The Role of Copper-based Root Control Treatments in Closed Subirrigation Systems

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Closed subirrigation systems offer the potential of water and nutrient savings along with increased growth rates and no polluting runoff. The use of a copper-based root control chemical on weed matting over capillary matting, as well as on the inside of pots, can prevent root penetration into the capillary matting and improve root development without having any adverse effects on growth rates.

INTRODUCTION

Recent work by Mayotte, Hall and Connellan (1996) has shown that "closed" subirrigation systems, where runoff is collected and re-used in capillary watering of nursery crops, can substantially reduce water use when compared to overhead sprinkler systems. Many workers over the last decade have shown that these subirrigation methods can also reduce the fertilizer requirements of crops while still maintaining rapid growth rates, since leaching of nutrients incorporated into the growing medium is largely eliminated. A further significant consequence of the use of "closed" capillary systems is that the environmental problem of nutrient-rich runoff leaving the nursery is, to a large extent, eradicated. This pollution aspect of nursery production is attracting substantial attention in Australia as it is elsewhere. Mayotte et al. (1996), by measuring electrical conductivity (EC), pH, and a range of individual nutrient ions, also showed that the build-up of nutrient salts in the closed, recirculating, irrigation system was not an issue for concern — at least for short-term crops. The solution remaining in the irrigation tanks for each system was dumped as a result of experimental necessity at the conclusion of each trial since no system of disinfestation of water was used. The three forms of subirrigation studied in comparative trials with an overhead sprinkler system were: constant flow on capillary matting, intermittent flow on capillary matting, and ebb and flood. Water inputs into each irrigation system were recorded as was the amount of runoff from the overhead sprinkler system. Dry mass of top growth was used to provide an indication of the comparative performance of each system. In this series of trials the capillary matting systems each utilized a cover of black woven polypropylene fabric (weed mat) over the capillary matting to reduce algal growth on the capillary matting and to help prevent root penetration from the container into the matting. It certainly helped prevent algal build-up but did not entirely prevent roots from the base of the container from growing into the capillary matting.

For a number of years the nursery at Burnley College has been painting a dilute solution of SpinOut™ (a copper hydroxide, 100 mg liter^{-1}, root control agent in a latex paint — Griffin Corp., Valdosta, GA) onto weed mat covering capillary sand beds in

order to prevent root penetration into the sand. It has proven quite effective in this role. However, we were concerned that copper may build up to toxic levels if this technique, or that of painting the inside walls of containers to prevent root circling, was to be used in a recycling system. Two trials (Thornby, 1997) were conducted growing small crops on 'closed' capillary matting systems with four different combinations of treatments using SpinOut™. These were established in order to assess the impact of SpinOut™-treated pots and weed mat on root circling within the pot, root growth into the capillary matting, and copper concentration in the recirculating water supply.

MATERIALS AND METHODS

In the trials to assess the impact of a copper-based root-control chemical in "closed", or recirculating, capillary irrigation systems, three different SpinOut™ treatments were used: the first on the inside of containers to control root circling, the second on weed mat to control root penetration into the capillary matting, and the third combining pot treatment with weed mat treatment. With a control this produced four treatments:

1) Neither pots nor matting treated;
2) Both pots and matting treated;
3) Pots treated, matting untreated;
4) Matting treated, pots untreated.

Sufficient replication was used to allow statistical analysis and a randomized block design ensured edge effects were eliminated. Four species were used per trial and these were predominantly Australian native tree and shrub species which had not previously been tested for their response to SpinOut™.

A series of trays were placed in an unheated glasshouse. The trays were established with a gradient of 1 in 40. The trays had drainage holes at one end and the trays were fitted with 3-mm fibrous capillary matting. The trays were then connected with irrigation lines and return lines from the drainage holes, all made from 15-mm flexible plastic pipe. Water was supplied to each tray from 100-liter cylindrical tanks equipped with submersible pumps. The containers used throughout the trials were 150-mm black plastic pots suitable for use on capillary beds — that is, they had drainage holes on the base to allow for a capillary connection to the matting.

