Recirculating Subirrigation Systems for Nursery Production

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Three recirculating subirrigation systems (constant-flow capillary mat, intermittent-flow capillary mat, ebb-and-flow) and an overhead spray irrigation system are being assessed for efficiency of water use and plant production, nutrient use and the amount of nutrient-laden leachate and run-off produced. Results to date indicate that plant growth is as good or greater than on overhead spray, on any of the subirrigation systems and that the subirrigation systems use 30% to 37% less water than the overhead spray. The ebb and flow system has produced the lowest levels (mg litre^{-1} N) and least fluctuation in leachate and run-off nitrate levels. The ebb and flow system also produces the least fluctuation in E.C. levels.

INTRODUCTION

In Australia, the principal method of irrigation for container nursery plants is the overhead sprinkler. It is an inefficient technology because (1) as much as 80% of the water applied fails to reach the container media, and (2) distribution is uneven, often resulting in over-watering. In addition, higher levels of nutrients are applied to compensate for high levels of nutrient leaching. Typically this leachate contributes to the pollution of waterways and groundwater.

Inefficient water and nutrient use by the containerised nursery in Australia is an issue that demands our attention. A recent initiative in New South Wales (The Clean Water Act, 1988) has alerted all of the Australian industry to the imminent introduction of guidelines or possible legal restrictions regarding nursery run-off.

In The Netherlands the year 2000 is targeted for a complete conversion of the industry to closed (no run-off) nursery systems (Runia, 1995); Australian best nursery practice needs to come in line with a growing world-wide trend to reduce nursery impacts on natural resources. There is an increasing awareness in the nursery industry of the finite nature of our useable water resources and the ensuing responsibility to conserve and protect this vital heritage.

MATERIALS AND METHODS

The research at Burnley College, University of Melbourne, is assessing four irrigation systems in a greenhouse environment. Five plant species; *Artemisia* 'Powis Castle', *Coprosma* ×*kirkii*, *Hebe traversii*, *Rhagodia spinescens*, and *Heliotropium arborescens* 'Lord Roberts' are being grown over four trial periods. Trials vary in duration from 5 to 9 weeks depending on the season. Plant material is grown on from tubestock that had been propagated as cuttings. Trials commence after potting the tubestock into 150-mm plastic capillary pots. The media used is bark-based and contains slow-release fertilisers. The 222 plants are set out pot to pot on each of four benches measuring approximately 1 m × 5 m. Plants are set out in a series of five rows (one species per row) that is repeated in sequence on the entire growing area of the bench. The perimeter plants on each bench are designated as edge-effect plants. At the conclusion of each trial, 11 plants per species (including 4 edge-effect plants) per bench are harvested for dry weight analysis. Only above-ground plant material is harvested.

The benching and irrigation systems were designed and built at Burnley. Each bench is irrigated by a separate and differing method of irrigation. There are three subirrigation systems that recirculate the applied mains water and one overhead spray system that does not. The subirrigation systems are; a constant-flow capillary mat, an intermittent-flow capillary mat, and an ebb-and-flow. The overhead spray bench is engineered to collect leachate and run-off, but does not recirculate it.

The overhead spray system uses six spray heads designed to deliver 54 litre h^{-1}. It is used 1 to 4 times per day for 3- to 5-min cycles. The constant flow capillary system uses six drippers positioned at the higher end of a bench with a 1 : 100 slope. These drippers emit onto a spun polyester capillary mat that is covered by black plastic weed mat. The constant-flow capillary system emits continuously at a seasonally adjusted rate of 0.21 to 0.25 litres min^{-1}. The intermittent flow system is identical in design to the constant-flow capillary system except that its drippers emit on a cycle of 4 to 6 min h^{-1} for 12 h and 4 to 6 min every 2 h for the next 12 h.

Each irrigation system or treatment occupies a new position in the greenhouse in each of four trials. The experimental design is a Latin square.

