A Straight Line Approach to Minimising Water Stress in the Propagatlon Environment

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INTRODUCTION

The vegetative propagation of plants by leafy cuttings requires the grower to control turgidity and water loss until roots form. While the importance of maintaining turgor is recognised, even a slight water deficit which may go undetected with no visual symptoms of distress can result in considerable delay or reduction in the rooting response (Evans, 1952; Loach, 1977). Cuttings are most visibly prone to moisture stress and wilting in the first few days that follow severance from the stock plant. Understanding the underlying physiological processes influencing water requirements by cuttings can create opportunities for plant propagators to improve their cutting strike rate through changes in their methods in ways that suit their particular situation.

Water loss from cuttings and hence water stress can be influenced by three interrelated factors: (1) the vapour pressure difference between the leaf and the surrounding air; (2) the resistance to water movement through stomata, the cuticle, and the epidermis; and (3) the plant water content. Plant propagators can aim to maximise plant water content through the use of techniques that decrease water loss, by minimising the leaf to air vapour pressure gradient or by increasing the leaf resistance to water movement, and by maximising water uptake by the stem.

CUTTINGS

Pre-severance.

Water Use Efficiency of Stock Plants. Plant material that has been grown with a restricted supply of water usually produces shoots that are firmer and have a higher water-use efficiency. This could be turned to good effect if growers were to reduce the water supply to stock plants in the period prior to cutting removal. Cuttings produced in this manner should have less tendency to develop moisture-stress in the propagation environment. Sciutti and Morini (1995) demonstrated a beneficial effect where plum plantlets are exposed in vitro to reduced relative humidities. This has a direct impact on water use efficiency during hardening-off (Fig. 1a).

Influence of Time of Cutting Collection. Water stress on stock plants is normally at its lowest level when the water content of cuttings is at its highest in the pre-dawn period just prior to sunrise (Fig. 1b). While this may be the best time to collect cuttings with the highest water content it is not a very popular time with most propagators. Pragmatism usually forces a compromise with the standard practice of collecting cuttings in the early morning, preferably before they are exposed to bright sunlight.

Post-severance.

Wounding. The entry of water to the base of the cutting is dependent on the contact the stem makes with the film of water around the particles of growing medium. Most of the water is taken up by the cut surface of the stem base as the stem itself is relatively impermeable to water. Water uptake by cuttings can be promoted by wounding, the more severe the wounding the larger the area of stem with increased permeability to water (Fig. 2a).

Treatment of cutting bases with strong acid or base has been advocated to enhance root formation in some woody plants (Lee et al., 1976). Cutting treatment in this manner may alter the permeability of the stem and facilitate uptake of water and entry of growth regulators.

