

# Inoculation with Ericoid Mycorrhizal Fungi Alters Root Colonization and Growth in Nursery Production of Blueberry Plants from Tissue Culture and Cuttings

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**ABSTRACT.** In nursery production, inoculation with mycorrhizal fungi is thought to be most beneficial when colonization occurs as early as possible during plant growth. Unrooted tissue culture plantlets (TC) and hardwood cuttings (HC) of different cultivars of highbush blueberry plants (*Vaccinium corymbosum* L.) were inoculated with mixed inoculum of three different isolates of ericoid mycorrhizal fungi (EMF) in a commercial blueberry nursery. Plants were monitored for root colonization by EMF and plant growth to determine if inoculation with EMF influences rooting, subsequent plant growth, or EMF colonization during one (HC) or two (TC) years after inoculation. Tissue culture plants became naturally colonized by EMF, however, the intensity of this natural colonization was low and inoculation with EMF increased colonization for some cultivars, especially in the first few months after inoculation. This suggests that low colonization during nursery production of blueberry may be at least partially a result of low inoculum potential of the grow-

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ing medium. However, we found that the frequency and intensity of colonization of certain cultivars decreased substantially after plants were transplanted and moved to an outside growing area. This decrease in colonization suggests that; (1) the fungi used for inoculation may not be suitable for this cultivar under the specific cultural conditions used in the nursery, (2) changes in cultural conditions from transplanting inhibited further colonization of the fungi that were present in the initial stages of propagation, or (3) there were possible changes in the type of fungi on the root system. Inoculation of TC plants with EMF caused measurable changes in root and aboveground plant morphology and biomass partitioning during the first two growing seasons; however, we found that the responses to inoculation with EMF can vary with cultivar, suggesting that a level of plant-fungus specificity may exist in EMF associations with blueberry plants that influences plant growth. Inoculation of HC with EMF increased colonization frequency and intensity on cuttings under the cultural practices used in the nursery; however, colonization decreased between 3 months and 5 months after sticking suggesting that the specific cultural conditions used during propagation decrease colonization by both natural and inoculated populations of the fungi. Even though colonization decreased during propagation, inoculation reduced the time required for rooting and caused measurable changes in root biomass of rooted cuttings. This increased root biomass may lead to increased quality and performance of rooted cuttings after transplanting. [Article copies available for a fee from The Haworth Document Delivery Service: 1-800-HAWORTH. E-mail address: <docdelivery@haworthpress.com> Website: <<http://www.HaworthPress.com>> © 2005 by The Haworth Press, Inc. All rights reserved.]

**KEYWORDS.** Ericoid mycorrhizal fungi (EMF), *Vaccinium corymbosum* L., *Vaccinium ashei*, *Vaccinium angustifolium*

### INTRODUCTION

Ericoid mycorrhizal fungi (EMF) form symbiotic relationships with roots of blueberry plants providing increased access to nutrients from fertilizer and soil (Read, 1996). Under field conditions, mycorrhizal infection of cultivated blueberries varies greatly with soil and cultural factors (Boyer et al., 1982; Goulart et al., 1986; Powell and Bates, 1981; Scagel and Yang, 2003; Yang et al., 1998). Colonization of blueberry can vary significantly with cultivar (Czesnik and Eynard, 1990; Eynard and Czesnik, 1989), rate of fertilizer application (Golldack et al., 2001;

Powell, 1982) and the amount and type of soil organic matter present in the soil.

Root colonization by EMF is common on plants in the wild. However, there are few reports detailing presence of ericoid mycorrhizae in blueberry nurseries. In nursery production, blueberry plants can become naturally colonized by EMF, however, colonization is sporadic and can be quite low depending on the cultivar and production method (Scagel et al., 2004). Low levels of colonization on blueberry plants in the nursery may be a result of nursery cultural conditions, low availability of EMF propagules, and aspects of plant-fungus compatibility. Little is known about the roles that EMF play in nursery production of blueberry and whether establishment of the plant-fungus relationship can influence the productivity and quality of blueberry plants produced in a nursery. A field study in Northeastern North America found that inoculation of tissue-cultured highbush blueberry can increase plant growth and root dry weight (Yang et al., 2002), while others reported no significant growth responses of lowbush blueberry (Smagula and Litten, 1989) or highbush (Reich et al., 1982) to inoculation with EMF. Optimal use of EMF inoculum has not been well defined. One common question is when to apply EMF inoculum 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.

The objectives of this work were to determine whether inoculation of blueberry nursery plants with EMF influences rooting, subsequent plant growth, or mycorrhizal colonization of blueberry plants produced from tissue culture and cuttings.

## MATERIALS AND METHODS

*Inoculum production.* A mixed inoculum of three EMF [*Oidiodendron griseum* Robak, ATCC 60377, isolated from *Vaccinium corymbosum* L. cv. Bluejay; *Pezizella ericae* Pearson et Read, ATCC 32985, isolated from ericaceous roots; and *Hymenoscyphus ericae* (Read) Korf & Kernan, UAMH 5828, isolated from *Vaccinium angustifolium* L.] was prepared from liquid cultures of each fungal isolate. Fungi were grown

as separate isolates in sterile culture in liquid Modified Melins-Norkrans (MMN) (Molina and Palmer, 1982). One day prior to inoculation, hyphae were harvested by filtration, fragmented with a blender, and the resultant fragmented hyphae were resuspended in 1 L sterile water. A subsample of 1 ml of each isolate was used to quantify inoculum concentration. This was assessed by aseptically transferring 0.25 ml of hyphal suspension onto MMN agar media (4 replicate plates per isolate) and incubating cultures for 7 days at 20°C. The remainder of the hyphal suspensions for each isolate were mixed together and used for inoculations. The mixed inoculum was prepared by diluting the hyphal suspensions of each isolate to 1200 ml with sterile water then combining 100 ml of water based inoculum of each isolate together for inoculation treatments. All inoculation treatments were performed on plants growing in a commercial blueberry nursery in Lowell, OR (Long. 43°92'06" N, Lat. 122°77'96" W).

