Using Mycorrhizal Fungi During the Propagation of Woody Horticultural Crops©

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INTRODUCTION

Plants with roots colonized by mycorrhizal fungi are more effective at nutrient and water acquisition, less susceptible to disease, and can be more productive under certain stressful environmental growing conditions than plants without mycorrhizae. A great deal of information is known about seedling responses to inoculation with mycorrhizal fungi however, there is little information describing the benefits of inoculation during the propagation of woody horticultural crops from cuttings. This paper reviews concepts associated with using mycorrhizal fungi to influence initiation and growth of roots during cutting propagation.

MYCORRHIZAL FUNGI

Types of Mycorrhizal Symbioses. Several types of mycorrhizal associations occur in woody horticultural crops including vesicular-arbuscular mycorrhizae (VAM), ectomycorrhizae, ericoid mycorrhizae, and arbutoid mycorrhizae (Smith and Read 1997). VAM are the most common underground symbioses and are found in a wide variety of host plants including angiosperms, gymnosperms, and some pterophytes. Ectomycorrhizae are found in several gymnosperms and angiosperms that are important to horticulture and forestry. Plants in the Ericaceae are important fruit and ornamental nursery crops and form either arbutoid or ericoid mycorrhizae. Arbutoid mycorrhizae form in members of the Arbutus subfamily including the genera *Arbutus* and *Arctostaphylos*. Inoculum for mycorrhizal fungi which form VAM, arbutoid, and ectomycorrhizae are readily available commercially, while inoculum for fungi which form ericoid mycorrhizae is not.

Inoculation. Optimal uses for commercially available inoculum of mycorrhizal fungi have not been well defined. One common question is when to apply inoculum of mycorrhizal fungi to obtain maximum benefits from the symbiosis. The benefits from root colonization by mycorrhizal fungi are thought to be highest when colonization occurs as early as possible during plant growth (Chang, 1994). In horticultural production systems, this means that inoculum should be present during radicle emergence in seed germination, during the acclimatization phase of tissue culture propagation, or during adventitious root formation in cutting propagation.

INOCULATION RESPONSES

Rooting. In easy-to-root woody perennials, the percentage of cuttings that produce roots is not a limiting factor to production, but the time it takes for cuttings to grow an adequate amount of roots may increase production time. Miniature roses (*Rosa* spp.) and florist azaleas (*Rhododendron* spp.) are commonly propagated by cuttings

