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Assessing the Infectivity of Commercial Mycorrhizal Inoculants in Plant Nursery Conditions[1]

Lea Corkidi[2], Edith B. Allen[3], Donald Merhaut[4], Michael F. Allen[5],
James Downer[6], Jeff Bohn[7], and Mike Evans[7]

Department of Botany and Plant Sciences and Center for Conservation Biology
University of California, Riverside CA, 92521

─── **Abstract** ───

The infectivity of ten commercial mycorrhizal inoculants was examined in nursery conditions. Corn plants were grown in a soil-based medium and in two different soilless substrates, a potting mix prepared with redwood bark, pine sawdust, calcined clay and sand, and the commercial Sunshine #5 mix, mainly composed of Canadian sphagnum peat moss. The percentage of mycorrhizal colonization obtained with the different mycorrhizal inoculants ranged from 0 to 50%. This variation might reflect the presence or absence of viable propagules, the difference in the recommended rates applied as well as the difference in the content and type of infective propagules of each product. However, the infectivity of each mycorrhizal inoculant was also influenced by the growing media. Two products promoted higher values of mycorrhizal colonization in the Sunshine mix, three in the nursery mix and one in the soil-based medium. Mycorrhizal colonization did not enhance plant growth. Only the plants inoculated with the products that did not promote mycorrhizal colonization increased their growth relative to the non-inoculated controls, suggesting the presence of other growth promoters in the inoculum products. Based on these results, nurseries should conduct preliminary tests to determine which inoculants will perform in their potting mixes to assure the best fit of inoculum with their particular conditions.

Index words: commercial mycorrhizal inoculum, mycorrhizal colonization, soilless potting mixes, corn, *Zea mays*.

Significance to the Nursery Industry

The number of nurseries that use mycorrhizal inoculum in their horticultural practices is increasing (11, 19). However, the infectivity of the commercial mycorrhizal inoculants available in the market has seldom been tested in standard nursery practices, so their efficacy in promoting mycorrhizal colonization is often unknown. Furthermore, the effectiveness of these products can be confounded by the presence of multiple nonmycorrhizal additives (e.g., fertilizers, organic matter, humic acid), which may result in increased plant growth but might not be conducive to mycorrhizal colonization.

We examined the infectivity of several commonly available commercial mycorrhizal inoculants in a soil-based medium and in two soilless mixes used in standard nursery practices. Although some of the tested products failed to promote mycorrhizal colonization in all the conditions tested, the growing media influenced the colonization percentage of the infective inoculants. We recommend that nurseries conduct preliminary tests to determine which products will perform in their potting mixes to assure the best fit of inoculum with their particular conditions.

Introduction

Mycorrhizal technology seems to be a promising field for the nursery industry because of the known growth benefits that plants may obtain from mycorrhizal fungi. Inoculation of horticultural crops with arbuscular mycorrhizal (AM) fungi often increases the survival and growth rates of seedlings and cuttings in greenhouse and natural conditions (18), improves the acclimatization of *in vitro* micropropagated plants (29), and promotes earlier flowering and fruiting (25). Since mycorrhizal plants are more efficient in the uptake of specific nutrients, and more resistant to diseases caused by soil-borne pathogens (2), AM inoculation of plants in containers offers the possibility of reducing fertilizer and pesticide applications (5, 9). Therefore, AM fungi are gaining popularity as 'biofertilizers', 'bioprotectors' and 'biocontrol' agents (2, 18, 27) and the industry of mycorrhizal inoculum production is expanding around the world (28, http://mycorrhiza.ag.utk.edu/).

The number of nurseries that include AM inoculum in their horticultural practices is also increasing (11, 19). However, the infectivity of the commercial mycorrhizal inoculants available in the market has not always been tested in standard nursery practices. To lower the risk of contamination by pathogenic organisms, horticultural crops are usually grown in soilless potting mixes containing different rates of perlite, vermiculite, peat moss and composted forest products. Soilless media also have a lower bulk density, provide better aeration, and a higher water-holding capacity than mineral soils (13, 27). While these artificial rhizosphere conditions may be advantageous to achieve rapid plant growth in containers, their effects on mycorrhizal colonization are not well understood. Some studies suggest that soilless potting mixes are not as favorable as growing media containing soil for the development of mycorrhizal colonization. It has

Table 1. Composition, application rate and expiration date reported in the labels of different commercial mycorrhizal inoculants.