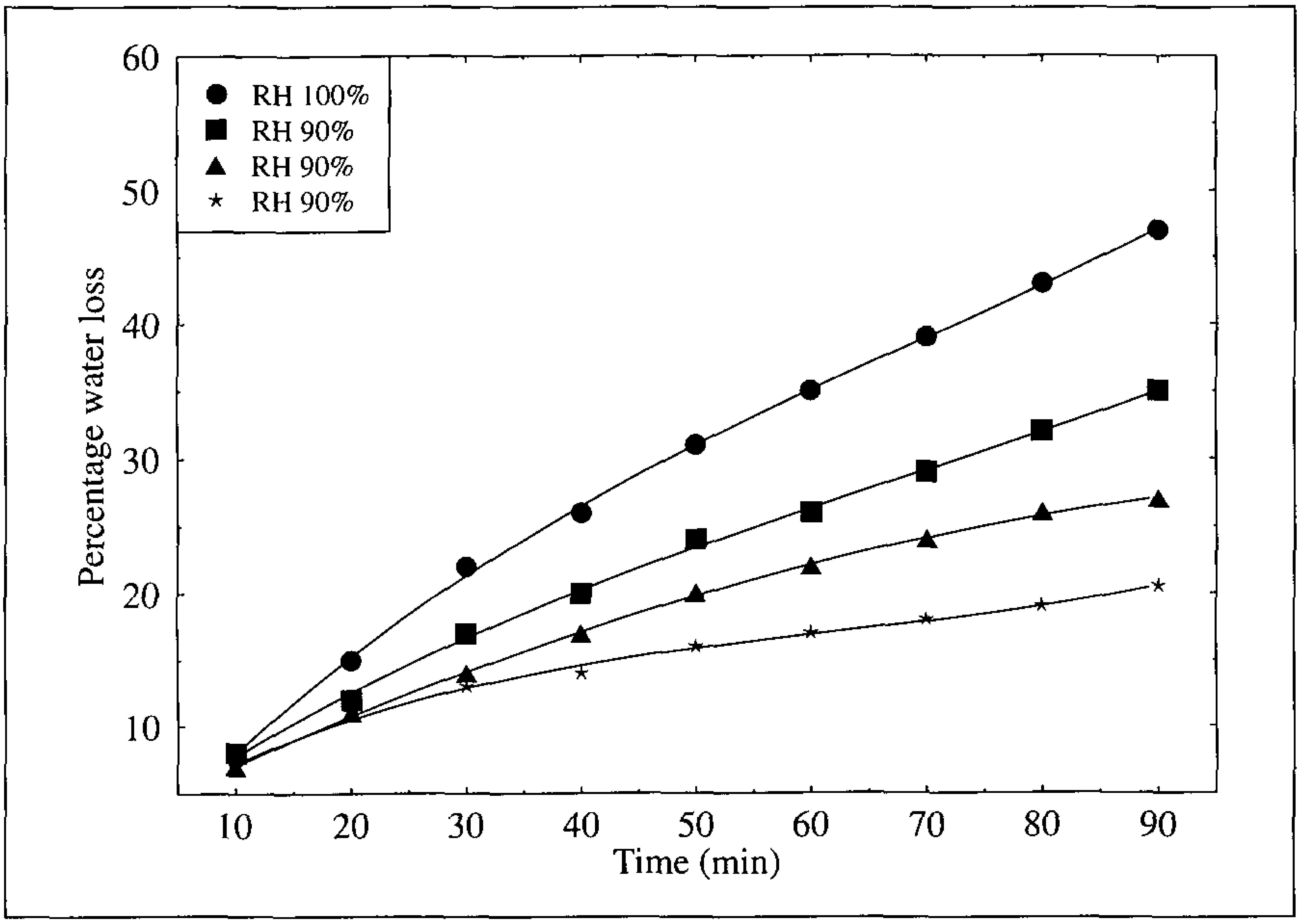

Figure 1a. Influence of relative humidity during growth on water loss during transplanting (Adapted from Sciotti and Morini, 1995).

Leaf Area. Water loss from leaves is related to their age and their size. Very young leaves have a lower diffusive resistance to water movement, which tends to increase as they become fully expanded and leaf tissues become firmer. The more hardened plant material tends to be more water-use efficient and use less water (Fig. 2b). Leaf area is often reduced on large leafy cuttings to reduce water loss where the propagation environment is unable to sustain the cuttings when severed from the stock plants. In commercial practice it is not uncommon to see leaf cutting or removal as an expedient measure to increase sticking density and reduce mutual shading. This pernicious practice should be avoided wherever possible as reduced leaf area delays root formation. Furthermore, cut leaves are more prone to disease entry and senescence, leading to leaf shedding that may spread rapidly in a moist propagation environment.

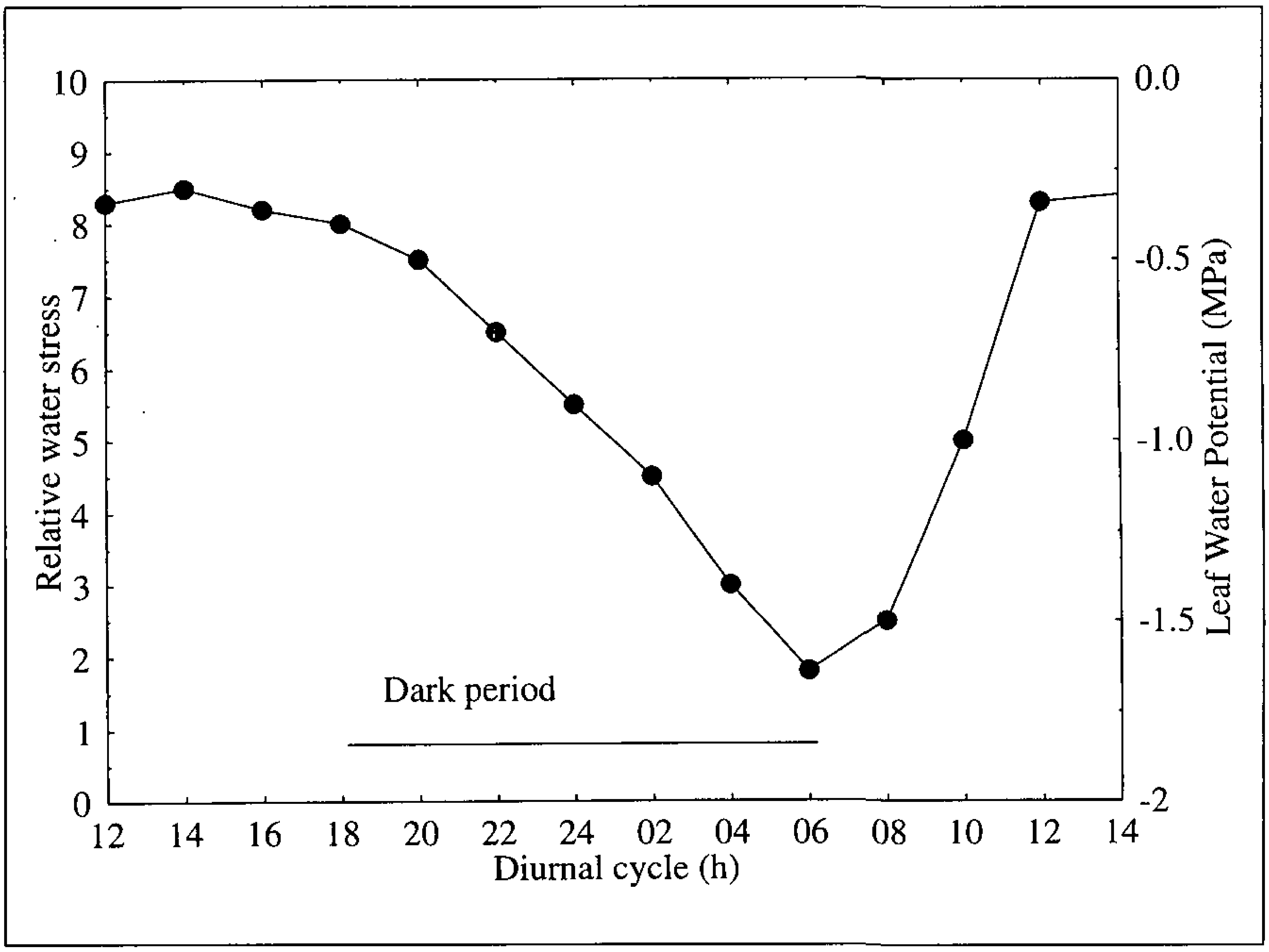

Figure 1b. Typical pattern of diurnal water stress.