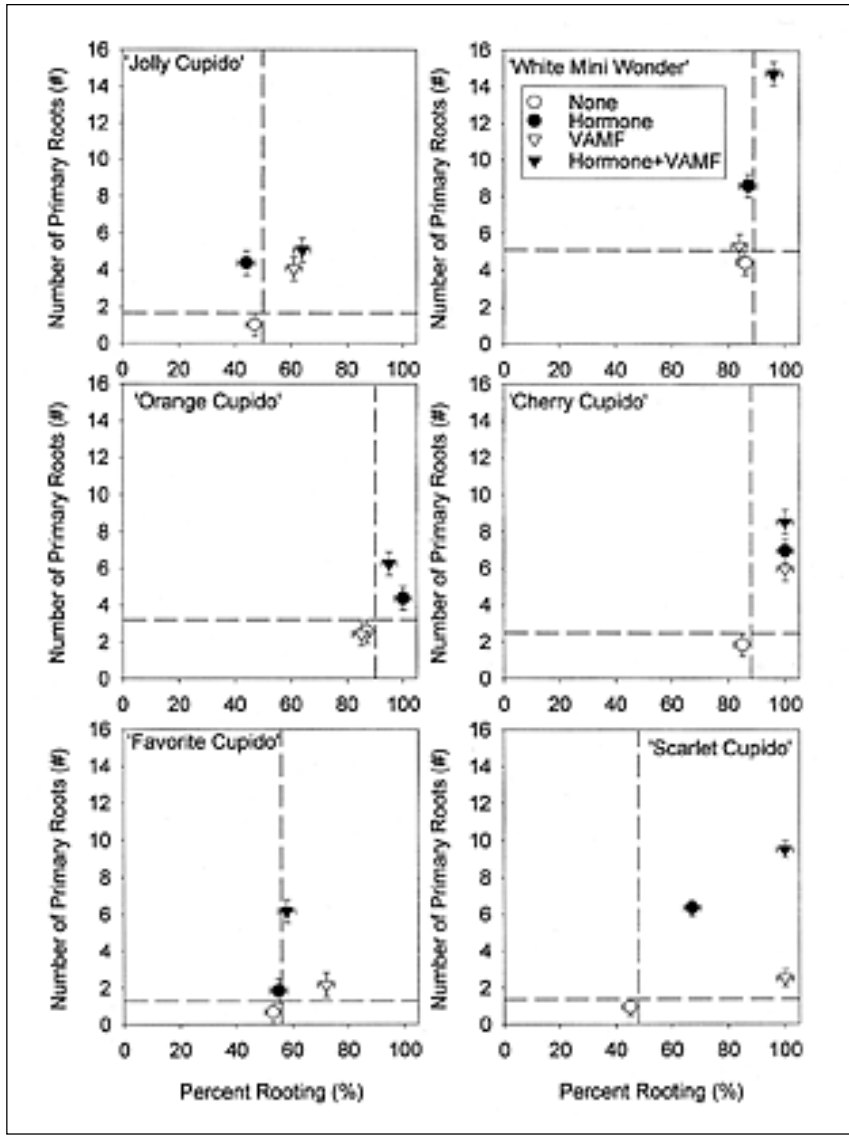

Figure 1. Number of primary roots and percentage of miniature rose (*Rosa* spp.) cuttings with roots 28 days after cuttings were stuck. None=no hormone and no VAMF; Hormone=1:10 dilution of 1.03% IAA and 0.66% NAA; VAMF=VAMF (*Glomus intraradices*) spores, and colonized root fragments in a clay-based carrier incorporated into rooting media [1 : 166 (v/v)]. Means based on 3 replicates of 16 cuttings per treatment. Vertical and horizontal broken lines represent percent rooting and primary root number significantly greater than cuttings treated with no hormone and no VAMF. Bars on data points represent LSDs.

and, in general, most commercially available cultivars are considered relatively easy to root. We have found that adding VAM fungi (VAMF) into the media of miniature roses increases rooting in several cultivars and even in cultivars that normally take longer to root (Fig. 1). We have also tested the effects of mixing ericoid mycorrhizal fungi into the rooting medium during propagation of florist azaleas and were able to increase rooting of azalea cuttings using two of the three different isolates of ericoid mycorrhizal fungi tested (Fig. 2). In more difficult-to-root species, the percentage of cuttings that produce roots can be a limiting factor to production. Mountain laurel (*Kalmia latifolia*) can commonly take three to 5 months to produce roots in commercial propagation systems. We have found that cuttings of *K. latifolia* rooted more quickly when a combination of hormones and ericoid mycorrhizal fungi were used during propagation (Fig. 3).

Root Initiation. During vegetative propagation, the number of roots initiated influences the length of the production cycle and the quality of the rooted cutting produced. We have found that application of rooting hormone and adding VAMF into the rooting medium of miniature roses increased the number of roots on several cultivars when compared to controls and cuttings to which only rooting hormone had been applied (Fig. 1).

