Control of Woody Root Systems using Copper Compounds

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INTRODUCTION

In the past 30 years in Australia there has been a major swing away from the production of woody plants as a field production system in favour of producing plants in containers. A container production system has many operational and marketing advantages over field production. The climate of Australia is more conducive to the production of woody plants in containers. The lack of any real winter dormancy over most of the country is a major factor in this country-wide trend to container plant production with woody plants.

THE NATURE OF THE PROBLEM

The shape and the relatively small size of nursery propagation containers have been major causes of serious root distortion in container-grown plants, especially large woody plants. In the woody nursery industry in Australia, a small, round container with a top diameter of 50 mm (the ubiquitous 2-in. tube), is extensively used as the first propagation container for both cutting propagation and for transplanting of woody plant seedlings.

Table 1. Causes of root deformity due to propagation and planting procedures (Moore, 1985).

Procedure	Aspect of procedure causing deformity		Kinking	Circling
Propagation	1) Depth of germination tray		x	
	2) Pot	(a) shape		x
		(b) diameter		x
		(c) depth	x	x
	3) Pricking out		x	
	4) Potting on		x	x
Planting	1) Hole	(a) shape		x
		(b) diameter		x
		(c) depth	x	x
	2) Twisting as planting			x
	3) Depth of planting		x	

Harris (1983) outlined the major root distortion problems of container-produced woody plants as:

1) Kinking of Roots. This form of distortion involves a bending or doubling back of the young main or tap root at an early stage in the nursery production process.

2) Circling or Girdling of Roots. This distortion is a response of the root system to the shape and size of the growing container. The roots will circle or spiral around the inside of the container, and after a period of time growing in the container, the whole root ball will assume the shape of the growing container.

In an examination of container-grown plants selected randomly in the VCAH Burnley Nursery in Victoria by Moore (1985), it was determined that the extent of root distortion problems was extremely high with many woody plant species. In this study, up to 100% of the plants of some woody plant species exhibited severe root distortion problems. There is no reason to suppose that the extent of root distortion problems in the commercial nursery industry across Australia is any less severe. Table 1 provides an overview of the extent to which nursery container production procedures influence root distortion.

Work carried out by Whitcomb and other researchers in the U.S.A. has supported the results obtained by Moore in Victoria. Whitcomb (1989) demonstrated that long-term root development of container-grown trees was heavily influenced by the container and the nursery production practices imposed on the plants during nursery production. In the nursery industry world-wide, it is now widely accepted that woody plants, particularly fast-growing seed-raised types, are extremely vulnerable to serious root distortion problems.

These root distortion problems are most severe when the seedlings are transplanted into small, round, plastic containers. The 50-mm plastic tube is probably the worst transplant container that nurseries can use. Its small volume, combined with the smooth inner surface, causes extensive spiralling of the roots around the interface between container and growing medium. If the plants are transplanted from the tubes before significant spiralling of roots occurs (i.e., at the optimum time for transplanting), the problems will be minor. However, if the plants are allowed to remain in the container for longer than the optimum period, severe root distortion will occur and the long-term development of the plants will be seriously impaired.

KINKING OF THE ROOT SYSTEM

Kinking of the roots usually occurs as a result of poor pricking out technique. It results from a doubling back of the main root during the pricking out process. Kinking of the roots is not perceived as a problem in the short term. The regular watering and fertilising programs carried out in the nursery allow the seedlings to grow quite normally.

The major impact of kinking of roots does not appear until well after the plant has been planted out into its final growing position. Cellular expansion of the woody roots in the vicinity of the kinked area causes enormous stresses in the kinked area. These stresses, combined with reduced availability of water, often result in sudden death of the plants. Most horticulturists will be familiar with this situation in many forestry and landscape situations. However, it is also a problem with many woody plants in plantation-style floriculture.

The prevention of root kinking can be very difficult for nurseries as it is largely a problem caused by poor operator technique. Many forestry nurseries are attempting to overcome this problem by eliminating pricking out of seedlings from their production systems. Direct seeding into tubes, using vacuum seedling equipment to plant one seed per tube, is now becoming widely used. The seed germinates and grows on in the tube without the need for pricking out, and the potential for root kinking is therefore reduced.