The greenhouse is clad with polycarbonate sheeting and has no supplementary heat or lighting. Temperatures in the greenhouse vary from 4 to 35C. Vents automatically open at 25C and at 30C a fan-driven ventilation system starts. Mains water is used, which also serves as the control for leachate analysis, having an E.C. $< 082\ \mu s\ cm^{-1}$ and nitrate levels < 0.25 mg $litre^{-1}$ N. Leachate is collected as it drains from the bench and so it contains both leachate and run-off. Leachate from each system is sampled on a weekly basis and is tested for pH, E.C., nitrate, ammonium, phosphate, potassium, manganese, calcium, and magnesium. Data is also taken fortnightly on pH and E.C. levels in the container media for each of the systems, using the 1 : 1.5 volume extract method (Handreck and Black, 1984). Water consumption is measured per system, per trial, using meters installed on each system.

RESULTS

A considerable percentage of the water applied by our overhead spray system either fails to land on the media (run-off) or leaves the media as leachate. In trial 2, 63% of the applied water on the overhead spray system was collected as run-off and leachate. Similarly, in trial 3, 55% and in trial 4, 45% of the applied water was collected as run-off and leachate. In the trials to date, the recirculating subirrigation systems use 30% to 37% less water than the nonrecirculating overhead spray system (Table 1).

If we were able to disinfest the water used in the recirculating systems (and thereby avoid the between crop dumping and refilling of the recirculating tanks to permit disinfestation) the subirrigation systems would use 43% to 49% less water than the overhead spray system.

In 1971 the World Health Organisation set the upper limit for safe levels of nitrate contamination in water for human consumption at 10 mg $litre^{-1}$ N (Lawrence, 1983). Occasionally, leachate nitrate levels were in excess of 10 mg $litre^{-1}$ N on each of the

Table 1. Water use (in kilolitres) by irrigation system per trial.

System	Trial 2	Trial 3	Trial 4	Total to date
Overhead spray	1.39	1.41	1.95	4.8
Constant capillary	0.84	0.88	1.52	3.2
Intermittent capillary	0.79	0.88	1.36	3
Ebb and flow	0.96	0.97	1.42	3.3

irrigation systems.

The ebb-and-flow system gave the best performance (lowest levels and least fluctuation) in terms of nitrate levels in the leachate and run-off. This may be due to the relatively large amount of water leaching only the small portion of the media in the bottom of the containers. The ebb and flow system also gave the least fluctuation in leachate E.C. levels.

Plant dry weights were significantly greater for *A.* 'Powis Castle' and *H. arborescens* 'Lord Roberts' when grown on subirrigation systems. Plant dry weights for *C. ×kirkii* ', *H. traversii,* and *R. spinescens* indicate that these species grow equally well regardless of the type of irrigation. All five species grow as well or better with recirculating subirrigation, as they do with overhead spray irrigation.

DISCUSSION

Plant growth, as measured by plant dry weights, is greatest on subirrigation systems for the two larger leaved and more vigorously growing of the five plant species that are grown in this research. Plant morphology may be one factor in determining species that will benefit most from subirrigation. Certainly, the possibility of enhanced growth rates is species dependent.

Shoot extension of up to 20 mm in 1 day was recorded on *H. arborescens* 'Lord Roberts' on the constant capillary bench. This exceptional growth rate is produced by providing *H. arborescens* 'Lord Roberts' with appropriate nutrient and light levels and by minimising water stress. It may be possible to grow some species more quickly using subirrigation than with conventional overhead spray. Conventional overhead spray irrigation, due to its inherent inefficiencies, both utilises more water and creates more waste than does a recirculating subirrigation system. With appropriate disinfestation of the recirculating water, subirrigation systems offer a substantial reduction in water use and amount of nutrient-laden leachate and run-off that is produced. More research needs to be undertaken to investigate low-flow disinfestation technology specific to the use of recirculating subirrigation by the nursery industry.

Best nursery practice can be changed to incorporate more efficient water and nutrient use, and less pollution of waterways by nutrient-laden run-off. These changes can be approached by careful and extensive fine-tuning of the current and dominant technology of overhead irrigation or the challenge can be met by the adoption of recirculating subirrigation. It is in the interest of the nursery industry and the community at large to affect these changes.