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Application of deficit irrigation to container-grown hardy ornamental nursery stock via overhead irrigation, compared to drip irrigation

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ABSTRACT

Growth control of container-grown hardy nursery stock generally requires substantial labour investment. Therefore the possibility of alternative growth control using deficit irrigation is appealing. Increasing water costs and limited availability of abstraction licences have added further incentives for nursery stock producers to use deficit irrigation. There are still, however, concerns that inherent non-uniformity of water uptake under commonly used overhead irrigation, and differing irrigation requirements of diverse crops and substrates, may limit the commercial relevance of a protocol developed for single crops growing in 100% peat and irrigated with a high precision drip system. The aim of this research was to determine whether growth control of hardy nursery stock is possible using deficit irrigation applied with conventional overhead irrigation. Over two years, crop growth under an overhead irrigation system was compared under full irrigation and two severities of deficit irrigation. Initially, two crops of contrasting canopy structure i.e. *Cornus alba* and *Lonicera periclymenum* were grown. In a subsequent experiment one crop (*Forsythia* × *intermedia*) was grown in two substrates with contrasting quantities of peat (60 and 100%). Deficit irrigation was found to be highly effective in controlling vegetative growth when applied using overhead irrigation—with similar results as when drip irrigation was used. This comparable response suggests that deficit irrigation can be applied without precision drip irrigation. Scheduling two very different crops with respect to their water use and uptake potential, however, highlighted challenges with respect to application of appropriate deficits for very different crops under one system; responses to deficit irrigation will be more consistent where nursery management allows for scheduling of crops with very different architecture and water use under different regimes. The effectiveness of deficit irrigation in controlling the growth of *Forsythia* was similar when a reduced peat based substrate was compared with pure peat; additionally, flowering was enhanced.

1. Introduction

Future global irrigation management will require users to look for methods of application which are efficient (Bacci et al., 2008; Kim et al., 2011; Majsztrik et al., 2011; Lea-Cox et al., 2013). For example, metrics such as water use and water productivity (Fereres and Soriano, 2006) may be required to justify irrigation practices. The use of deficit irrigation not only provides the means by which water use can be reduced and its use efficiency enhanced, but also enables crop growth and quality to be controlled (Jensen et al., 2010; Cirillo et al., 2014). Deficit irrigation is the application of less water than a crop would lose by evapotranspiration if water availability was not limiting (Fereres et al., 2003). However, for deficit irrigation to be effective requires understanding crop growth patterns, and some commentators suggest that use of advanced irrigation systems is also essential (Evans and Sadler, 2008; O'Meara et al., 2013). Deficit irrigation is applied either as sustained deficit irrigation i.e. by systematically applying water at a constant fraction of potential evapotranspiration through the season, or as regulated deficit irrigation, in which case soil moisture deficits are imposed only at certain plant developmental stages (Costa et al., 2007).

The primary challenges in the development of effective application of deficit irrigation to control growth and quality in container

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Fig. 1. Typical habit of *Lonicera periclymenum* 'Graham Thomas' (left), *Cornus alba* 'Elegantissima' (middle) and *Forsythia* × *intermedia* 'Lynwood' (right).

grown crops, such as hardy nursery stock, are a multitude of species and cultivars with different water requirements, and sensitivities to deficit irrigation, combined with a general absence of economic justification for the use of sophisticated precision irrigation systems (Kim et al., 2011; Majsztrik et al., 2011). There are examples, however, where economic assessment reveals apparently good initial savings and returns from investment in irrigation automation (Majsztrik et al., 2011; Belayneh et al., 2013). The successful application of deficit irrigation in hardy nursery stock production offers environmental and economic benefits, such as reduced container leaching of nutrients and pesticides and a reduction in fertiliser and pesticide costs associated with wastage (Caron et al., 1998). This combination of economic with environmental benefits has been recently highlighted (Levidow et al., 2014) as critical if producers are to take up opportunities for improved water management. Other benefits may arise from nursery production of more robust plants when subjected to environmental stresses, such as drought (Cameron et al., 2008). Some studies have now begun to elucidate the mechanisms by which deficit irrigation approaches achieve these 'carry-over' effects in the container crop production cycle (Sánchez-Blanco et al., 2004; Bañón et al., 2006; Cameron et al., 2006; Franco et al., 2006). HNS production approaches are economically constricted by the need for mass production to consistently high crop quality (Warsaw et al., 2009). Despite retailer requirements for producers to meet precise crop-specific quality criteria (Álvarez et al., 2009; Majsztrik et al., 2011), retail margins often mean that investment in sophisticated irrigation approaches is not easily justified. Despite the high labour costs in nurseries' budgets, at least in UK, Dutch, and Irish production (Thorne et al., 2002), and the potential for deficit irrigation to remove or reduce the need for costly operations such as manual pruning (Cameron et al., 1999), there is still a lack of commercial confidence in the application of the approach (Kim et al., 2011). There are a number of questions which need answering before widespread uptake of deficit irrigation for container production is likely (Belayneh et al., 2013).

One of the concerns with respect to commercial application of deficit irrigation is whether approaches developed for high precision drip irrigation can be adapted for extensive commercial practice, which still relies heavily on overhead irrigation (Briercliffe et al., 2000; Pettitt 2014). The drawbacks of overhead irrigation are well described and for hardy nursery stock focus on a lack of spatial uniformity of irrigation supply meeting crop water 'demand'; this may have considerable implications for crop uniformity when deficit irrigation reduces container substrate water availability (Beeson and Knox, 1991; Beeson and Yeager, 2003; Grant et al., 2011). Related to the use of overhead irrigation is the tendency to grow several crops under one system. Differences in water use and uptake amongst species may mean that a deficit appropriate for one crop is detrimental for another.

The capacity of the container substrate to sustain the applied deficit irrigation regime must also be considered. Most commercial experience lies with the use of pure peat, but continued

Table 1
Final plant canopy width of *Cornus alba* 'Elegantissima' following eight weeks of full or deficit (50% or 25% ET_A) irrigation.

Irrigation quantity	Irrigation system	Plant width (cm)
Full	Drip	80.7 ± 2.6 e*
	Overhead	67.7 ± 2.1 d
50% ET_A	Drip	53.0 ± 0.9 c
	Overhead	46.1 ± 2.4 b
25% ET_A	Drip	45.7 ± 1.5 b
	Overhead	32.1 ± 1.2 a

* Data are means ± s.e.; means with different letters differ significantly, $P < 0.05$, LSD following ANOVA. Plant width is the average of the width at the widest point in the canopy and the width perpendicular to that measurement.