SPIRALLING OF ROOTS

Root spiralling is largely a response to the size and shape of the growing container. When a plant is potted into a container, the roots will grow outwards (and downwards) until they come into contact with the walls of the container. In the case of round, smooth plastic containers, the root will be deflected by the inside wall of the container and will grow round and round in a circular shape until removed from the container and planted out.

The consequences of severe root spiralling usually do not show up until well after the plants have been planted in their final growing position. Undoubtedly the small circular containers used in most nurseries are the principal cause of root spiralling. The smaller the container, the more serious the spiralling will be. In extreme cases where severe root spiralling has occurred in the nursery, the plants may die through strangulation of the base of the stem by the spiralled roots. This extreme situation usually occurs as a result of root spiralling in small propagation containers, such as 50-mm tubes.

After planting out, plants with spiralled root systems may respond in a number of different ways:

a) Reduced Growth. The efficiency of the root system will be impaired, and this reduces its ability to forage successfully for water and nutrients. Poor and often unsatisfactory growth results.

b) Poor Root Anchorage. The inability of the roots to grow out in the normal way leads to an inability to withstand strong winds, and affected plants are frequently blown over and lost.

c) Strangulation of the Stem. As outlined earlier, when spiralling has been allowed to occur in very small propagation containers, secondary thickening of the stem base and the woody roots often leads to a severe stem constriction, which eventually means that the tree is strangled by its own root system.

PREVENTION OF ROOT SPIRALLING

There are three main strategies that can be used to reduce or eliminate the degree of root spiralling which occurs with small plants in nursery containers:

Avoid Leaving Young Plants in Nursery Containers for too Long. Keeping plants in the nursery for excessive periods of time inevitably leads to severe root binding. This is a serious operational problem for many nurseries and it requires a serious decision to destroy plants with badly spiralled roots, rather than to pot them up into a larger size container. Potting up of plants with spiralled roots does not solve the problem; it merely masks the problem.

Use Nursery Containers which are Designed to Minimise or Eliminate spiralling of Roots. There have been many examples of nursery containers which have been designed specifically to redirect the growth of roots so that spiralling does not occur. Examples of these include:

1) The Speedling Tray. The Speedling Tray, or Todd Planter Flat, is a multi-celled polystyrene tray with the cells configured as an inverted pyramid shape, with one central drainage hole in the base of each cell. The cell shape directs the developing roots vertically downwards and out through the basal drainage hole. The growing benches on which the trays sit have no base, and the young roots grow out through the base of the container into dry air beneath the bench. This results in a drying off and death of the root tip immediately below the base of the tray. Lateral root development occurs from further back along the root system, and the net result is a more branched root system with all roots growing vertically downwards. This concept of root pruning is known as air pruning (Todd, 1981), and it is now used with a variety of other container styles.

2) Vic Pots or Native Tubes. These containers are deep square shaped pots with an open base. They are also designed to be elevated above ground level so that the open base creates an air pruning effect. The square shape inhibits circling of roots inside the container and encourages downward growth of the roots. Air pruning occurs as a result of the air space at the base of the container.

3) Jiffy Pots and Jiffy Strips. These types of propagation containers are made from compressed peat or other organic constituents, which allow the roots of young newly propagated plants to grow out through the walls of the container. This ensures that circling of roots inside the container is minimised. At the end of the propagation period the newly propagated plant is either planted out, or potted up with the container left intact on the young plant. It is important during the early stages of establishment of plants put into the field with these fibre containers, to ensure that the watering program keeps the containers uniformly moist. Prolonged drying out of these fibre containers after planting may lead to some root constriction problems.

4) Queensland Forestry Tubes. This is a deep circular-shaped propagation container with a series of raised vertical moulded ribs on the inside of the tube. These ribs prevent circling of roots and direct the roots vertically downwards and out through the base of the tube into open air for air pruning.

5) The Whitcomb Rootmaker Pot. This is probably the most complex design of propagation container for root control. It consists of an elaborate series of 24 air-pruning openings in the walls of the container, which are designed to air prune the root system so that secondary roots will be encouraged to develop as far back as the base of the stem (Whitcomb, 1989). Although this container may have the desired effect of preventing root circling, they are very expensive and their design complexity makes them very difficult for a pot manufacturer to produce.