*Inoculation of plants produced from tissue culture.* In March, 2001, tissue culture plants were inoculated during rooting (the same day unrooted tissue culture cuttings were stuck) with the mixed EMF inoculum and maintained in a production greenhouse until plants were moved outside. The experiment consisted of 3 replicate flats per inoculation treatment (mixed inoculum) and 3 replicate flats per control for each cultivar (*Vaccinium corymbosum* L. 'Bluecrop', 'Rubel', and 'Misty'). Flats contained a minimum of 180 plantlets in single 80 ml cells filled with a proprietary peat growing medium that had been steam pasteurized prior to sticking. Each cell per flat was inoculated with 20 ml of mixed inoculum by drenching rooting medium with the inoculum. Plants were grown under commercial production conditions with applications of a proprietary liquid fertilizer and pest and disease control measures used as needed. Subsamples from inoculated and control populations were assessed for EMF colonization, and growth measurements were made for two production seasons. During the first growing season, random samples of plants from each flat ( $n > 5$ ) were destructively harvested for colonization. Biomass determinations occurred during the rooting phase (March), prior to plants being moved to outdoor conditions (April-May), after transplant into 2 L containers containing a proprietary growing medium of bark, peat, and perlite with a proprietary slow release fertilizer blend (June-July), and several times through the remainder of the first growing season. A random sample ( $n > 5$ ) of non-inoculated and inoculated plants were also harvested four times during the second growing season (2002).

*Inoculation of plants produced from cuttings.* In May, 2001, cuttings were inoculated during rooting (the same day cuttings were stuck) with the mixed EMF inoculum and maintained in an unheated plastic covered hoop house. The experiment consisted of 3 replicate flats per inoculation treatment and 3 replicate flats per control for each cultivar (*Vaccinium corymbosum* L. 'Duke', 'Rubel', and 'Reka'). Flats contained a minimum of 140 cuttings stuck into a proprietary propagation medium of peat and perlite. Flats were inoculated by drenching the rooting medium with 1400 ml of mixed inoculum and cuttings were rooted under commercial production conditions with applications of a proprietary liquid fertilizer and pest and disease control measures used as needed. For five months after sticking, a random sample of plants from each flat ( $n > 5$ ) were taken at monthly intervals from treated and control populations and were assessed for rooting (percentage of cuttings with roots), EMF colonization and root growth.

*Root colonization.* Root colonization by EMF was assessed as previously described (Scagel et al., 2004). Colonization frequency was calculated as a percentage of plants in the sample population that showed signs of colonization by EMF. Colonization intensity was calculated as the percentage of root length on a plant showing signs of colonization by EMF.

*Statistical analyses.* Data from each inoculation trial were subjected to separate three-factor ANOVA procedures with time after inoculation, cultivar, and inoculation treatments as main effects. Means were separated at  $p < 0.05$  using Tukey's Honestly Significant Difference for unequal sample size (THSD). Root weight and length data were arcsin transformed and specific root length and root colonization data were square root transformed prior to analysis to equalize between sample variance ( $p > 0.05$  Brown-Forsythe Test for Homogeneity of Variances) and achieve best model fit. Back transformed data are presented in figures. Correlations between specific variables were analyzed using Pearson's Product Moment Correlation Coefficient ( $r$ ). All analyses were performed using the Statistica® statistical package (Statsoft, Inc., Tulsa, OK, USA, 1996).

## RESULTS

*Inoculation of plants produced from tissue culture.* For all cultivars, more plants from flats inoculated with EMF showed signs of colonization (percentage of plant colonized = colonization frequency) in the first

two months after inoculation (April-May) than plants from non-inoculated flats (Figures 1A, C, E). After transplanting and relocating plants to an outdoor growing area, the number of plants showing signs of colonization by EMF decreased for all cultivars, then increased for the remainder of the summer. Inoculation had little effect on the percentage of 'Misty' and 'Rubel' plants colonized by the end of the first growing season but more inoculated 'Bluecrop' plants showed signs of EMF colonization than non-inoculated plants at the end of the first growing season.

Inoculation increased the percentage of root length colonized (percentage of root length colonized = colonization intensity) by EMF for all cultivars during the first growing season (Figures 1B, D, F). The intensity of colonization on non-inoculated plants was low (< 5%) for most of the first growing season. Plants of 'Misty' showed the highest levels of root colonization in both inoculated and non-inoculated treatments very early during the rooting process prior to when plants were transplanted and relocated to an outdoor growing area. After transplanting, root colonization of 'Misty' decreased for both inoculated and non-inoculated plants while root colonization increased after transplanting for inoculated 'Bluecrop' and 'Rubel' plants. Both 'Rubel' and 'Bluecrop' had the highest colonization intensity in August, after which colonization decreased for the remainder of the growing season. At the end of the first growing season, inoculated 'Bluecrop' and 'Rubel' plants were more colonized than non-inoculated plants, while there was no significant difference in colonization intensity between inoculated and non-inoculated 'Misty' plants. Intensity of root colonization was correlated with colonization frequency only on plants of 'Bluecrop' during the first growing season (Table 1).

Root length (m/plant) of inoculated and non-inoculated plants were similar until five to six months after inoculation (Figures 2A, C, E). Inoculated plants of all cultivars had longer total root length than non-inoculated plants during August and September of the first growing season. Inoculated plants of 'Misty' and 'Bluecrop' had greater total root length than non-inoculated plants by the end of the first growing season while non-inoculated and inoculated 'Rubel' plants had a similar total root system length. Root length was positively correlated with colonization intensity in all cultivars during the first growing season (Table 1).

Non-inoculated 'Misty' plants had more fine roots (higher length per root system weight) prior to transplanting while after transplanting, roots of inoculated 'Bluecrop' and 'Rubel' were finer than roots of

FIGURE 1. Change in the percentage of EMF-colonized blueberry (*Vaccinium corymbosum* L. 'Misty', 'Bluecrop', and 'Rubel') plants (A, C, E) and EMF-colonized root length (B, D, F) during the first growing season after inoculation of plants from tissue culture (Control = non-inoculated plants; Inoculated = inoculated plants). Error bars represent 95% least significant differences (LSDs).