PROPAGATION MEDIUM

Influence of Physical Properties of the Medium. Water and oxygen are both required in the propagation medium to promote root formation on stem cuttings. The physical properties of the medium are markedly influenced by the particle-size distribution of the growing medium components. The finer the particles in the growing medium the smaller the pores, this is reflected in higher water holding capacity at the expense of the air supply. The ideal medium is composed of a balance between fine and coarse particles that provide both water and air holding capacity, respectively. The uptake of water from propagation media is increased as the proportion of water in the media is increased in both freshly prepared and older cuttings (Fig. 3a, 3b). Many cuttings may be rooted directly in water, while this may provide a good supply of water, oxygen is frequently limited, particularly when bacteria accumulate in the water. A practical solution to this dilemma is made possible in an aeroponic propagation system, where cutting bases are bathed in a highly aerated water or nutrient spray, combining the requirement for a good supply of both water and air.

Depth of Medium. As the water content of the medium is related to the container depth, and the basal 1 to 2 cm of most propagation and growing media is saturated with severely limited gas exchange, it is prudent to follow Matkin's (1965) advice to use a container as deep as practicable. This will facilitate both drainage and aeration of media, and the base of the cuttings can be set about 3 cm from the base of the container out of the zone of saturation.

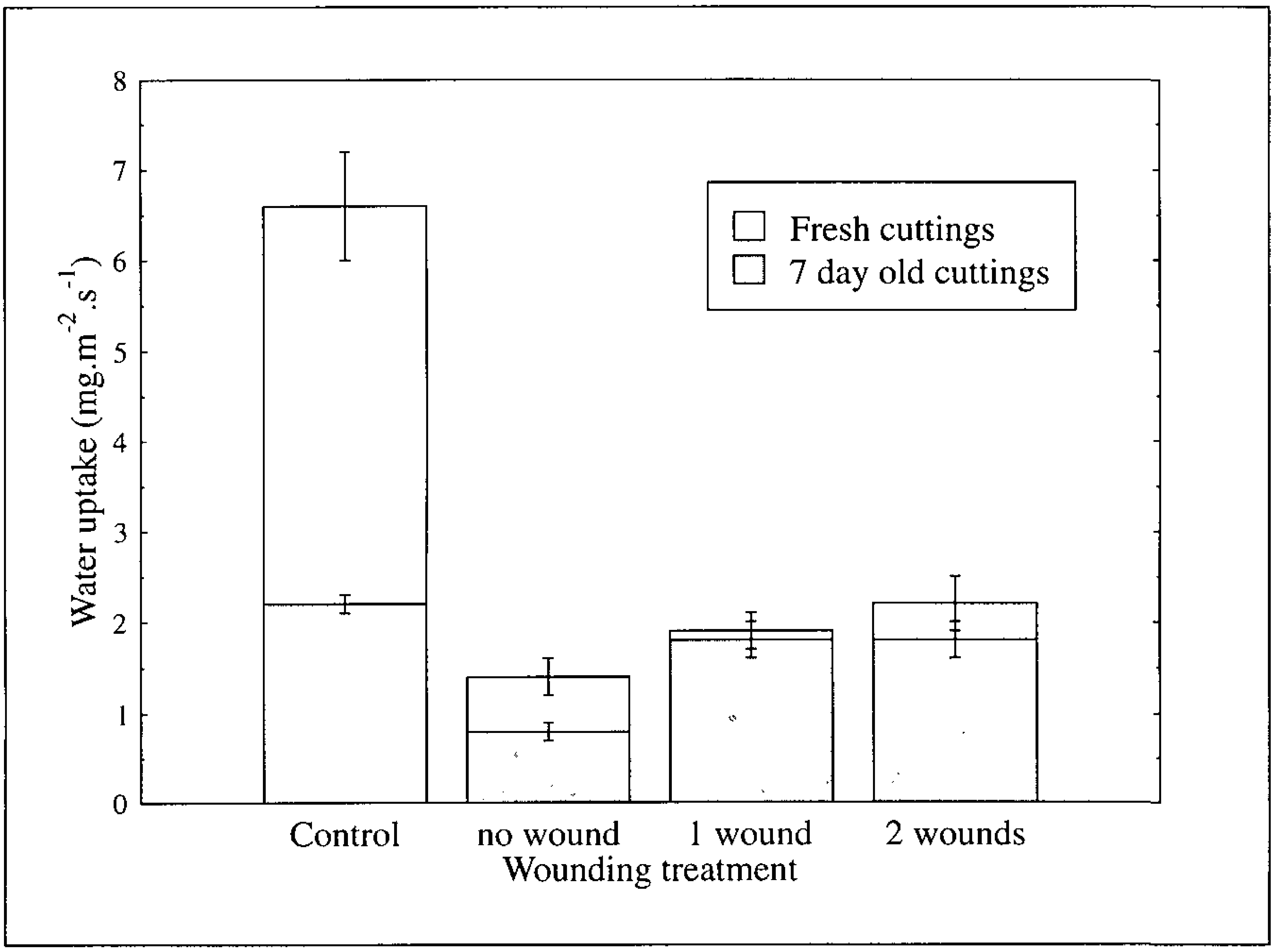

Figure 2a. Influence of wounding on cuttings on water loss in propagation medium relative to a water control (Adapted from Grange and Loach, 1983).