There are many more individual styles of propagation containers which are designed to control root development, but the ones listed here will serve as sufficient examples to illustrate the techniques. There is no doubt that if these containers are used properly, they will result in a major improvement to the quality of the root systems of woody plants. The real problem is that most nursery producers are reluctant to use these types of containers. There are many reasons, including: "they are too expensive", "they don't fit our production systems", "our customers don't like them", "our staff don't like them", or " we can't grow a good quality plant in them". Whatever the reasons, most nurseries refuse to use these types of containers. This means that the customer is not getting the quality of root systems that they should be getting. It is also the reason why we are seeing this third option becoming a potentially viable one for the Australian nursery industry.

Use Chemical Compounds to Control the Young Developing Roots. Most early work on evaluating the effect of copper compounds was carried out in the U.S.A. and Canada, and was primarily concerned with coniferous forestry species such as pines and spruce (Beeson and Newton, 1992). Early problems focussed on how to apply the compounds to nursery containers. The most common method of application now in use is to incorporate the copper compound into a latex or acrylic paint, and to paint or spray the compound onto the inside wall of the nursery container.

Subsequently, a number of researchers have evaluated the technique with a wide variety of woody ornamental trees and shrubs. Furuta, et al. (1972), working in California, demonstrated that the technique could be used on many ornamental trees, including *Eucalyptus* species. Struve (1990), working at Ohio State University, incorporated copper treatment of containers into a wider tree production system called The Ohio Production System (OPS). This system enables nurseries to produce tree whips to a plantable size in containers in one year, compared to the three to five years normally required for conventional field production.

FORMULATIONS OF COPPER

A number of different formulations of copper have been assessed by different researchers. Copper carbonate was the formulation used by most early researchers, but many forms of copper will produce similar root inhibition. However, copper hydroxide now appears to be the most widely used compound. Copper hydroxide is the active constituent of the registered fungicide Kocide™. It is manufactured by the Griffin Chemical Company of Valdosta, Georgia, U.S.A. This company is currently marketing a product in the U.S.A. under the trade name of Spin Out™ which consists of 7.1% copper hydroxide in a latex paint solution.

Spin Out™ has received United States Environment Protection Agency registration for use as a root controlling compound. The Griffin Chemical Company, which markets the product in the U.S.A., is now selling Spin Out™-coated containers to the nursery industry. The product Spin Out™ has now been registered for nursery use in New Zealand, and it is expected that registration for Australia will be obtained by early 1995.

A similar product which originated in South Africa, is available with copper oxychloride as the root-control compound, and is marketed under the trade name Prune™. As far as I can ascertain, this product was initially developed as a coating for polystyrene speedling type trays, to prevent root growth in between the polystyrene beads of the trays. Root growth into the spaces between the beads of used trays makes seedling extraction very difficult, and dipping of the trays into a solution of this compound eliminates the problem.

Prune™ is presently not registered in Australia for root control in containers, but is being used by some forestry nurseries and seedling producers. The legal position regarding this manner of use is not clear.

For the last 3 years at Gatton College we have been experimenting with copper coating of native tubes for growing woody plants. Because of the unavailability, until recently, of any pre-mixed compound, we have been making our own preparation based on the recommendations of Struve at Ohio State University, which I visited in December, 1990. We use Kocide 101™ at the rate of 100 g per litre of white acrylic paint. This is then applied to the inside surface of the growing containers using a spray gun.

BENEFITS OF COPPER TREATMENT

Redistribution of Roots within Container. The primary effect of the copper treatment is the prevention of root circling within the container. At the point where the root tip comes in contact with the container wall, the root tip ceases growth. Secondary lateral root growth develops from further back and when these laterals reach the container wall they are also inhibited or "pruned" by the copper.

Overall root distribution within treated containers is quite different to untreated containers. In an untreated container, most of the roots will be located on the outside of the ball of media in the interface area between media and container wall. This type of root distribution is relatively inefficient, as most water and nutrients are located within the volume of media in the pot. With treated containers, the young feeder roots tend to be located within the container media volume rather than on the outside, and this leads to more effective utilisation of water and nutrients from the growing media. A number of researchers have reported a greater total amount of growth on plants in treated containers, and it is likely that this improved utilisation of water and nutrients is the principal reason.