In those treatments where SpinOut™ was applied to the weed mat it was diluted 1 : 1 (v : v) with water in order to avoid clogging the weave. Where pots were treated, undiluted SpinOut™ was applied by brush to the inside of the containers. Plants were hand-potted from 50-mm tubes (liners) 24 h after painting the inside of the pots. The potting medium was a composted pine bark with an air-filled porosity (AFP%) of approximately 15%.

The medium had an incorporated controlled-release fertilizer (16.5N : 4.1P : 9.6K) at 4 kg m^{-3}, trace elements in the form of Micromax® (1 kg m^{-3}), and with the pH adjusted using dolomitic lime to 5.5 to 6.0.

The plant species used in Trial 1 were: *Eucalyptus torquata, Acacia pendula, A. iteaphylla*, and *Callistemon speciosus*. In Trial 2 the species used were: *E. alligatrix, C. citrinus, A. pycnantha*, and the non Australian native, nonwoody *Salvia splendens*.

Water samples were taken from the supply tanks at the conclusion of each trial and assessed for pH, EC, iron (Fe), and Cu levels. Copper toxicity usually manifests itself

as iron deficiency symptoms (Handreck and Black, 1994). The iron and copper were measured using Reflectoquant® (E. Merck) test strips and a calibrated strip reader. The test strips used had a stated range of 5 to 200 mg liter^{-1} Cu. The growing medium was also analyzed for copper content at the conclusion of the trial.

The trials were terminated when excessive root growth was apparent from the base of control (no treatment) containers. Root growth into the weed mat was then assessed using a devised 1 to 5 scale where 1 represented no root growth into the matting and 5 represented no control over root growth from the pot. A similar 1 to 5 scale was used to determine the amount of root circling within the container. Finally each plant was decapitated at the surface of the medium and top growth dry mass measured in order to assess if the treatments were having any impact on growth rates. The means of dry mass were then statistically analyzed using the analysis of variance.

RESULTS

A concern with the use of SpinOut™-treated weed mat or containers in a "closed", or recycling, subirrigation system was the possibility of copper build-up in the irrigation supply having an adverse impact on growth rates. The analysis of variance of the dry mass of the aerial portion of the plants indicated no statistically significant reduction in growth as a consequence of the treatments except for *E. torquata* where the two treatments where pots were treated provided significantly increased growth (Table 1).

Table 1. Aerial portion dry weights in grams (means of treatments by species).

Species	Neither mat nor pot treated with SpinOut™	Both mat and pot treated	Pots only treated	Mats only treated
TRIAL 1				
Eucalyptus torquata	3.68 a	4.91 b	5.15 b	3.18 a
Acacia pendula	13.70	12.52	12.76	12.53
A. iteaphylla	4.14	4.02	4.40	4.54
Callistemon speciosus	6.11	5.96	4.36	8.08
TRIAL 2				
E. alligatrix	1.20	1.45	1.51	1.50
C. citrinus	2.18	2.04	2.10	2.12
A. pycnantha	2.82	2.75	2.32	1.97
Salvia splendens	4.33	5.43	4.05	4.89

The concentration of copper in the irrigation water at each sampling and for each treatment was below the threshold of accuracy of measurement of the technique — in this case 5 mg liter^{-1}. As there was no impact on growth and no visible symptoms observed, it was assumed that the actual level of copper content in the irrigation supply was below that which would cause toxicity.

The effect of the treatments on root growth into the capillary matting is provided in Table 2. While the technique of using a devised, and somewhat subjective, scale to measure the effectiveness of the treatments is less than ideal, the results do provide clear evidence that the treatments of painting the weed mat and pots or simply the weed mat, results in minimal root penetration into the capillary mat. The lowest means indicate the least penetration of roots into the capillary matting underlying the weed mat.

Table 2. Root growth into matting (means of treatments by species).

Species	Neither mat nor pot treated with SpinOut™	Both mat and pot treated	Pots only treated	Mats only treated
Trial 1				
Eucalyptus torquata	4.8	1.0	2.1	1.3
Acacia pendula	4.5	1.1	2.0	1.3
A. iteaphylla	3.8	1.0	1.8	1.0
Callistemon speciosus	3.3	1.0	1.6	1.0
Trial 2				
E. alligatrix	2.5	1.0	1.0	1.0
C. citrinus	3.5	1.0	1.2	1.3
A. pycnantha	3.5	1.0	1.2	1.3
Salvia splendens	4.3	1.0	1.0	1.0

Table 3. Degree of root circling in containers (means of treatments by species).