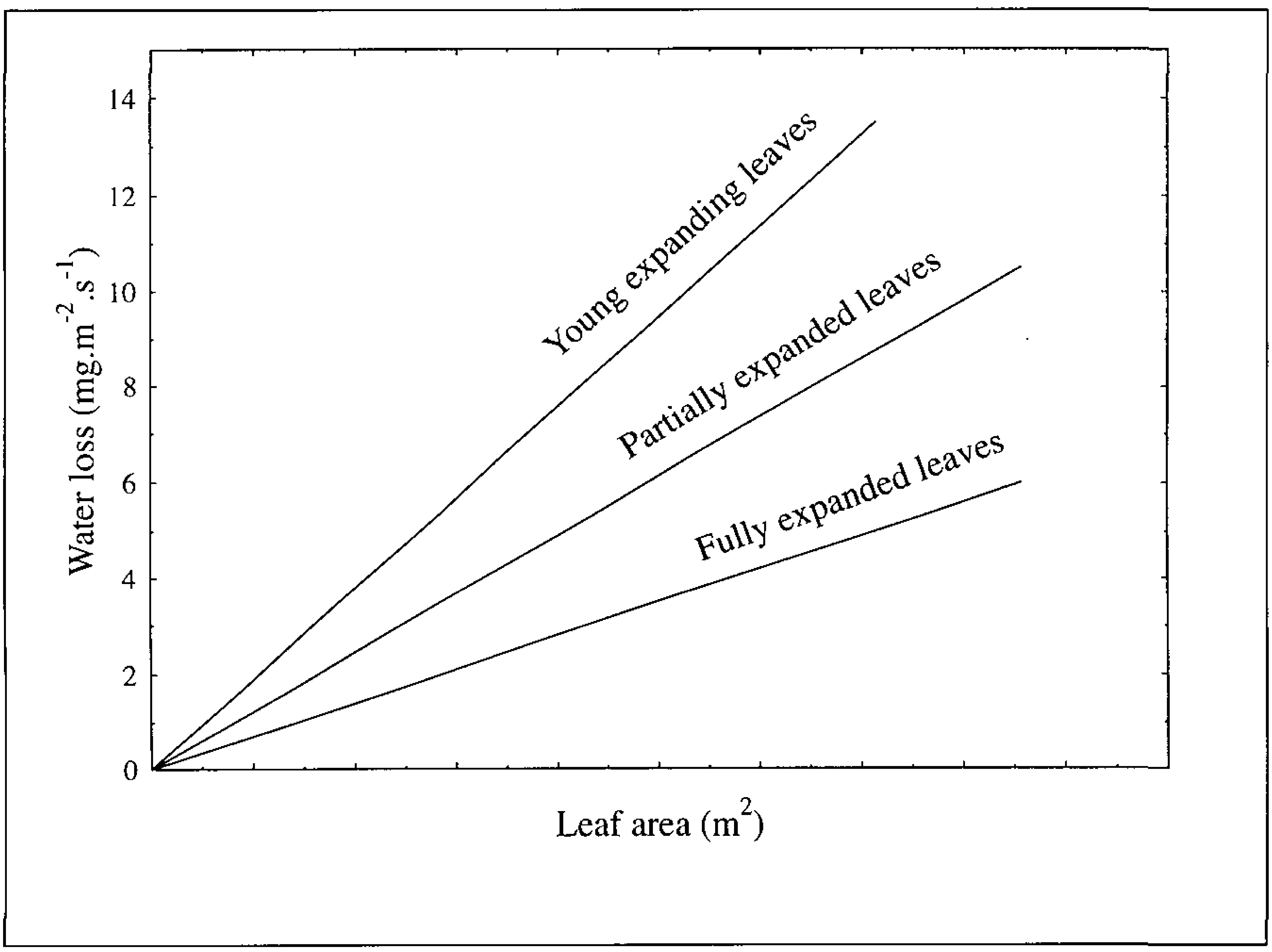

Figure 2b. Typical pattern of water loss by leaves of increasing age.

pH, Acidity and Water Transport. The acidity of the propagation medium has been known to facilitate plant propagation for a long time, and studies with cut flowers have shown that water transport in stems is enhanced by the use of acidified water with a low pH of about 4. This would explain the almost forgotten practice of adding glacial acetic acid to the propagation medium and (among other reasons relating to the physical properties) why peat has been so useful as a universal propagation medium. In many plants root formation is increased as water uptake is increased by decreased pH.

Stem Blockage Physical / Chemical / Microbial. Blockage of the stem appears to be a normal plant response (refer to Table 1) that may be accelerated by using propagation media or water loaded with finely suspended soil particles or micro-organisms. Recutting the base of the cutting restores the flow of water in most plants, but in the meantime, if the cutting is going to survive, then it has to become more water-use efficient with the newly established rate of water use usually less than a freshly prepared cutting. Postharvest treatments used for cut flowers have not provided marked improvements in plant water content or water-use efficiency in our studies with *Camellia* and *Pittosporum*.

Nutrients in the Propagation Medium. Relatively few nutrients are taken up in any significant quantity by unrooted cuttings. If cuttings are held in the propagation medium for an extended time after root formation has occurred, then normal nutrient uptake will occur. During the rooting stage, there is evidence to suggest that while some plants are not responsive, there are indications that nutrients repress root development which may be related to an osmotic stress that reduces water uptake by cuttings. Some investigators have applied nutrient mists to foliage to compensate for leaching of nutrients where an excess of water is applied to cuttings. The results from these studies have suggested there might be some gains from nutrient mist, but in practice, this has been difficult to implement and probably most beneficial with poorly adjusted misting systems, that encourage leaching through repeated excessive application of water.

