Restriction of the Root System, A Survey of Non-Chemical Methods

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INTRODUCTION

Regulation of the root system is an obvious necessity whenever plants need to be transported from the site of production to the final habitat. Therefore, in any commercial plant production the question of how to minimize root damage must be dealt with. Since the use of copper compounds is treated elsewhere in this symposium this will be a brief survey of other means of root regulation.

Methods that confine the root system in a limited space, i.e., container culture, differ markedly from methods of pruning that entail a loss of existing root mass, which usually is the youngest part of the root system. In the evaluation of these methods their effects on essential root functions should be considered. The importance that various root problems may have on plant quality depends on the culture in question, but a number of typical effects of root system restriction may be outlined.

ROOT/SHOOT RATIO

The root/shoot ratio (which = dry weight of root/dry weight of shoot) in a woody plant attains a value typical of the climatic adaptation of the species in question. In a stable environment the ratio is stable, but with a long-term decrease with age. Environmental conditions affect this equilibrium within certain limits; protection from winds, ample water supply, and high concentration of nutrient salts tend to reduce the ratio, whereas wind and light exposure tend to increase it.

The homeostasis is maintained by means of cytokinins, produced mainly in the roots which stimulate shoot growth, and auxin, produced within the top which is required for root development. When conditions for either part of the plant are changed, for instance by pruning, compensatory growth occurs in such as way as to reestablish the previous ratio (Kramer and Kozlowsky, 1979; Geisler and Ferree, 1984).

Effects Of Cutting The Root System. Root cutting usually means removal of the peripheral parts of the root. This affects the cytokinin production both by the loss of production sites and by the stress reaction. In conjunction with root cutting the roots are often subjected to some desiccation, which also decreases the cytokinin production and increases ABA production (Hubick et al., 1986).

Root cutting usually results in a reduction in shoot growth (Rook, 1971). There are indications that the generation of side shoots is also inhibited (Harmer and Walder, 1994; unpublished observations in this lab). Depending on the culture this could be an unwanted or desirable effect.

Provided that growth conditions are suitable, the root system responds to cutting with increased growth rate and branching, probably due to an accumulation of auxin in the roots that remain. The reaction is observable 2 to 14 days after the cutting

(Geisler and Ferree, 1984). Branching occurs mainly immediately behind the cut, and usually several minor branches emerge from the same point, thus forming a much finer root system than before (Harmer and Walder, 1994). Some species, however, tend to produce only one or few replacement roots, so that a branched system is difficult to achieve by root surgery.

The consequences of replacing the strongest roots with a multitude of finer ones are not fully known. It is assumed that some of the new roots take on a dominating role and by secondary growth reach the same proportions and mechanical properties as the original laterals. However, Coutts (1983) showed that the major roots in 9-year-old *Picea sitchensis* all had much primary xylem, indicating that they had been among the largest roots initially. Heterogeneity in the soil environment can cause local proliferation of roots, but usually this does not lead to a lasting dominance of that part of the root system (Coutts and Philipson, 1977).

Since most of the carbohydrates stored in roots is located in the central parts of the root system, loss of the peripheral parts of the root does probably not affect the function of the root as storage organ and sink to any great extent. Obviously, strong pruning can reduce the stores considerably. For instance, Insley and Buckley (1985) found a 20% to 60% loss of root storage carbohydrates with various cutting regimes. Reduced water and ion supply from the root can also limit photosynthesis in the days after root cutting and hence cause an overall decline in the carbohydrate status of the plant (Geisler and Ferree, 1984). Impeded shoot growth and increased root development after root cutting may in fact result in a situation in which a relatively larger part of the plant carbohydrates is stored in the root (Rook, 1971).

The time after cutting is critical for the plant, particularly with respect to temperatures and precipitation. Uptake of water and ions are naturally affected by the reduction in the root surface and loss of many of the young, non-suberized parts. However, it is now widely accepted that the mature roots absorb a substantial amount of water and ions. No ion deficiencies have been detected as a result of root cutting (Geisler and Ferree, 1984). When new growth and branching has taken place the absorbing surface will be more than compensated for.

The biological effects of air pruning are probably rather much the same as by mechanical root cutting, although the process is continuous and the roots that stay within the substrate block are largely unaffected by it.

CONFINEMENT OF THE ROOT SYSTEM

By growing the plants in containers actual cutting of the roots is avoided. The root tips remain intact, apart from those escaping through the drainage holes, and the size hierarchy of roots is maintained. However, the orientation of the roots are strongly affected by the curvature of the pot.

Confinement of roots may in itself affect the physiology of the plant. Plants in small containers have relatively small leaves (lower leaf-area ratio), and other growth parameters are likewise reduced in small containers as compared to plants in large containers (Dubik et al., 1992; Rieger and Marra, 1994). This is not only due to differences in amount of substrate, similar results are obtained when the availability to nutrient ions is kept the same in all container sizes. Even in hydroculture crowding of roots results in reduced leaf size and growth rate (Ternesi et al., 1994). This effect is associated with a marked rise in the ABA content of the root.

Lasting root deformations in trees caused by container production are amply documented and can often be traced several years after planting (Halter et al., 1993). Asymmetrical root systems and winding and bent roots are among the typical problems. This leads to instability and impeded secondary growth. Specially shaped containers (vertical rims, corners, slanting bottom) improve the situation somewhat (Lindström, 1978). Most important is not to let the plant remain too long in the same container. Because of their permanent nature these deformations have serious consequences, particularly for large and long-lived plants, as compared to the short-term physiological setbacks that a cultivation system can otherwise impose.

OTHER KINDS OF REGULATION

Plasticity of the root system makes it possible to produce almost any root form. Not only the relative size of the root, but also the shape, can be manipulated by growth factors. The root reacts with strong local proliferation in pockets of nutrient salts or water resources in the soil. Growth is also concentrated in the most penetrable layers of soil. By applying point fertilizer, restricted watering, or using the right soil management, these reactions can be exploited to produce root development where it is required. For a practical example, see Gilman et al. (1994). These options are not used to their full potential.

CONCLUSION

Methods of root restriction all have their merits and drawbacks, and none are ideal. The preferred method much depends on the culture in question and the duration of production.

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