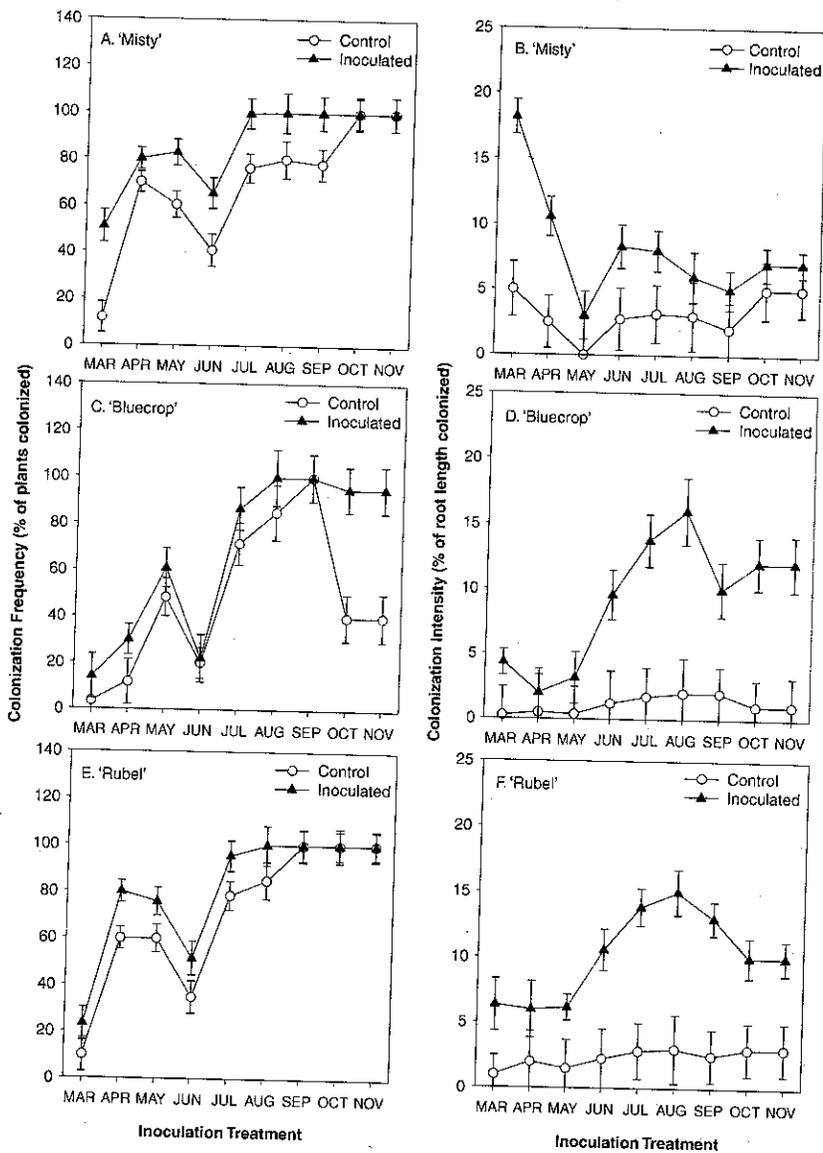


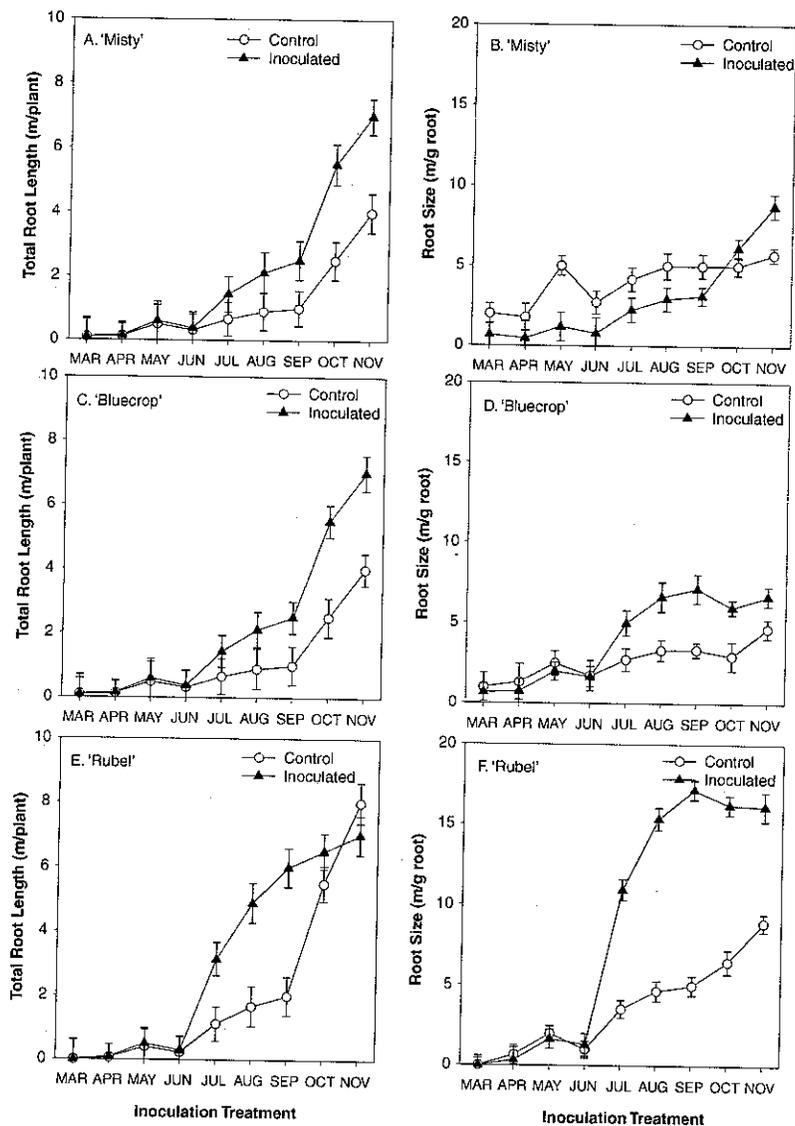
TABLE 1. Significant ( $p < 0.05$ ) correlations (Pearson  $r$ ) between ericoid mycorrhizal colonization and plant growth parameters measured during the first growing season for inoculated and non-inoculated blueberry (*Vaccinium corymbosum* L. 'Misty', 'Bluecrop', and 'Rubel') plants.

Parameter	$r$					
	Cultivar	Colonization Intensity	Colonization Frequency	Root Length	Root Size	Root Biomass
Colonization Intensity	'Misty'	-	ns <sup>2</sup>	-	-	-
	'Bluecrop'	-	0.600	-	-	-
	'Rubel'	-	ns	-	-	-
Root Length	'Misty'	0.632	ns	-	-	-
	'Bluecrop'	0.536	0.507	-	-	-
	'Rubel'	0.739	ns	-	-	-
Root Size (m/g)	'Misty'	ns	ns	0.792	-	-
	'Bluecrop'	0.831	0.729	0.777	-	-
	'Rubel'	0.697	0.673	0.740	-	-
Root Biomass	'Misty'	0.789	ns	0.791	ns	-
	'Bluecrop'	ns	ns	0.932	0.610	-
	'Rubel'	0.628	ns	0.851	ns	-
Leaf Number	'Misty'	0.765	ns	0.493	0.483	ns
	'Bluecrop'	0.716	0.683	ns	0.604	ns
	'Rubel'	0.688	0.632	0.490	0.780	ns
Leaf Size (no./g)	'Misty'	-0.642	0.619	-0.557	-0.608	-0.550
	'Bluecrop'	ns	ns	-0.598	ns	-0.718
	'Rubel'	ns	ns	ns	ns	ns
Leaf Biomass	'Misty'	0.792	ns	0.818	0.778	0.731
	'Bluecrop'	0.803	0.654	ns	0.702	ns
	'Rubel'	0.615	0.696	0.528	0.822	ns
Stem Weight	'Misty'	0.618	ns	0.926	0.814	0.670
	'Bluecrop'	0.728	0.531	0.904	0.859	0.885
	'Rubel'	0.707	ns	0.936	0.525	0.964