AERIAL ENVIRONMENT

Water Loss from Leafy/Hardwood Cuttings. The highest rates of water loss from leaves occur in bright light rather than in dull conditions or darkness when stomata are usually more closed. In the dark rates of water loss are typically less than half the rate in the light (Table 1). Water loss by cuttings declines rapidly over time and is markedly influenced by the water availability in the propagation medium.

Leafless hardwood plum cuttings rooted slightly better when cuttings were permitted to loose 10% moisture before treatment with IBA and planting (Nahlawi and Howard, 1972), this improvement in plant performance has been attributed to improved IBA uptake. Related studies with quince cuttings clearly demonstrated benefits from wrapping treatments that reduce water loss from the stem after planting (Blain and Dudney, 1978).

Air Movement. Water loss from leaves increases with air movement. The boundary layer resistance to water movement from a leaf is proportional to the air velocity, therefore it follows that air flow through a propagation area should be

Table 1. Rates of transpiration and water uptake (mg m^{-2} s^{-1}) in several species for fresh and 7-day cuttings before and after removal of 10 mm from the basal stem.

Species	Treatment	Uptake rate		Rate of change in cutting weight		Transpiration rate in the light		Transpiration rate in the dark
		uncut	cut	uncut	cut	uncut	cut	
Nothofagus dombeyi	F	10.7	12.0	0.7	0.0	10.0	12.0	1.5
	7	3.6	7.8	-3.0	2.9	6.6	4.8	0.6
Cornus alba 'Spaethii'	F	11.4	10.4	0.8	-0.2	10.3	10.6	5.5
	7	2.6	10.5	-7.7	2.6	10.3	7.9	3.5
Forsythia ×*intermedia* 'Lynwood'	F	12.5	11.1	1.8	0.6	10.7	10.5	3.4
	7	1.3	5.1	-3.6	1.8	4.9	3.4	1.5
Garrya elliptica	F	6.8	9.2	0.3	0.6	6.4	8.6	0.6
	7	1.1	3.8	-6.3	0.4	7.4	3.4	1.7
Ilex ×*altaclerensis* 'GoldenKing'	F	4.9	7.4	-1.3	0.4	6.2	7.0	0.6
	7	2.4	3.9	-4.1	1.4	6.5	2.5	1.1
Skimmia japonica 'Rubella'	F	6.7	6.6	0.7	0.6	6.0	6.1	1.4
	7	3.0	5.3	-3.6	2.7	6.7	2.6	0.7
Hebe 'Amy'	F	3.5	6.1	-0.6	0.4	4.0	5.7	1.2
	7	1.2	5.0	-11.0	2.8	12.2	2.2	0.9

Source: Grange and Loach (1983)