Product	Composition	Application rates/pot[z]	Expiration date
1.[y]	Vesicular arbuscular mycorrhizal fungi	1 tsp	2004
2.[y]	*Glomus intraradices*	10 g	—
3.[y]	*Glomus intraradices*	1 tsp	2004
4.[y]	*Glomus intraradices*	1 g	2002
5.	*Glomus intraradices*	2 tbsp	2004
6.[y]	*Glomus intraradices*	30.5 ml	2002
7.	*Glomus and Gigaspora spp.*	¼ tsp	2004
8.	One or more species of arbuscular mycorrhizal fungi.	2.9 g	2003
9.	Endo/Ectomycorrhizal inoculum	1 tsp	—
10.	*Glomus intraradices*	1 tsp	—

[z]tsp = teaspoon; tbsp = tablespoon; g = gram; ml = milliliter.

[y]Products 1, 2, 3, 4 and 6 are Earth Roots, mycoApply endo, VAM 80, Ascend PB and NTC, respectively (disclosed by permission of the manufacturer).

been reported that redwood shavings, some barks and high content of certain peats have inhibitory effects on mycorrhizal colonization (3, 14, 16, 22); but some investigations have successfully induced mycorrhizal formation in plants grown in soilless media by adding soil, and either using slow-release fertilizers (8) or reducing or optimizing phosphorus solutions (4, 24).

The unpredictability of soilless media to promote mycorrhizal colonization can further be confounded by the multiple additives in the commercial mycorrhizal inoculants, including the different carriers, fertilizers, humic acid, and soil conditioners (31). The objectives of the current study were to test the infectivity of several commonly available commercial mycorrhizal inoculants in standard nursery practices and to analyze plant growth response to inoculation with these products.

Materials and methods

Commercial mycorrhizal inoculants were obtained from several companies that agreed to participate in this study. All the inoculants were stored under the specified conditions for no longer than the recommended expiration date (Table 1).

To compare the infectivity of the different inoculants in nursery conditions, two bioassays were conducted with *Zea mays* (sweet corn, silver queen hybrid), the standard host plant used for mycorrhizal inoculum potential assays (http://invam.caf.wvu.edu/). The experiments were done in a greenhouse at the Tree of Life Nursery in San Juan Capistrano, CA. The first bioassay was conducted from June to August 2002 and the second bioassay from November 2002 to January 2003. Average high/low temperatures were 30/14C (86/58F), respectively during the summer and 23/4C (74/40F), respectively during the fall and early winter.

First bioassay. To determine the time required for commercial mycorrhizal inoculants to promote mycorrhizal colo-

nization, corn plants were grown in a standard nursery mix (NM) prepared with redwood bark, pine sawdust, calcined clay and sand (1:2:1:1, by vol). The NM was steam sterilized at 70C (158F) for three hours on two consecutive days. After sterilization, it was amended with 2 lbs/cu yd (1.17 kg/cu m) of dolomite and 0.5 lb/cu yd (0.28 kg/cu m) of Sierra Micromax® trace element mix. The pH, macronutrients and micronutrients were determined at the Soil and Plant Laboratory, Inc., in Orange County, CA (Table 2) before the incorporation of 1 lb/cu yd (0.6 kg/cu m) of 18N–6P$_2$O$_5$–12K Osmocote® slow release fertilizer.

Plastic containers [656 ml, 25 cm (9.8 in) deep × 6.4 cm (2.5 in) diameter Deepots, Steuwe and Sons, Corvallis, OR], were filled with the NM 9 cm (3.4 in) from the top and in most cases, a layer of inoculum was added at the manufacturer recommended dose (Table 1). One 5-day-old pre-germinated corn seedling was placed directly in the mycorrhizal inoculum and covered with sterilized NM. One product came in a liquid carrier and it was applied directly onto the root system of each seedling at the time of transplanting. There were 30 replicate plants in each of the ten mycorrhizal inoculant treatments and 30 non-inoculated controls (330 experimental units).

Ten randomly selected plants per treatment were harvested 2, 4, and 6 weeks after transplanting. Shoots were separated from roots and were oven-dried at 70C (158F) to record shoot dry mass. A subsample taken from the portion of the root system 8–11 cm (3–4.3 in) below the root-shoot junction was used to assess the percentage of mycorrhizal colonization. Fresh root pieces were cleared and stained using the technique of Koske and Gemma (17) and 50 one-cm (0.4 in) root pieces were mounted in polyvinyl alcohol lacto-glycerol on microscope slides. The percentage of mycorrhizal colonization was determined in 100 intersections by the magnified intersection method of McGonigle et al. (21). ANOVA was used to analyze differences in percentages of mycorrhizal

Table 2. Analysis[z] of three growing media before incorporation of Osmocote® 18N–6P$_2$O$_5$–12K slow release fertilizer. Macro and micronutrients in parts per million.