<sup>2</sup>ns = non-significant correlation ( $p > 0.05$ )

non-inoculated plants (Figures 2B, D, F). The amount of fine roots was positively correlated with colonization frequency and intensity in both 'Bluecrop' and 'Rubel'. Plants with finer roots usually had more leaves per plant and a greater total weight of stems and leaves per plant (Table 1). Inoculation of 'Misty' increased total root biomass during both the growing seasons while inoculation of 'Bluecrop' only increased

FIGURE 2. Total root length (A, C, E) and root size (m/g-specific root length) (B, D, F) of non-inoculated and inoculated blueberry (*Vaccinium corymbosum* L. 'Misty', 'Bluecrop', and 'Rubel') plants produced from tissue culture during the first growing season after inoculation (Control = non-inoculated plants; Inoculated = inoculated with ericoid mycorrhizal fungi). Error bars represent 95% least significant differences (LSDs).



root biomass during the second growing season and had little effect on root biomass of 'Rubel' (Figures 3). Plants with longer total root length generally had a higher total root biomass. Both total root length and root biomass were positively correlated with stem biomass during the first growing season for all cultivars (Table 1).

Inoculation generally increased the number of leaves on 'Bluecrop' and 'Rubel' throughout the first growing season (Figures 4C, E) but only increased the number of leaves on 'Misty' during the first two months after inoculation (Figures 4A). In the fall of the first growing season, inoculated 'Bluecrop' plants lost approximately twenty percent of their leaves by October while non-inoculated 'Bluecrop' had lost over 50% of their leaves. The number of leaves per plant was positively correlated with colonization intensity in all cultivars during the first growing season (Table 1). When plants of 'Misty' were growing in the greenhouse, inoculated plants generally had smaller leaves (leaves/g) than non-inoculated plants. However, after plants were transplanted and moved to an outdoor growing area, leaves on inoculated plants were a similar size as leaves on non-inoculated plants (Figure 4B). Leaves of 'Rubel' and 'Bluecrop' were similar in size regardless of inoculation treatment (Figures 4D, F).

Inoculated 'Rubel' had a higher leaf biomass than non-inoculated plants for both the first and second growing season while inoculation only increased leaf biomass of 'Misty' and 'Bluecrop' during the second growing season (Figures 5A, B, C). At the beginning of the second growing season, inoculated plants of all cultivars produced leaves earlier than non-inoculated plants. Inoculation had little effect on stem biomass during the first growing season while inoculated plants had higher stem biomass during the second growing season than non-inoculated plants for all cultivars (Figures 6A, B, C). During the first growing season the weight of leaves and stems were positively correlated with the colonization intensity and fine roots (root size-m/g) (Table 1). Stem weight was also positively correlated with total root length and root weight. Inoculated 'Misty' plants partitioned more biomass to roots than shoots (higher shoot:root weight ratio) than non-inoculated plants for most of the first growing season while inoculated 'Rubel' and 'Bluecrop' plants generally partitioned more biomass to shoots than roots (Figures 7A, B, C). In the second growing season after inoculation, inoculated plants generally partitioned more biomass to shoots than roots for all cultivars.

*Inoculation of plants produced from cuttings.* Inoculation of propagation media increased colonization frequency and intensity on roots of

FIGURE 3. Root biomass of non-inoculated and inoculated blueberry (*Vaccinium corymbosum* L. 'Misty', 'Bluecrop', and 'Rubel') plants produced from tissue culture during the first and second growing seasons after inoculation (Control = non-inoculated plants; Inoculated = inoculated with ericoid mycorrhizal fungi). Error bars represent 95% least significant differences (LSDs).

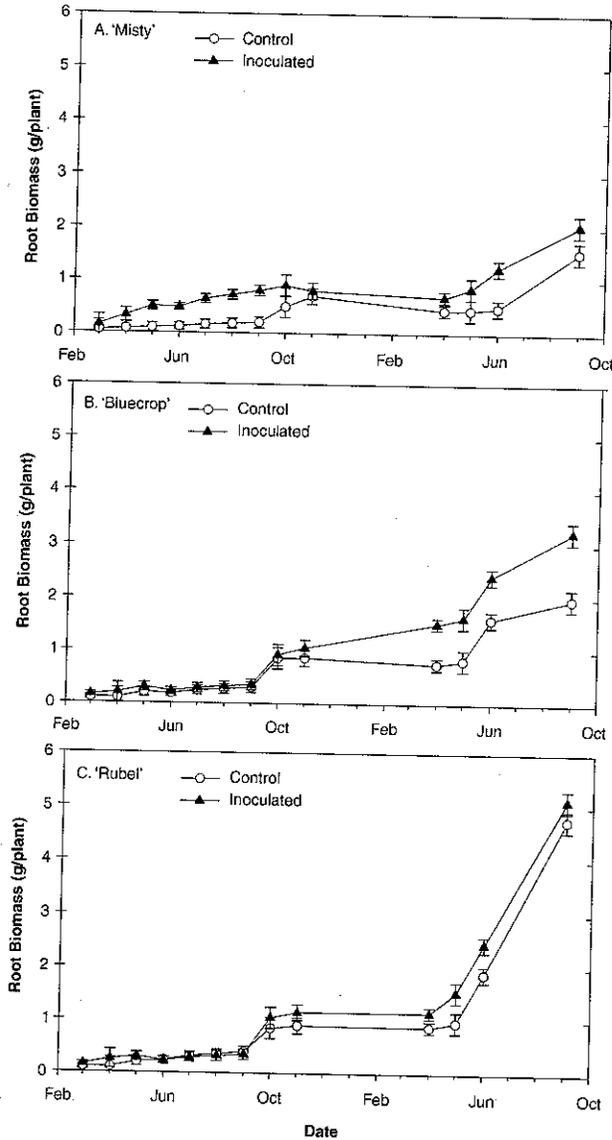


FIGURE 4. Number of leaves (A, C, E) and leaf size (B, D, F) of non-inoculated and inoculated blueberry (*Vaccinium corymbosum* L. 'Misty', 'Bluecrop', and 'Rubel') plants produced from tissue culture during the first growing season after inoculation (Control = non-inoculated plants; Inoculated = inoculated with ericoid mycorrhizal fungi). Error bars represent 95% least significant differences (LSDs).