Longer "Shelf Life" for Plants in Small Containers. Probably the main reason why we experience serious problems with woody plants grown in small nursery containers, is that frequently the seedlings remain in the containers for far too long before planting out or potting on. This may not be the fault of the nursery producer as factors such as availability of water for planting, weather conditions, and land preparation may contribute to this problem.

Plants grown in copper-treated containers will not experience the extensive root circling problems experienced in untreated containers. This means that the plants can be held in treated containers for much longer before planting out, without root distortion problems occurring.

Better Root Establishment after Planting in the Field. Burdett (1978), working with lodgepole pine in Canada, demonstrated that roots which were inhibited by copper treatment in the nursery container would resume growth once the plant was planted out in a field position. This means that the natural pattern of root development will occur after these treated plants are planted out. As the root system grows outwards and downwards in the natural pattern, the root system will provide greatly improved anchorage compared to untreated root systems with distortions present.

It also means that the root system is better able to forage for water and nutrients and that results in faster establishment after planting out. Many other researchers have confirmed that plants with roots grown in copper-treated systems have faster rates of establishment after planting out compared to plants with roots grown in untreated systems.

Increased Survival after Planting out. McDonald et. al. (1981) compared the survival rate of ponderosa pine (*Pinus ponderosa*) planted into a forest location from copper-treated containers, and from containers which had varying patterns of holes for air pruning to occur. Survival of plants which had been exposed to copper treatment was averaged at 93%, compared to average survival from air-pruning containers of 39%.

PRODUCT COMPARISON TRIALS

During 1994 a series of trials were undertaken to assess the performance of Spin Out™, Prune™, and the Kocide 101™ plus paint mix used experimentally at Gatton College. These products were evaluated using three species: *Jacaranda mimosifolia, Eucalyptus grandis,* and *Grevillea robusta.*

All three species were raised from seed sown in community trays, transplanted into 50-mm tubes, and some of each species subsequently grown on in 140-mm pots at the Gatton College Plant Nursery Unit during 1994. Due to time constraints I will only refer to results obtained with *E. grandis*.

The objectives of these trials were to:

1) Investigate the use of copper compounds to control root growth in general.
2) Evaluate the three copper products in relation to:
   - Their ability to reduce root system malformation in containers.
   - Their effect on shoot growth in treated containers.
   - Their effect on shoot growth and root regeneration once removed from treated containers.

Treatment Applications:

Control:	No treatment
Prune™:	This was mixed at the recommended rate of 1 kg of copper oxychloride to 1.8 kg of Plazdip (the paint carrier), and 7 litres of water. The initial preparation was thickened by the addition of extra Plazdip to provide better coverage on the containers.
Spin Out™:	This was supplied as a ready-to-use paint by Griffin Corporation.
Kocide™:	A mixture comprising 33 g of Kocide 101, 200 ml of white latex paint, and 50 ml of water was used. This is the standard experimental mix used at Gatton College.