Root Growth. Root size in terms of root biomass and root length can affect several aspects of root function as well as the quality of rooted cuttings produced during propagation. Using florist azalea cuttings, we found that application of rooting

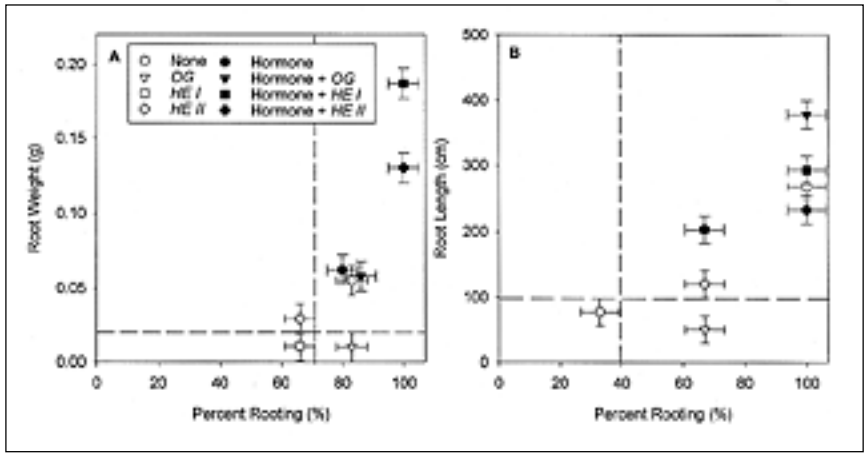

Figure 2. (A)Root weight and percentage of florist azalea (*Rhododendron* spp. 'Snowcap) cuttings with roots 54 days after cuttings were stuck. (B) Root length and percentage of *Leucothoe racemosa* cuttings with roots 84 days after cuttings were stuck. None= No hormone and no mycorrhizal fungi; Hormone= 1 : 10 dilution of 1.03% IAA and 0.66% NAA. OG= hyphae of *Oidiodendron griseum* and HE= hyphae of either of two isolates of *Hymenoscyphus ericae* (HE I or HE II) incorporated into the rooting medium [1 : 18 (v/v); ~ 0.1 g dry weight of hyphae]. Means based on 3 replicates of 20 cuttings per treatment. Vertical and horizontal broken lines represent percent rooting and root weight significantly greater than cuttings treated with no hormone and no mycorrhizal fungi. Bars on data points represent LSDs.

hormone in combination with ericoid mycorrhizal fungi increased root weight on azalea cuttings and root length on *Leucothoe racemosa* cuttings when compared to cuttings treated with hormones or untreated controls (Fig. 2).

Interactions with Hormones. Mycorrhizal fungi are known to produce many plant hormones and polyphenolic compounds which decrease auxin oxidation. Using miniature roses, we found that adding VAMF to the rooting medium increased rooting on cuttings from cultivars that did not respond to hormone application, but did not affect rooting on cuttings from cultivars that responded to hormone application (Fig. 1). With florist azalea, *L. racemosa*, and *K. latifolia* cuttings, application of hormone and mixing one of either two isolates of ericoid mycorrhizal fungi into the rooting media increased rooting above the level attained with hormone application alone (Figs. 2 and 3).

Cultivar- and Fungal-specific Responses to Inoculation. When several different cultivars of the same species are commercially propagated, it is financially beneficial to have uniform cultural practices and uniformity in the rooted cuttings produced across cultivars. Using different cultivars of miniature roses (Fig. 1) and *K. latifolia* (Fig. 3), we found that the degree and type of response cuttings displayed when mycorrhizal inoculum was added to the rooting medium varied with cultivar. When different isolates of ericoid mycorrhizal fungi were mixed into the rooting media of florist azalea, *L. racemosa*, or *K. latifolia* (Figs. 2 and 3) we also found that the degree and type of response of cuttings was dependent on the isolate of ericoid mycorrhizal fungus used for inoculation.