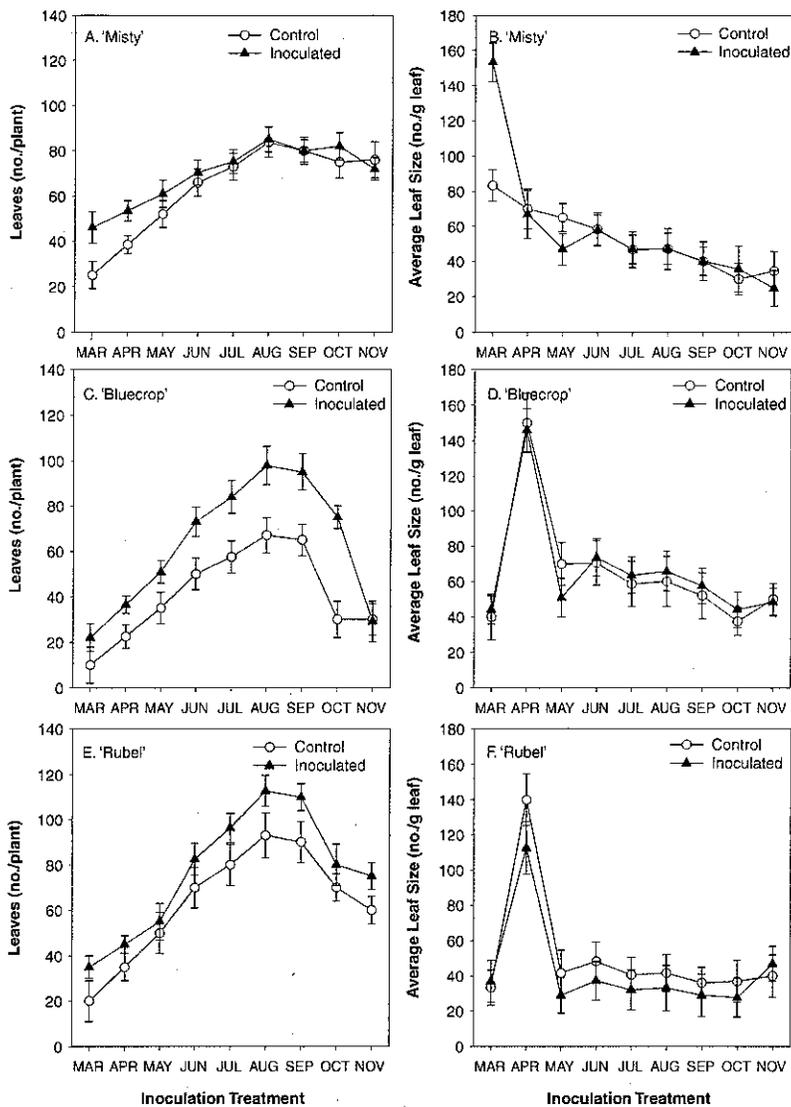


FIGURE 5. Leaf biomass of non-inoculated and inoculated blueberry (*Vaccinium corymbosum* L. 'Misty', 'Bluecrop', and 'Rubel') plants produced from tissue culture during the first and second growing seasons after inoculation (Control = non-inoculated plants; Inoculated = inoculated with ericoid mycorrhizal fungi). Error bars represent 95% least significant differences (LSDs).

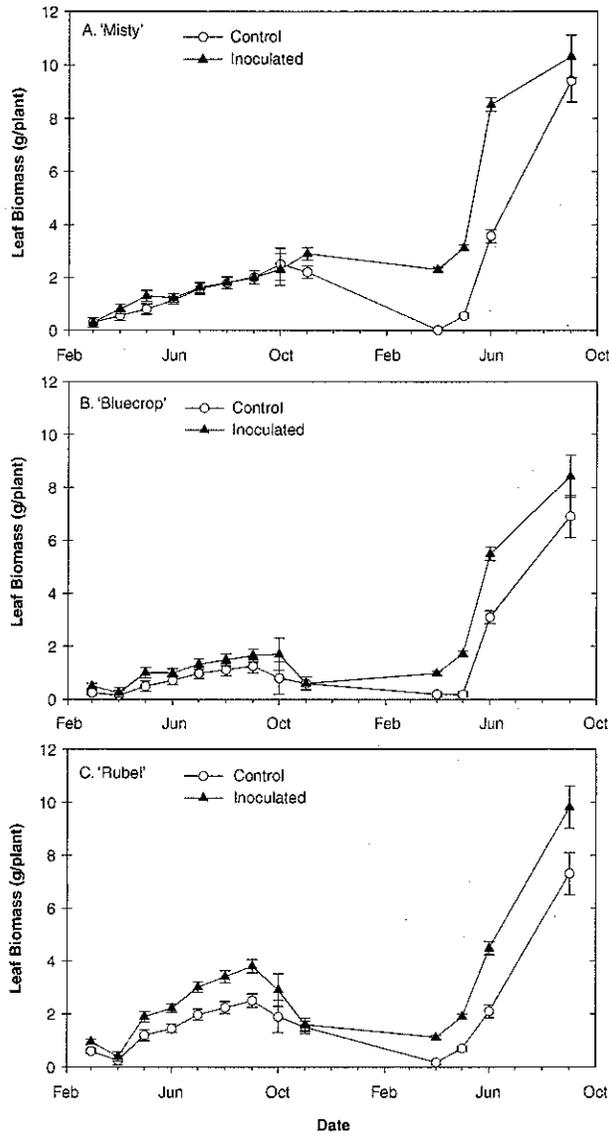


FIGURE 6. Stem biomass of non-inoculated and inoculated blueberry (*Vaccinium corymbosum* L. 'Misty', 'Bluecrop', and 'Rubel') plants produced from tissue culture during the first and second growing seasons after inoculation (Control = non-inoculated plants; Inoculated = inoculated with ericoid mycorrhizal fungi). Error bars represent 95% least significant differences (LSDs).