Species	Neither mat nor pot treated with SpinOut™	Both mat and pot treated	Pots only treated	Mats only treated
Trial 1				
Eucalyptus torquata	5.0	1.3	1.3	5.0
Acacia pendula	5.0	1.3	1.4	5.0
A. iteaphylla	4.9	1.0	1.4	5.0
Callistemon speciosus	4.6	1.1	1.5	4.9
Trial 2				
E. alligatrix	3.3	1.2	1.0	3.3
C. citrinus	4.5	1.0	1.3	4.5
A. pycnantha	4.5	1.0	1.3	4.5
Salvia splendens	5.0	1.0	1.0	5.0

Table 3 provides evidence of the effectiveness of the copper-hydroxide-based root-control treatments in preventing root circling within the container.

The results of the analysis of the growing medium at the conclusion of the growing trial were: control, 56 mg kg^{-1}; both matting and pot treated, 68 mg kg^{-1}; pot only treated, 66 mg kg^{-1}; matting only treated, 103 mg kg^{-1}. Clearly the growing medium, including the control, contains moderate levels of copper. Micromax® — the trace supply used — contains 0.5% Cu in the form of copper sulfate. Total copper levels in soils vary widely, but are usually in the range of 1 to 50 mg kg^{-1} although much of this is unavailable.

DISCUSSION

Mayotte et al. (1996) have shown that "closed" (recirculating) subirrigation systems offer a viable alternative to overhead irrigation. That work provided evidence that these systems would deliver water savings of between 43% to 49%, depending on the system employed and assuming that a system of disinfestation of water was being used. These systems also offer the potential of no leachate-enriched runoff leaving the nursery and polluting groundwater or streams. This work also showed that, at least with some of the test species, statistically significant increases in growth rates could be achieved from subirrigation systems. Other researchers have also found this to occur. Presumably, these enhanced growth rates were achieved by eliminating the water stress which can occur between irrigations when using overhead sprinklers and by minimizing fertilizer loss in the leachate. Also, by eliminating the large losses of nutrients in leachate, fertilizer savings should be possible when using subirrigation systems. Other workers such as Clemens, et al. (1981) have shown this to be possible.

One problem that growers have found when using capillary matting systems is that of root penetration into the matting. At Burnley this has been controlled by the use of copper-treated weed mat over the capillary matting. The current study has shown that the copper treatment of the weed mat or pots treated to control root circling causes no reduction in growth rates. A cautionary note is that these trials took place using a small number of plant species and a relatively short growth period.

The results obtained for the copper concentration of the irrigation water were low [below the limits of accuracy (5 mg $liter^{-1}$) for the measurement technique employed]. When these low concentrations are coupled with the results for the dry mass of plants in both trials, which clearly indicated no adverse impact on growth from the copper treatments, the level of copper appears to be safe for the growing of the species tested in recycling, capillary irrigation systems. Copper ions from the root-control paint appear not to be particularly mobile over the medium term (2 to 3 months) or, if they are released from the paint, they are possibly 'fixed' on cation exchange sites within the growing medium. The moderate concentrations of copper in the growing medium at the conclusion of the trial probably reflect this. Why the matting only treatment was substantially higher than the treatment where both matting and pots were treated is difficult to explain. In any event this copper is clearly not particularly mobile, as evidenced by the content of copper in the irrigation water and had no adverse impact on the growth of the trial crops.

CONCLUSION

The use of a copper-based root-control paint on weed mat in a closed, or recirculating, capillary irrigation system had no adverse effects on the trial plants. Growth rates

were not adversely effected and no toxicity symptoms were observed although only a small number of species were used in the trial. The copper does not appear to be particularly mobile and less than 5 mg liter^{-1} of copper was present in the recirculating irrigation water. The treated weed mat was effective at preventing root growth into the capillary matting and the treated pots were effective at preventing root circling in the containers. The treatment of the weed mat appears to overcome the problem of root penetration into the capillary matting while still allowing the use of "closed", or recirculating, subirrigation systems with their inherent benefits.

At this stage the results are encouraging; however, further work is required with a broader range of species over longer growing periods to ensure that the copper treatments do not represent a toxicity problem to crops.

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