	Potting soil	pH	NO$_3$	NH$_4$	PO$_4$	K	Ca	Mg	Cu	Zn	Mn	Fe
First bioassay	Nursery mix	7.4	50	13	12	300	3180	528	—	—	—	—
Second bioassay	Nursery mix	7.4	66	91	10	640	9520	1140	9	12	34	18
	Soil:sand	7.3	16	9	7	170	4460	476	1.4	3	7	8
	Sunshine #5	5.2	452	65	224	1000	9800	2920	6.4	28	48	292

[z]Growth medium analysis determined at the Soil and Plant Laboratory, Inc. in Orange County, CA. Major elements by sodium chloride extraction (phosphorus by sodium bicarbonate extraction). Cu, Zn, Mn & Fe by DTPA extraction.

colonization of the plants inoculated with different products. Prior to statistical analysis, AM colonization percentages were arcsine-square root transformed. Mean contrasts were performed using Fisher's protected least significant difference (PLSD) with P < 0.05 as the level of significance (32).

Second bioassay. The percentage of AM colonization of the same inoculants used in the first bioassay was compared in three different potting mixes: a soil-sand medium (SSM; soil:sand, 1:1, by vol) and two different soilless substrates, the commercial Sunshine #5 mix (SUN) (http://www.sungro.com/products/profmixwin5.html), mainly composed of Canadian sphagnum peat moss, and the previously described NM. The SSM and the NM were steam sterilized as mentioned above and the growing medium analysis was determined as in the first bioassay. The three potting mixes differed in their content of nitrogen (N), phosphorus (P) and potassium (K) and the SUN had a considerably lower pH than the SSM and NM (Table 2).

To increase the chance of contact of the inoculant with the host root system, smaller plastic containers were used [160 ml capacity, 21 cm (8.2 in) deep × 3.8 cm (1.5 in) diameter Super Cells, Steuwe and Sons, Corvallis, OR]. Eighty-four Super cells were ¾ filled with each of the three different mixes and watered to compact the potting medium.

Five-day-old pre-germinated corn seedlings were inoculated with the ten different products (Table 1) and covered with potting mix. There were seven replicates of each mycorrhizal inoculant in each potting mix and seven non-inoculated controls (231 experimental units). The 21 Super cells of each mycorrhizal inoculum treatment were distributed in racks that were rotated weekly in the greenhouse bench.

The shoot height of the plants was recorded every ten days, and the relative growth rate (RGR) was calculated as the increase of the shoot height in each period per cm/cm/day (7).

All plants were harvested seven weeks after transplanting. Shoots were separated from roots, oven-dried at 70C (158F) and weighed to record shoot dry mass. The roots of plants grown in the SSM and NM were divided in two subsamples and the fresh weight was determined on both. The 8–11 cm (3–4.3 in) portion of the root system was maintained fresh and stained with trypan blue (17) to assess AM colonization percentage as in the previous bioassay, but the percentage of root length colonized by intraradical hyphae, arbuscules and vesicles was also recorded (21). The remaining root was oven-dried and used to calculate root dry mass based on fresh/dry mass relationship. In plants grown in the SUN, the same portion of the root system was used to assess AM colonization. However, it was not possible to remove the peat moss from the roots, so the root mass of these plants was not determined.

Two way ANOVA with potting medium and commercial mycorrhizal inoculant as factors was performed on shoot height, shoot dry mass and AM colonization. One way ANOVA was performed to analyze significant differences between mycorrhizal inoculant treatments in each potting medium. Prior to statistical analysis, data were tested for normality with the Kolmogorov-Smirnov test (32) and AM colonization percentages were arcsine-square root transformed. Mean contrasts were performed using Fisher's protected least significant difference (PLSD) with P < 0.05 as the level of significance (32).

Results and Discussion

First bioassay. Only plants inoculated with products 1 and 2 showed mycorrhizal colonization two and four weeks after transplanting (AM colonization percentage mean ± standard error of products 1 and 2 was 9.7 ± 2.1 and 0.8 ± 0.6, at the first harvest; and 31 ± 8 and 23 ± 3, at the second harvest, respectively). Six weeks after transplanting, plants inoculated with products 3, 4, 5 and 7 were also colonized by AM fungi. Four of the 10 products (6, 8, 9 and 10) did not promote mycorrhizal colonization in the first bioassay.