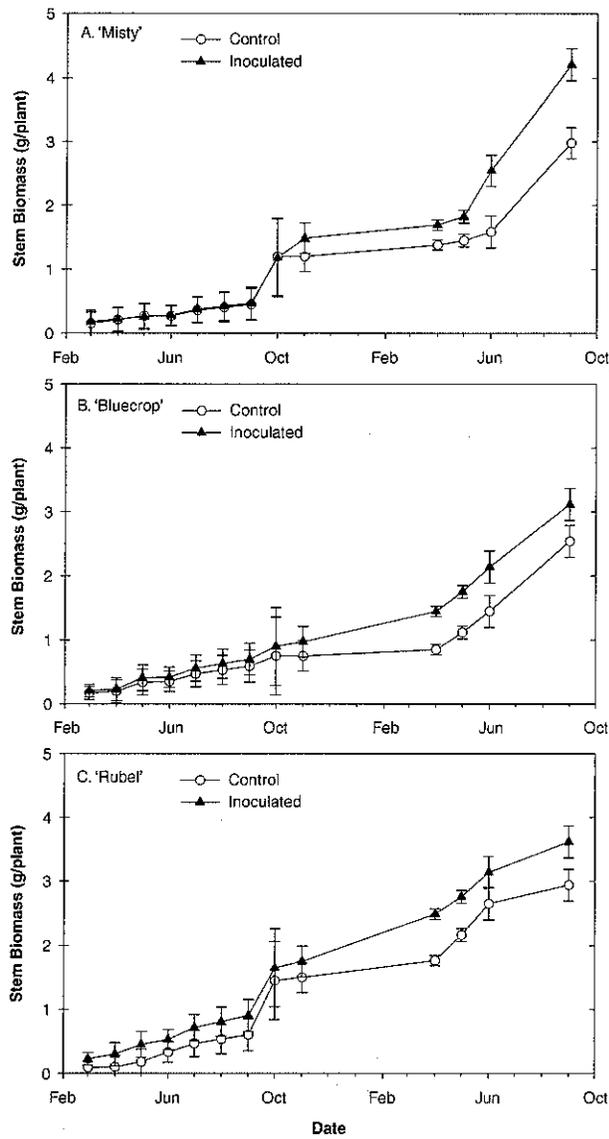
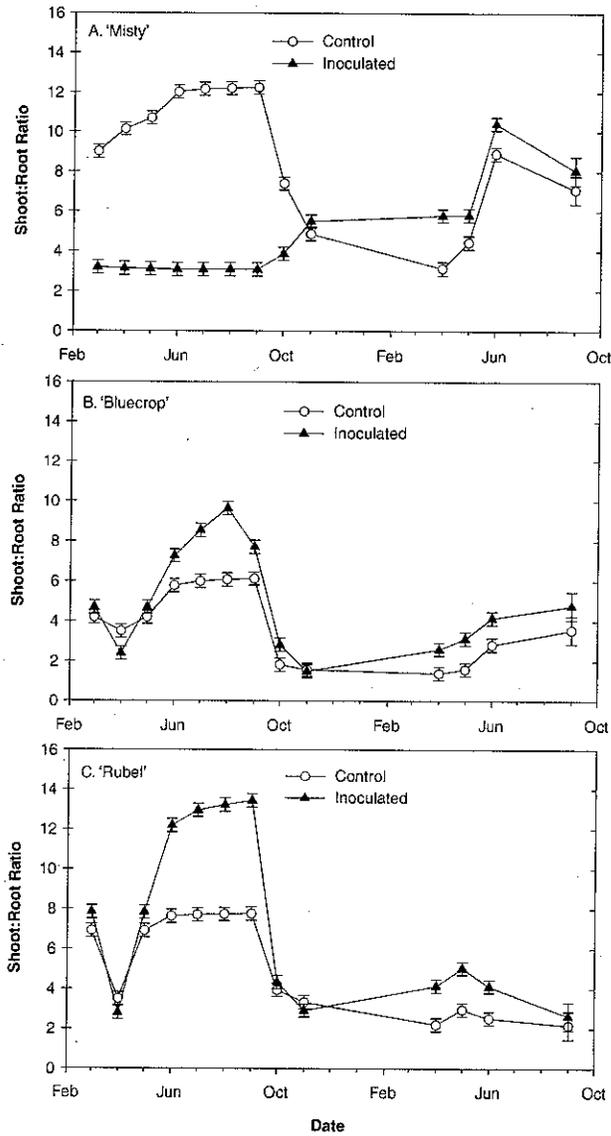


FIGURE 7. Shoot to root ratio of non-inoculated and inoculated blueberry (*Vaccinium corymbosum* L. 'Misty', 'Bluecrop', and 'Rubel') plants produced from tissue culture during the first and second growing seasons after inoculation (Control = non-inoculated plants; Inoculated = inoculated with ericoid mycorrhizal fungi). Error bars represent 95% least significant differences (LSDs).



cuttings for all three cultivars (Figures 8A, C, E). With control cuttings, natural colonization frequency generally decreased between three and five months after sticking cuttings in flats. Colonization had a patchy distribution in control flats and a more uniform distribution in inoculated flats (data not shown). Colonization intensity on cuttings was lower on control cuttings than inoculated cuttings during the first 5 months after sticking (Figures 8B, D, F). Colonization intensity of inoculated 'Duke' and 'Rubel' decreased between 3 and 5 months after inoculation while colonization intensity of 'Reka' increased.

Two months after sticking, rooting of inoculated cuttings of 'Reka' and 'Rubel' was greater than rooting of non-inoculated cuttings (Figures 9C, E). Differences in rooting between inoculated and non-inoculated 'Duke' cuttings were detectable 3 months after sticking (Figure 9A). By 4 months after sticking, the percentage of rooted cuttings in inoculated and non-inoculated flats was the same. Root biomass on inoculated 'Reka' and 'Rubel' cuttings was higher than on non-inoculated cuttings during the first four months after sticking (Figures 9D, F). Differences in root biomass between inoculated and non-inoculated 'Duke' cuttings were detectable 3 months after sticking (Figure 9B).

### DISCUSSION

Under conditions in a commercial blueberry nursery, plants produced from tissue culture plantlets can become naturally colonized by EMF from propagules in the growing media during the first few months of propagation. Smagula and Litten (1989) also reported that lowbush blueberry plants from tissue culture could become naturally colonized with EMF during production and Moore-Parkhurst and Englander (1989) reported that *Rhododendron* spp. can become naturally colonized by EMF in commercial nurseries. Powell and Bates (1981) found that the degree of EMF colonization of blueberry roots was related to media sterilization; however, they concluded that the peat based potting mixes they used were low in EMF capable of colonizing highbush blueberry. We found the intensity of colonization by EMF indigenous to the potting mix was generally low and that inoculation of unrooted blueberry tissue culture plantlets with EMF can increase EMF colonization for some cultivars. This suggests that low colonization during nursery production of blueberry may be at least partially a result of low inoculum potential of the growing medium. However, we found that the frequency and intensity of colonization of 'Misty' decreased substantially

FIGURE 8. Change in the percentage of EMF-colonized blueberry (*Vaccinium corymbosum* L. 'Duke', 'Reka', and 'Rubel') plants (A, C, E) and EMF-colonized root length (B, D, F) during the first growing season after inoculation of plants from cuttings (Control = non-inoculated plants; inoculated = inoculated plants). Error bars represent 95% least significant differences (LSDs).