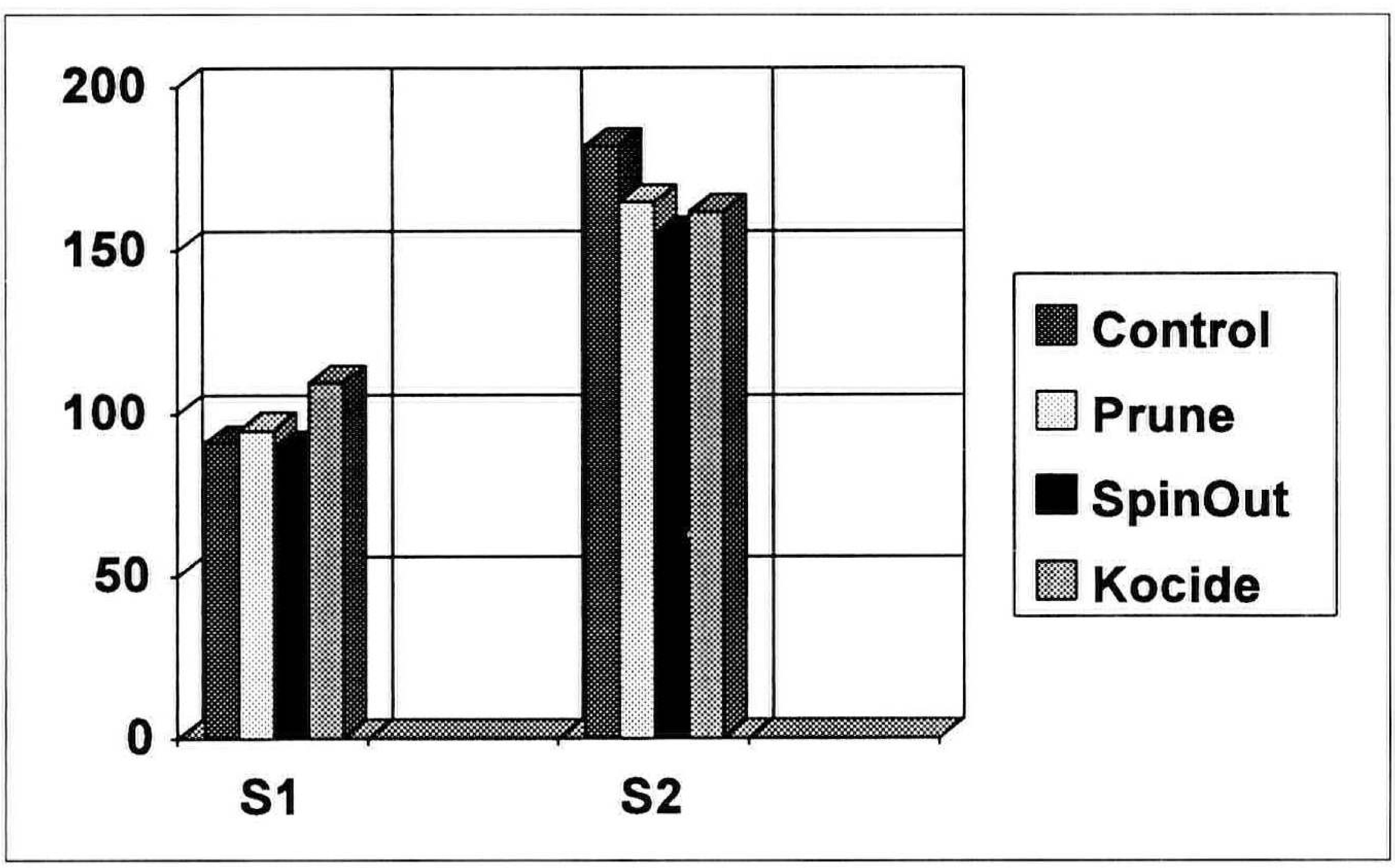

Figure 1. *Eucalyptus grandis* shoot height (mm).

RESULTS

Root System Malformation. All three products greatly reduced root system malformation in containers compared to the untreated controls with all three species. All products also altered root distribution in treated containers, with root growth within the container media rather than at the container wall-media interface.