Second bioassay. The factorial ANOVA indicated a significant effect of inoculant but not potting medium on the percentage of mycorrhizal colonization. There was a significant interaction between mycorrhizal inoculant and potting medium (Table 3).

The most infective inoculants were products 1, 2, 3 and 4. Plants inoculated with these products reached up to 20–50 percent of AM colonization in at least one of the growing media (Table 4). The percentage of mycorrhizal colonization in plants inoculated with products 5 and 6 was lower than 5% in all the growing media (Table 4). Plants inoculated with product 7 had less than 1% of mycorrhizal colonization in the NM only and no mycorrhizal colonization was found in plants inoculated with products 8, 9 and 10.

Significant differences were found in the mycorrhizal colonization obtained with each inoculant in the three different potting mixes, but there was no consistent pattern (Table 4). In plants inoculated with product 1, there was no statistically significant difference in the total percentage of AM colonization obtained in the different growing media. However, plants grown in SUN had higher percentage of arbuscules than plants grown in SSM and NM (Table 4).

Corn plants inoculated with product 2 had higher values of mycorrhizal colonization when grown in the NM than in SSM; while plants inoculated with product 3, showed considerably lower values of mycorrhizal colonization in the in the SUN than in the SSM and NM than (Table 4). In contrast, plants inoculated with product 4 showed a significantly

Table 3. *F* ratios of two way ANOVA of potting medium and commercial mycorrhizal inoculant effects on mycorrhizal colonization and growth response of corn. Plants were harvested 7 weeks after transplanting. There were three treatments in the potting medium factor (soil-sand, nursery mix and Sunshine #5) and 11 different inoculum treatments (10 products of commercial mycorrhizal inoculants and one nonmycorrhizal control).

	Mycorrhizal inoculant	Potting medium	Mycorrhizal inoculant × Potting medium
Percentage of Mycorrhizal colonization	34.1***[z]	0.14NS	4.10***
Shoot height	25.6***	245.40***	3.70***
Shoot dry mass	21.1***	212.60***	3.42***

[z]NS and ***, indicate that *F* ratios were not significant or significant at $P \leq 0.001$, respectively.

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Table 4. Mycorrhizal colonization of corn plants inoculated with different commercial mycorrhizal inoculants (percentage of arbuscules (Arb%), vesicles (Ves%) and total (intraradical hyphae, arbuscules and vesicles). Plants were grown for 7 weeks in a soil:sand medium (SSM), in a standard nursery mix (NM) and in Sunshine # 5 potting mix (SUN).

Mycorrhizal inoculant	Mycorrhizal colonization	SSM	NM	SUN
1[x]	Total	A[z] 35.2 ± 4.1a[y]	A 35.1 ± 6.1a	A 50.7 ± 7.9a
	Arb%	22.4 ± 3.0a	26.8 ± 4.2a	47.7 ± 5.9b
	Ves%	23.5 ± 2.8a	13.7 ± 4.4b	6.8 ± 2.1b
2[x]	Total	B 9.2 ± 1.3a	A 21.7 ± 3.9b	B 13.9 ± 2.9ab
	Arb%	8.7 ± 1.1a	19.8 ± 3.9b	12.4 ± 3.3a
	Ves%	0.2 ± 0.2a	0.6 ± 0.5ab	1.7 ± 0.5b
3[x]	Total	B 17.9 ± 3.3a	A 42.9 ± 6.5a	C 06.5 ± 3.2b
	Arb%	8.2 ± 1.7ab	18.3 ± 4.0a	5.3 ± 2.9b
	Ves%	14.7 ± 3.2a	30.9 ± 6.2 a	1.3 ± 0.60b
4[x]	Total	C 3.6 ± 1.8a	B 2.8 ± 2.4a	B 21.5 ± 11.0b
	Arb%	3.2 ± 1.7a	2.0 ± 1.6a	9.8 ± 3.3b
	Ves%	2.4 ± 1.6a	1.3 ± 1.3a	5.5 ± 2.2b
5	Total	C 4.5 ± 2.6a	B 0.8 ± 0.4a	C 0.9 ± 0.5a
	Arb%	2.9 ± 1.6a	0.8 ± 0.4a	0.6 ± 0.4a
	Ves%	3.2 ± 1.8a	0.3 ± 0.2a	0.4 ± 0.3a
6[x]	Total	C 0.2 ± 0.2a	B 4.7 ± 2.7a	C 1.0 ± 0.4a
	Arb%	0.2 ± 0.24ab	4.7 ± 2.7b	0a
	Ves%	0a	0.8 ± 0.4b	0a

[z]Different upper case letters (within columns) indicate significant differences among commercial mycorrhizal inoculants at $P \le 0.05$.