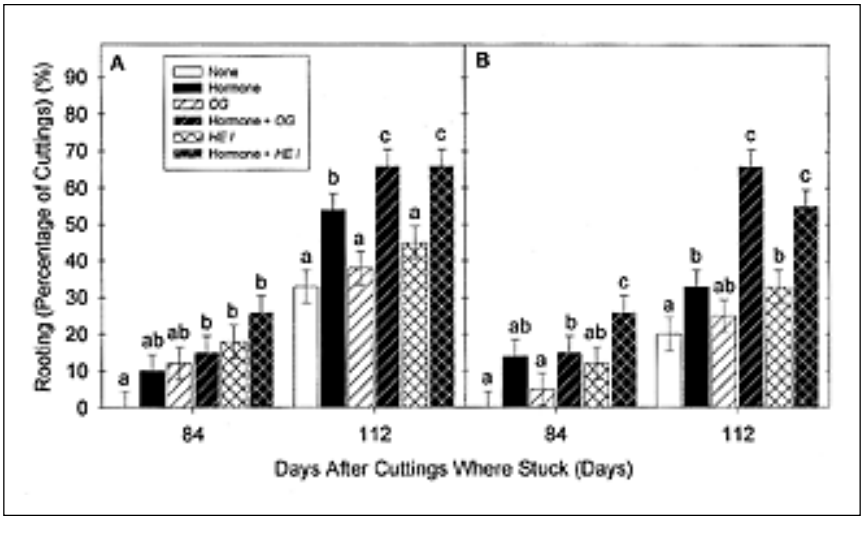

Figure 3. Percentage of (A) *Kalmia latifolia* 'Pink Charm' and (B) 'Olympic Fire' cuttings with roots 84 and 112 days after cuttings were stuck. None= no hormone and no mycorrhizal fungi; Hormone = 1:5 dilution of 1.03% IAA and 0.66% NAA. OG= hyphae of *Oidiodendron griseum* and HE I= hyphae of *Hymenoscyphus ericae* incorporated into the rooting medium [1 : 18 (v/v)]. The same letter above a column within a measurement date and cultivar are not significantly different ($p < 0.05$, Fischer's Protected LSD). Means based on 3 replicates of 10 cuttings per treatment. Bars on columns represent standard errors.

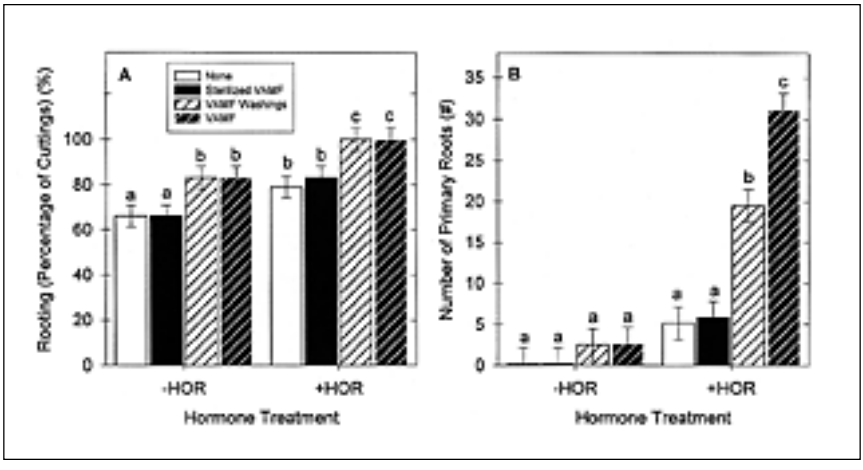

Figure 4. Number of (B) primary roots and (A) percentage of miniature rose (*Rosa* spp. 'Sunrise Cupido') cuttings with roots 28 days after cuttings were stuck. -HOR= no hormone; +HOR= 1 : 10 dilution of 1.03% IAA and 0.66% NAA. None= no mycorrhizal fungi; VAMF= VAMF (*Glomus intraradices*) spores and colonized root fragments in a clay-based carrier incorporated into the rooting media [1 : 166 (v/v)]; Sterilized VAMF= sterilized VAMF inoculum; VAMF Washings= VAMF inoculum washed with sterile distilled water, filtered, and incorporated into the rooting media [1 : 100 (v/v)]. Means based on 3 replicates of 18 cuttings per treatment. The same letter above a column are not significantly different ($p < 0.05$, Fischer's Protected LSD). Bars on columns represent standard errors.