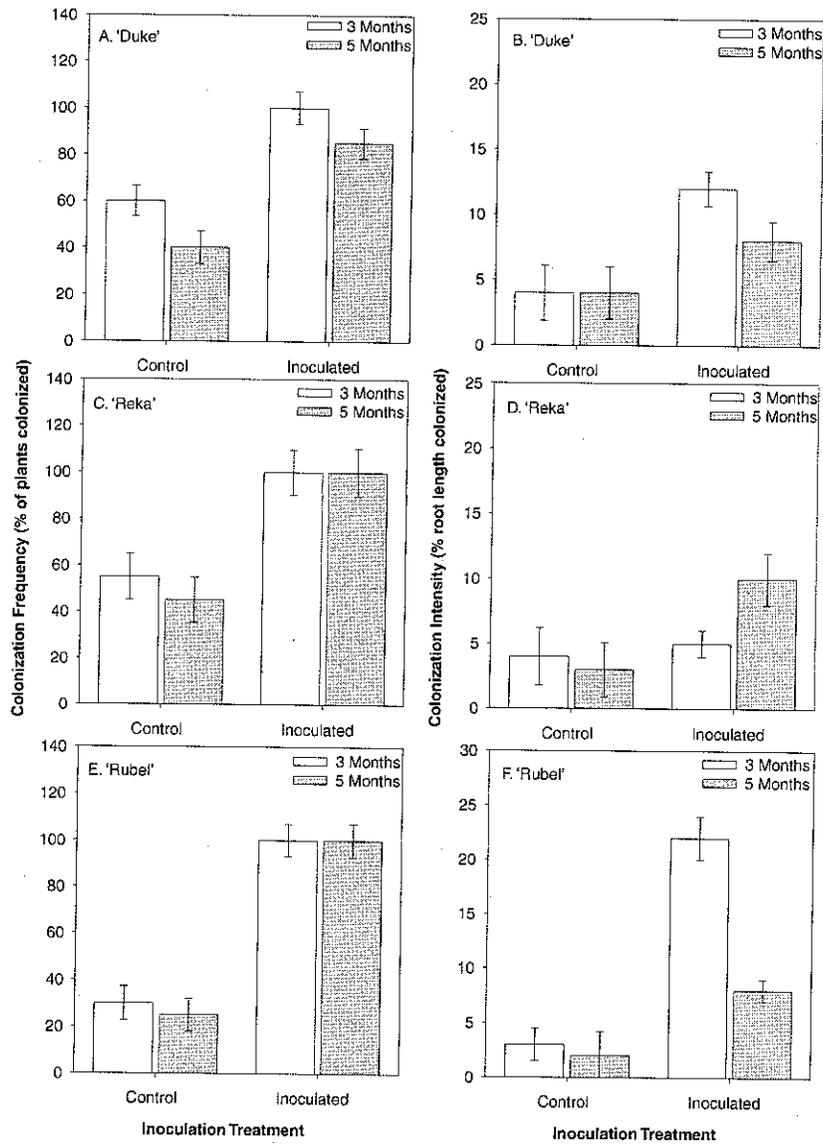
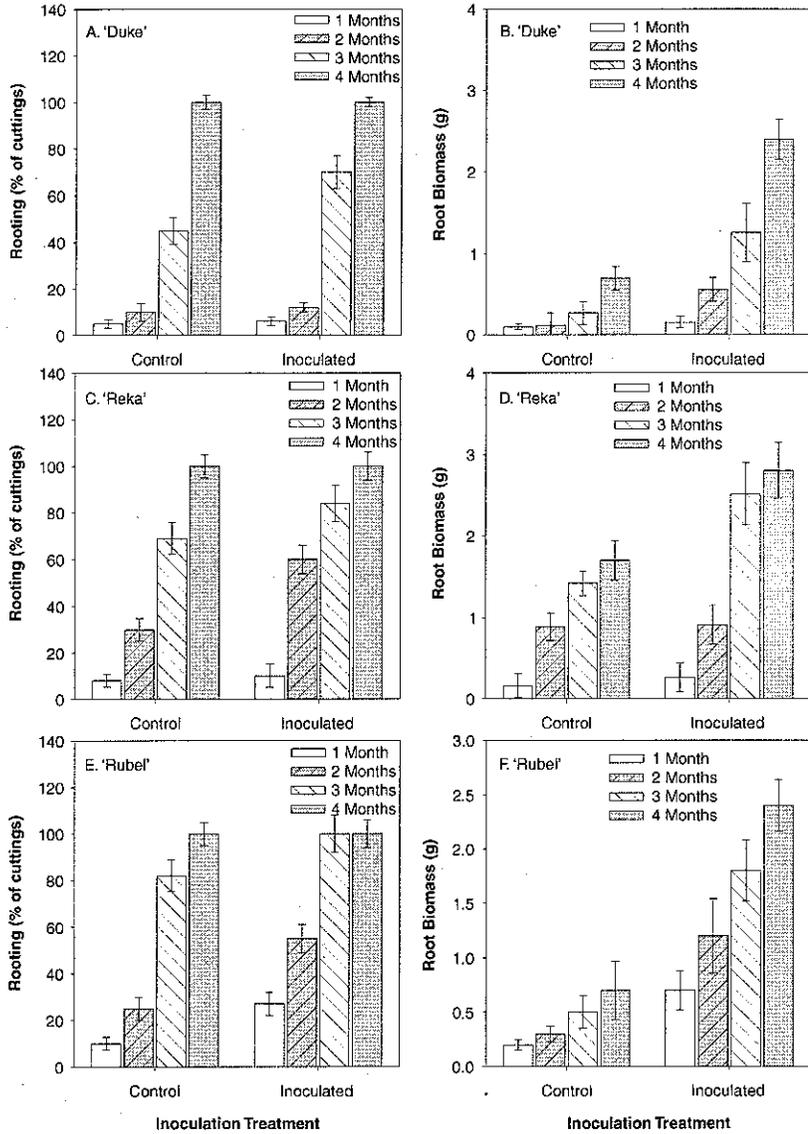


FIGURE 9. Change in the percentage of inoculated and non-inoculated blueberry (*Vaccinium corymbosum* L. 'Duke', 'Reka', and 'Rubel') cuttings with roots (A, C, E) and roots biomass (B, D, F) during the first four months after sticking (Control = non-inoculated plants; inoculated = inoculated plants). Error bars represent 95% least significant differences (LSDs).



after plants were transplanted and moved to an outside growing area. This decrease in colonization in plants produced from tissue culture implies that the fungi used for inoculation may not be suitable for this cultivar under the specific cultural conditions used in the nursery. Scagel et al. (2004) reported a similar decrease in natural EMF colonization of 'Misty' plants produced from tissue culture during their first growing season in the same commercial nursery. This decrease in colonization may be due to changes in cultural conditions that inhibit colonization of the fungi that were present in the initial stages of propagation (Haynes and Swift, 1985; Johansson, 2000) or a possible change of the type of fungi on the root system.