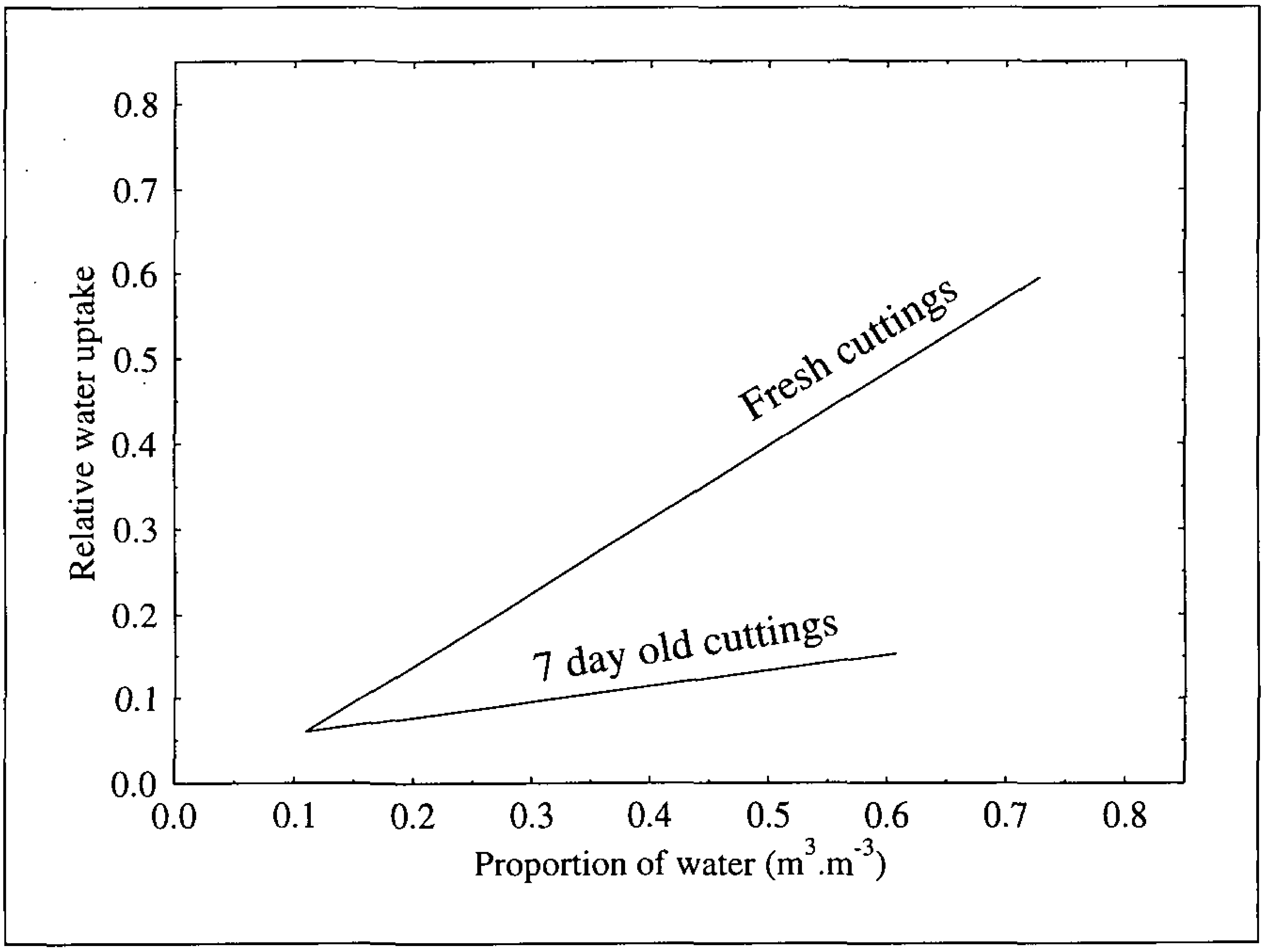

Figure 3a. Typical rate of water uptake relative to pure water in peat and perlite medium at different water contents for freshly prepared cuttings and 7 days after preparation (Adapted from Grange and Loach, 1983).

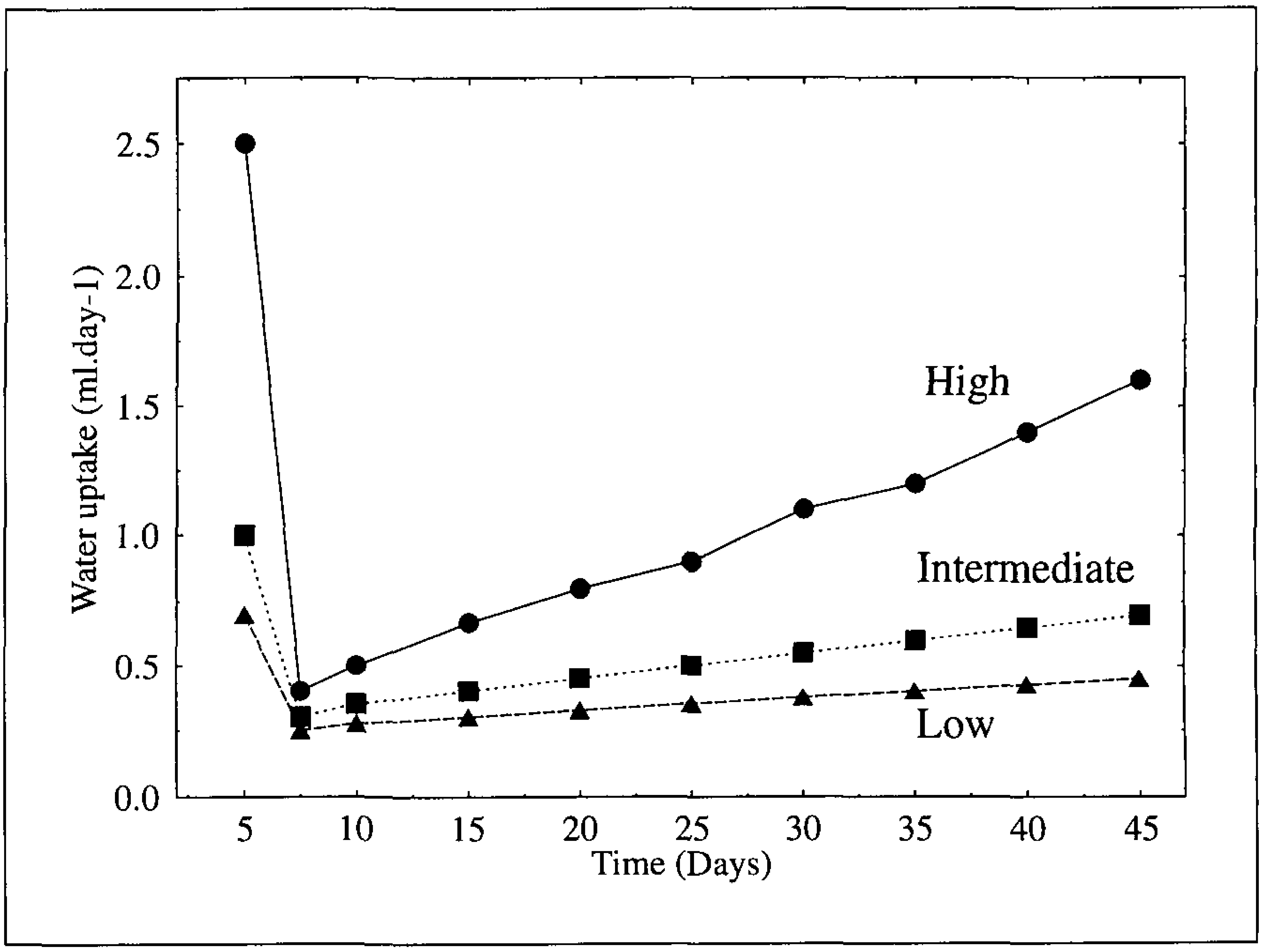

Figure 3b. Typical time course of water uptake in media with three different water contents.

minimised. In practical terms the amount of water lost from a leaf surface doubles as the air speed doubles. Water loss is also a function of leaf geometry with thin leaves loosing more water and being at a lower temperature than thick leaves.

Relative Humidity. This is the ratio of the actual vapour pressure of water (or the amount of water) in the air to the vapour pressure if the air were saturated with water at the same temperature. This is commonly quoted to give an estimate of the amount of water in the air. Water vapour moves from leaves into the air because of a vapour pressure difference between each region. Water loss from cuttings may decrease as the humidity increases but the real driving force for this process is the vapour pressure deficit.

