulgaris* 'Madame Lemoine', which also showed that the response of cuttings to environment can be altered by stockplant treatments such as etiolation (Howard and Harrison-Murray, 1995).

FUTURE DEVELOPMENTS

The Gradient Controlled Propagation Environment is a flexible facility and in future could be modified readily to extend the range of conditions or to examine another factor altogether, such as base heating. Interest has also been expressed in the commercial application of the CPE concept, both for more consistent rooting of high value difficult-to-root plants and to remove a major seasonal constraint on production.

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