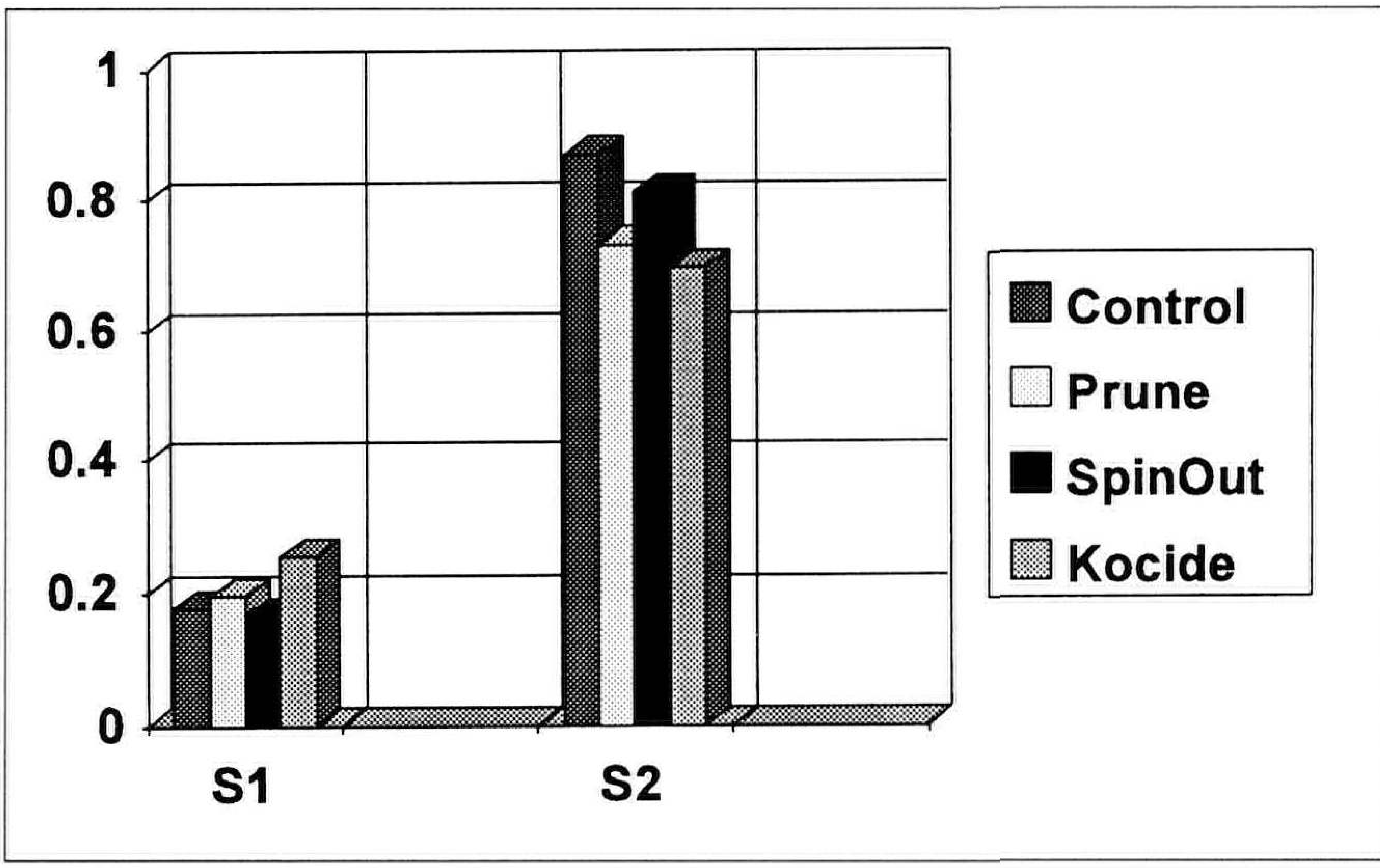

Figure 2. *Eucalyptus grandis* shoot dry weight (g).