Vapour Pressure Deficit. Water loss by plants increases as the temperature increases because the amount of water required to saturate the air increases rapidly, and unless there is a rapid injection of water into the air, the difference between the moisture content of the air and saturated air at the same temperature (the vapour pressure deficit), will also increase. Many of the strategies employed by plant propagators to reduce moisture stress do so by increasing the relative moisture content of the air to lower the vapour pressure deficit.

MODIFICATION OF AERIAL ENVIRONMENT

Reducing Water Loss from Plant Material.

Solar Radiation/Temperature. Water loss from cuttings is highly correlated with incoming solar radiation. The energy input from sunlight drives up the leaf temperature and water loss from leaves by transpiration, this process helps regulate the increase in leaf temperature. Further temperature regulation can be achieved through evaporative cooling of water applied by misting or irrigation. Many cuttings can be rooted without mist so long as moisture stress is managed. Lowering solar radiation by shading has a direct effect on the percentage rooting (Fig. 4a). Reducing the light level to approximately 20% of full sunlight has a beneficial effect on rooting response, and is reflected in decreased vapour pressure deficit experienced by cuttings in both misted and nonmisted environments (Fig. 4b).

Physical / Chemical Barriers to Water Loss. Antitranspirants have been used with very limited success. Surprisingly, they have little effect on leaf conductance, indicating that cutting turgor is regulated primarily by the vapour pressure gradient between the leaf and the air. Antitranspirants appear to offer most use in environments where the humidity is already relatively high (Gay and Loach, 1977).

Triazole fungicides (Triadimefon) and growth regulators (Paclobutrazol) improve water-use efficiency and may have wider application in protection of plant propagules by reducing water stress (Fletcher and Hofstra, 1988).

Greenhouse Strategies to Minimise Moisture Stress in Unrooted Cuttings. The polytent or closed frame is an inexpensive approach to controlling moisture stress, but it will only work if the incoming solar radiation is low. As the system is passive, relying solely on transpiration and evaporation of condensed water to saturate the air, severe moisture deficits occur if the enclosure is exposed to bright sunlight, because the temperature rises faster than the air can become saturated with water at the new temperature.

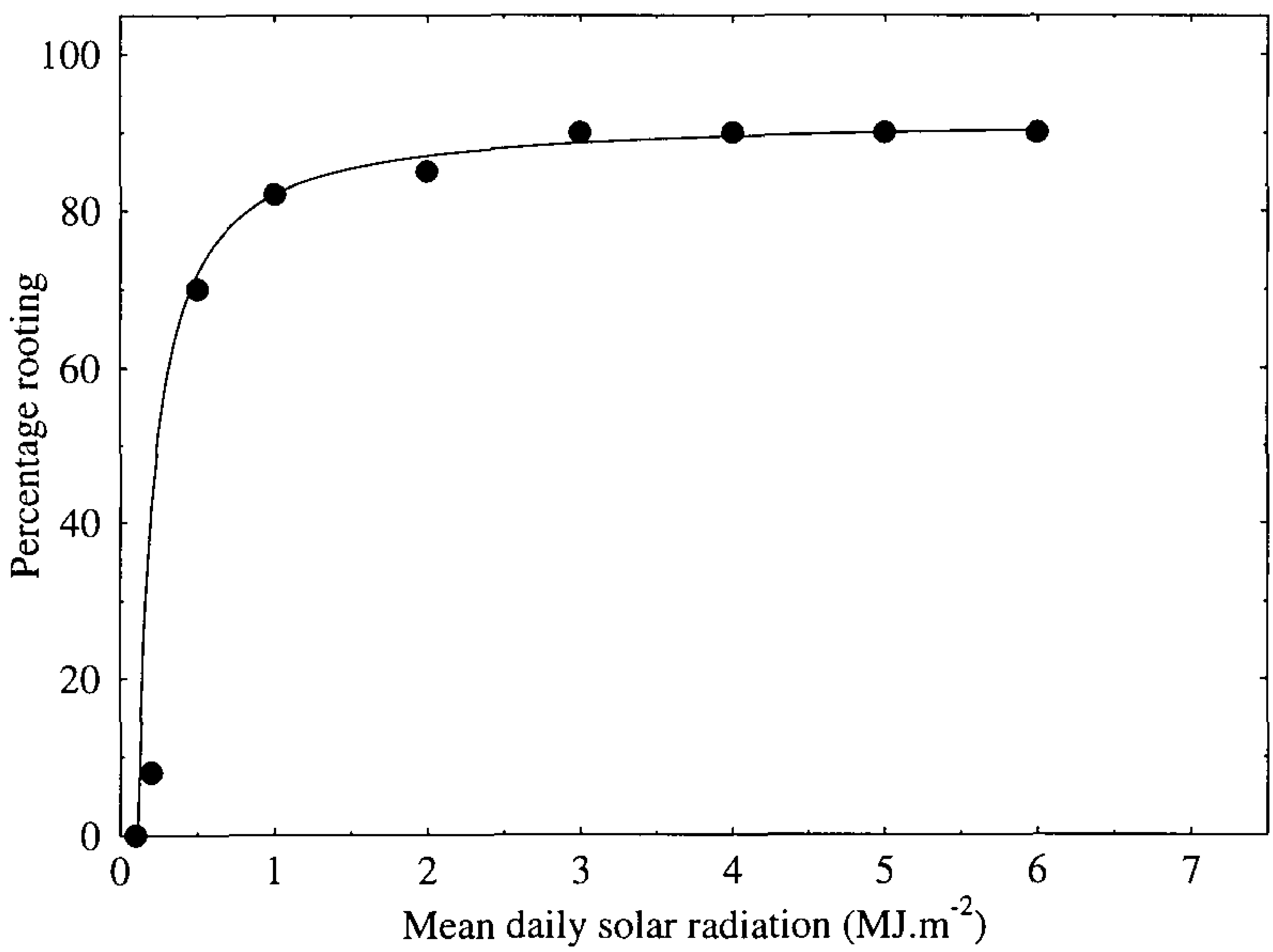

Figure 4a. Typical influence of solar radiation on percentage rooting in a diverse range of plants in an unmisted environment (Adapted from Grange and Loach, 1983).