Responses to inoculation without colonization. In our studies, increases in root initiation and root growth of cuttings rooted in medium containing mycorrhizal fungi was not always associated with increased colonization, and the response of cuttings to mycorrhizal fungi was sometimes detectable prior to root colonization. The VAMF inoculum used in many of our experiments consists of spores and root fragments colonized by the fungi mixed with clay particles. This type of inoculum contains not only the VAMF, but also bacteria associated with components of the inoculum. We have tested the activity of washings from VAMF inoculum on rooting cuttings of miniature rose and found that the percentage of rooted cuttings was similar when cuttings were treated with VAMF or washings from the inoculum however root initiation was higher in cuttings treated with VAMF than with only the washings (Fig. 4). We have also found that mixing VAMF into the rooting medium increased rooting and root initiation on cuttings from plants that do not form VAM (e.g., *A. uva-ursi*, Fig. 5).

SUMMARY

The degree of response of cuttings to mycorrhizal fungi appears to vary with cultivar and isolate of fungus. Our results and results reported in the literature suggest that adding VA, ecto-, ericoid, or arbutoid mycorrhizal fungi into the rooting medium can achieve a rooting response that is equal to or better than the response obtained by using rooting hormones alone. The combination of using rooting hormone and

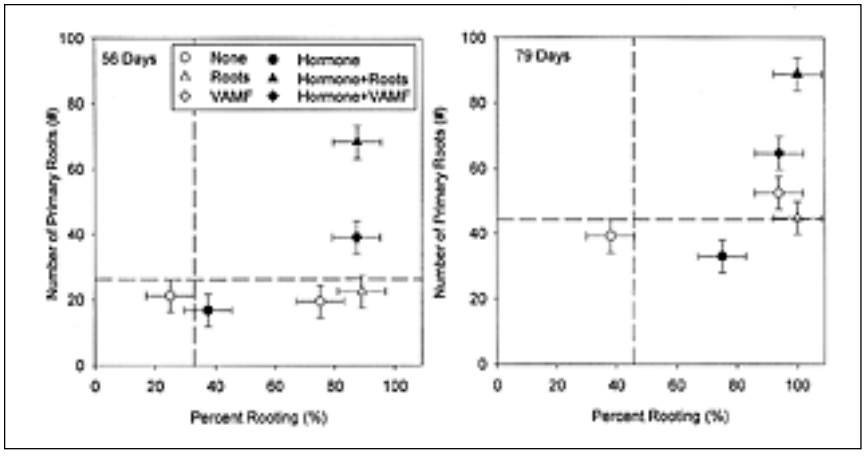

Figure 5. Number of primary roots and percentage of kinnickinnick (*Arctostaphylos uva-ursi* 'Massachusetts') cuttings with roots 56, and 79 days after cuttings were stuck. None= no hormone and no mycorrhizal fungi, Hormone= 1:10 dilution of 1.03% IAA and 0.66% NAA. VAMF= *Glomus intraradices* incorporated into the rooting media [1 : 166 (v/v)]. Roots= ground root fragments from kinnickinnick, suspended in sterile water, and incorporated into the rooting medium [1 : 18 (v/v)], approximately 0.3 g dry weight of root tissue. Means based on 3 replicates of 15 cuttings per treatment. Vertical and horizontal broken lines represent percent rooting and number of primary roots significantly greater than cuttings treated with no hormone and no mycorrhizal fungi. Bars on data points represent LSDs.

mycorrhizal fungi generally produces a higher percentage of rooted cuttings with more roots than cuttings treated only with hormone. Although incorporating mycorrhizal fungi into the rooting medium does not always increase root growth, inoculation (especially in combination with hormone application) does increase root colonization by mycorrhizal fungi. In soilless substrates lacking indigenous mycorrhizal fungi, colonization can increase crop uniformity, reduce transplant mortality, and increase productivity (Vosatka et al, 1999).

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