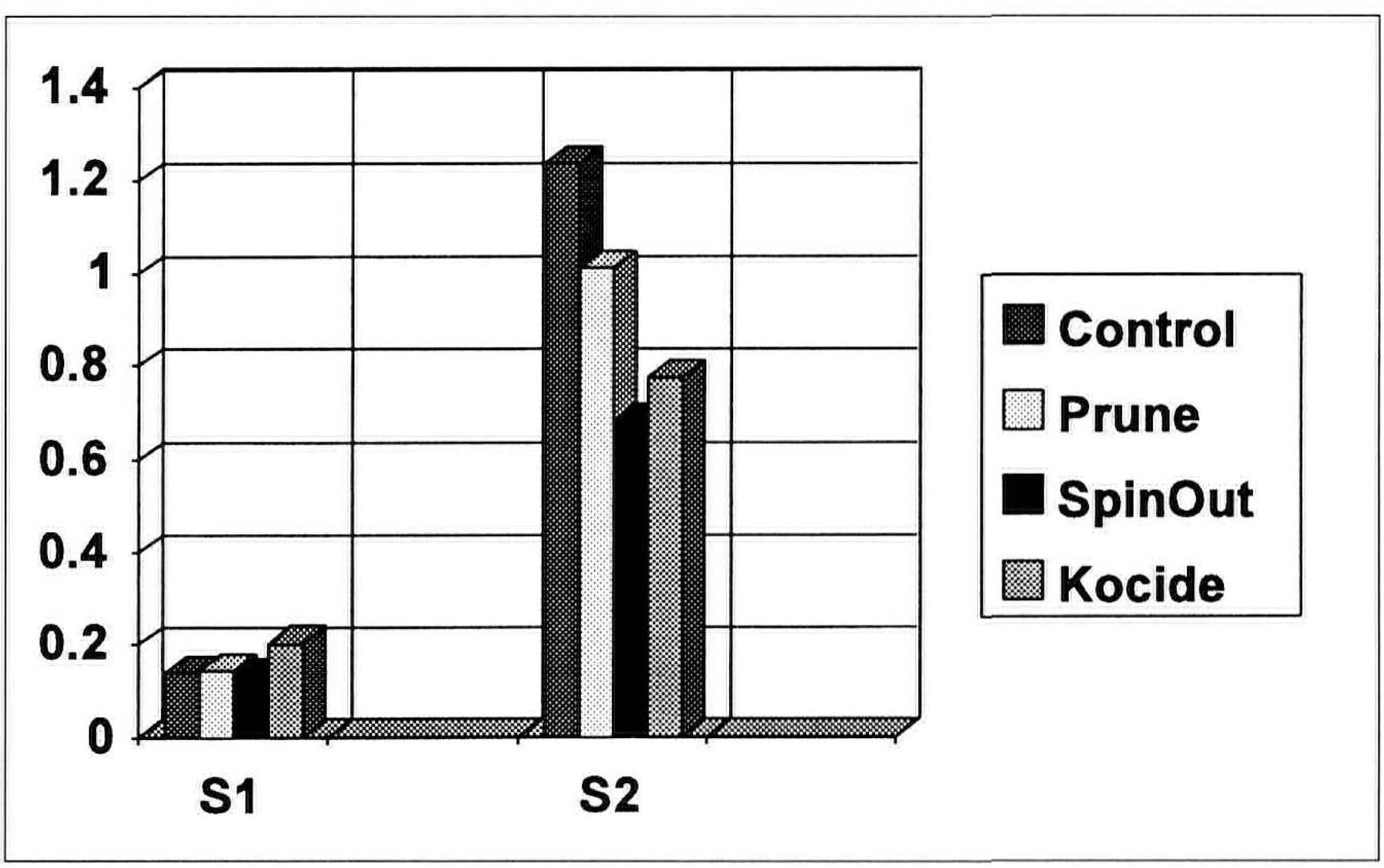

Figure 3. *Eucalyptus grandis* root dry weight (g). Note: Figure 3 root dry weight at S2 is root growth generated from the 50-mm tubes.

Shoot Growth. Fig. 1 illustrates that shoot growth of *E. grandis* in treated containers (S1) was not significantly suppressed with any of the copper treatments. Measurement of growth after further growing on in untreated containers (S2) was also not significantly suppressed.

Shoot dry weight (Fig. 2) was also not significantly different either at the end of growth in the treated containers (S1), or after further growth in untreated containers (S2).

Root Growth. Fig. 3 indicates that there was no significant difference at the end of the growing period in treated propagation containers (S1). However, after a period of further growth in untreated 140-mm containers (S2), root regeneration dry weight was significantly suppressed in those plants which had been grown in propagation containers treated with Spin Out™ and Kocide™ (at $P = 0.05$).

CONCLUSION

It is clear from the work of a number of researchers that the use of copper for woody root system control is an effective substitute for the various air-pruning systems outlined earlier in this paper. As more formulations of copper achieve registration in Australia, its popularity with nursery producers should increase.

The most significant current barrier to its use by nurseries is that it has to be applied to containers in the nursery. This constitutes another step in the plant production process and an additional cost to the producer, and many nursery producers will be reluctant to use the products for this reason. There is undoubtedly an opportunity here for the pot manufacturers to follow the lead of the Griffin Chemical company in the U.S.A. and supply pre-treated containers directly to the nursery producer. The additional convenience of purchasing pre-treated containers may make acceptance of this process by nursery producers more likely.

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