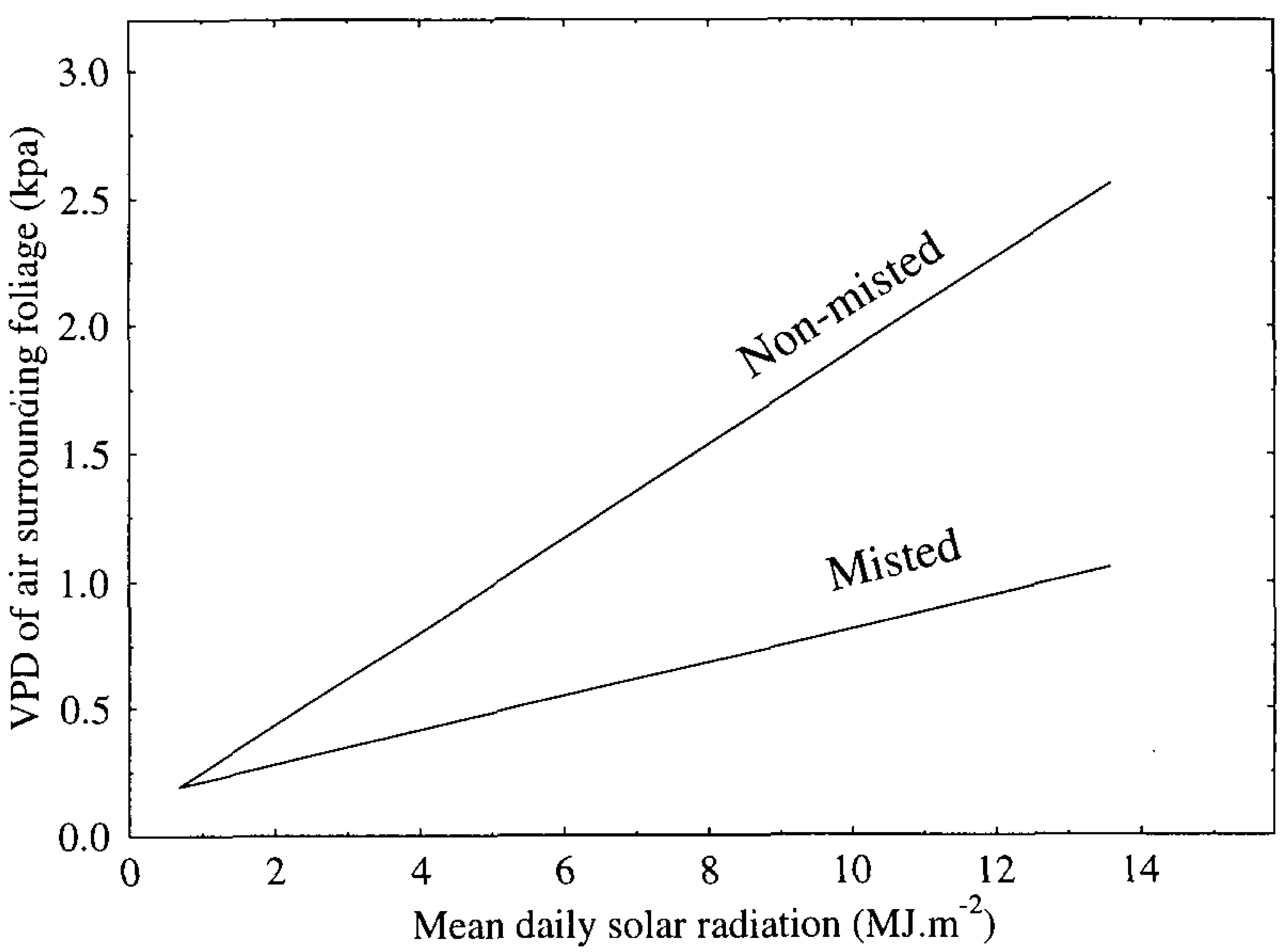

Figure 4b. The relationship between air vapour pressure and solar radiation in misted and nonmisted environments.

More active methods of controlling the moisture vapour pressure deficit utilise techniques to apply water to cuttings as a fine mist or a fog as required. At the heart of all these systems, is a controller that attempts to regulate the loss of water from the leaf surface by applying a film of water or maintaining the atmosphere in a near-saturated condition. Intermittent misting controllers may be based around timing devices that cannot respond directly to changes in the weather and hence the water requirements of the cuttings. Mechanical systems such as a moisture balance that sense the weight of water or the electronic version with an artificial leaf are prone to fault when the sensor is not maintained correctly. The most reliable system is probably based on a solar-integrating sensor that measures the amount of incoming radiation, without the sensors being exposed directly to the potentially corrosive propagation environment.

In conclusion, regulation of water stress is a key issue when propagating plants vegetatively, particularly with leafy cuttings. Many factors are involved in this process, which allows growers to choose a range of strategies that suit their particular enterprise, to manage water loss and increase root formation in different propagation environments.

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