Hardwood cuttings from blueberry plants can become naturally colonized by EMF during the rooting phase of propagation in a commercial nursery, although colonization from natural inoculum was sporadic in this study. This non-uniform colonization of plants is likely due to the low inoculum potential of the rooting medium. Inoculation with EMF can be used to increase colonization frequency and intensity on cuttings under the cultural practices used in a nursery; however, the drop in colonization we found between 3 months and 5 months after sticking suggests that the specific cultural conditions used during propagation decrease colonization by both natural and inoculated populations of the fungi. For example, a similar decrease in natural EMF colonization of 'Duke', 'Reka', 'Rubel', and 'Powderblue' cuttings was also found in the same commercial nursery (Scagel et al., 2004).

In general, inoculation with mycorrhizal fungi has been found to increase plant growth; however, there are many reports which describe an initial lag-phase after inoculation when non-inoculated plants are larger than inoculated plants due to the carbon demands of establishing the symbiosis. Our results suggest that initial demands of establishing the symbiotic association between EMF and blueberry plants produced from tissue culture plantlets did not negatively influence plant growth. Although responses to inoculation with EMF varied with cultivar, we found that inoculation caused measurable changes in root and above-ground plant morphology and biomass partitioning during the first two growing seasons. Differences in biomass between inoculated and non-inoculated plants were generally greater in the second growing season after inoculation. Inoculation caused differential partitioning of biomass above and below ground depending on the cultivar. For example, inoculated 'Rubel' had higher leaf biomass than non-inoculated plants but the same amount of roots while inoculated 'Misty' had more roots than non-inoculated plants but similar leaf biomass. These changes in

biomass partitioning that result from inoculation may influence stock quality. Yang et al. (2002) also reported that inoculation of 'Elliott' highbush blueberry with EMF enhanced plant growth (higher dry weight and larger canopy volumes), while others (Yang et al., 1998; Smagula and Litten, 1989; Reich et al., 1982) reported that inoculation with native, unidentified EMF isolates caused no change in growth of blueberry plants. Differences in plant responses to inoculation between these studies and ours could be related to differences in plant culture (e.g., field soil versus soilless potting medium) and the fungal isolates used for inoculation. We found cultivar-specific growth responses to inoculation with a mixed inoculum of three different isolates of EMF, suggesting that a level of plant-fungus specificity may exist in EMF associations with blueberry plants that influence plant growth.

Plant vegetative development can influence productivity and growth of plants. For example, timing of leaf development in the spring and leaf drop in the autumn can influence photosynthesis and storage of reserves. We found that inoculated blueberry plants produced from tissue culture retained leaves longer in the autumn during the first growing season and produced leaves earlier in the spring of the second growing season. This response to inoculation and higher colonization intensity may be a compensatory response of the plant to the carbon demand of the fungus. In other types of mycorrhizal associations, mycorrhizal colonization has been shown to increase photosynthetic activity and hasten leaf appearance (Eissenstat et al., 1990; Lynch et al., 1991) and may be an adaptive response of the plant to the increased carbohydrate demands resulting from colonization.

Even though colonization decreased during propagation, we found that inoculation decreased the time required for rooting and caused measurable changes in root biomass of rooted cuttings. This increased root biomass may lead to increased quality and performance of rooted cuttings after transplanting. Scagel (2001, 2004) reported a similar decrease in the time required for rooting and increase of root biomass on cuttings of *Rhododendron* spp., *Kalmia latifolia*, and *Leucothoe racemosa* in response to inoculation of propagation media with EMF. With *K. latifolia*, the degree and type of response cuttings displayed to EMF inoculum varied with cultivar. When different isolates of EMF were mixed into the rooting media of *Rhododendron* spp., *L. racemosa*, or *K. latifolia* the degree and type of response of cuttings was dependant on the isolate of EMF used for inoculation. Ectomycorrhizal fungi have been found to produce auxins and cytokinins and induce changes in root hormone levels (Niemi et al., 2002; Niemi et al., 2004), however, little

information is known about hormone production by ericoid mycorrhizal fungi or the changes they may cause in plant hormone (Gay and Debaud, 1986). It is possible that EMF may produce hormones or induce plant production of hormones that cause a stimulation of root development and growth. Although incorporating EMF into the rooting medium of cuttings may not always increase root growth, inoculation does increase EMF root colonization. In the soil-less growing media that may contain low populations of indigenous mycorrhizal fungi, colonization may increase crop uniformity, reduce transplant mortality, and increase productivity (Vosátka et al., 1999).

### GROWER BENEFITS

Inoculation of blueberry with EMF can result in measurable differences in mycorrhizal colonization and plant growth under commercial nursery cultural conditions; however, the responses to inoculation appear to be cultivar-specific. The differences we have reported may not necessarily equate to a significantly higher quality of nursery stock. This work needs to be extended to assess the survival and production performance of inoculated plants in field trials. Results from field trials will enable nursery and field growers of blueberries to understand the role that these fungi may play in nursery stock quality.

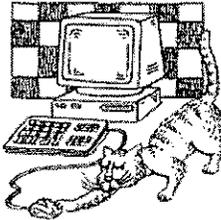
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**CONVERSION TABLE**  
(all figures approximate)

Col. 1	Col. 1 times this = col. 2	Col. 2	Col. 2 times this = col. 1
<b>Length</b>			
inches	2.54	centimeters	0.3937
feet	0.3048	meters	3.2810
miles	1.69	kilometers	0.6214
feet	30.38	centimeters	0.3280
yards	0.9144	meters	1.0940
<b>Area</b>			
acres	0.4047	hectares	2.4710
sq. in.	6.452	sq. cm.	0.1050
sq. yd.	0.8	sq. m.	1.2000
sq. mi.	0.4	sq. km.	2.6000
acres	0.004	sq. km.	247.00
sq. ft.	0.093	sq. m.	10.800
<b>Volume</b>			
acre-in.	102.80	cu. in.	0.0097
qt. (liq. US)	0.9463	liters	1.0570
qt. (imp.)	1.136	liters	0.8799
gal. (US)	3.785	liters	0.2642
gal. (imp.)	4.546	liters	0.2200
oz. (liq. US)	29.57	milliliters	0.0338
teas.	4.9	milliliters	0.2000
tbl.	15	milliliters	0.0670
cups	0.24	liters	4.1700
pints	0.47	liters	2.1300
cu. ft.	0.03	cu. m.	35.000
cu. ft.	0.2832	hectoliters	3.5320
cu. yd.	0.76	cu. m.	1.3000
bushel	0.352	hectoliters	2.8400
bushel	36.00	liters	0.2800
<b>Weight</b>			
oz. (avoir)	28.35	grams	0.0353
lb. (avoir)	0.4536	kilograms	2.2050
cwt.	0.4540	quintal	2.2050
tons (short)	907.2	kilograms	0.0011
tons (short)	0.9072	tonne	1.1020