[y]Different lower case letters (across rows) indicate significant differences among soil, nursery and Sunshine # 5 potting mixes at $P \le 0.05$.

[x]Products 1, 2, 3, 4 and 6 are Earth Roots, mycoApply endo, VAM 80, Ascend PB and NTC, respectively (disclosed by permission of the manufacturer).

higher percentage of mycorrhizal colonization when grown only in the SUN. Plants inoculated with product 5 tended to have higher values of colonization in the SSM, and with product 6 in the NM (Table 4), but the differences were not statistically significant. In plants inoculated with product 7, less than 1% of AM colonization was detected only in those grown in the NM (data not shown).

Plant growth responses in the first and second bioassay were similar, therefore, only the results of the second bioassay are shown.

The two way ANOVA indicated a significant effect of commercial mycorrhizal inoculant, potting medium, and a significant interaction between both factors for shoot height and dry mass (Table 3).

One-way ANOVA results indicated that there were no significant differences in the shoot dry mass of the plants grown in the NM and SSM in 8 of the 10 inoculum treatments seven weeks after transplanting. Only the plants inoculated with products 4 and 10 had greater dry mass in the NM than in the SSM (Table 5). However, except corn plants inoculated with products 2 and 9, most of the plants grown in the NM were significantly taller than those grown in the SSM (Table 5).

Plants grown in the SUN were the tallest and had the greatest shoot dry mass (Table 5). These plants nearly doubled the shoot height of the plants grown in the SSM and NM at the beginning of the growing period (data not shown). Ten days after transplanting, the RGR of the shoot height was significantly higher in the SUN than in SSM and NM in plants

Table 5. Shoot dry mass (g) and Shoot height (cm) of corn plants inoculated with ten commercial mycorrhizal inoculants (1–10) and non-inoculated control (control). Plants were grown for seven weeks in a soil:sand medium (SSM), in a standard nursery mix (NM) and in Sunshine # 5 potting mix (SUN).

Mycorrhizal inoculant	Shoot dry mass (g)			Shoot height (cm)		
	SSM	NM	SUN	SSM	NM	SUN
1	A[z] 0.247 ± .019a[y]	A 0.306 ± .040a	C 0.589 ± .040b	C 30.2 ± 1.9a	A 40.1 ± 2.9b	C 50.7 ± 1.4c
2	A 0.396 ± .052a	A 0.492 ± .106a	A 1.040 ± .075b	A 38.2 ± 2.4a	A 43.0 ± 4.0a	C 53.6 ± 3.2b
3	A 0.308 ± .037a	A 0.426 ± .056a	A 1.039 ± .062b	C 30.0 ± 1.4a	A 42.8 ± 1.6b	A 58.0 ± 2.4c
4	C 0.163 ± .030a	A 0.406 ± .066b	A 0.852 ± .033c	C 21.9 ± 1.1a	A 39.9 ± 3.5b	C 56.3 ± 1.8c
5	A 0.277 ± .031a	A 0.309 ± .025a	A 0.787 ± .047b	A 31.7 ± 1.1a	A 39.8 ±1.3b	C 55.8 ± 2.0c
6	A 0.272 ± .028a	A 0.312 ± .028a	A 0.856 ± .071b	A 32.0 ± 1.0a	A 39.6 ± 1.5b	C 54.0 ± 2.4c
7	A 0.413 ± .040a	A 0.500 ± .090a	A 0.850 ± .120b	A 39.2 ± 1.9a	A 49.4 ± 4.5b	C 56.7 ± 4.5b
8	A 0.313 ± .034a	A 0.380 ± .059a	A 0.853 ± .052b	A 36.4 ± 1.5a	A 44.4 ± 1.9b	C 58.4 ± 2.6c
9	B 0.630 ± .075a	B 0.733 ± .213a	B 1.397 ± .095b	B 47.1 ± 1.7a	A 47.8 ± 5.7a	A 63.5 ± 1.8b
10	B 0.487 ± .064a	B 0.820 ± .180b	B 1.190 ± .040c	A 40.0 ± 2.4a	A 51.3 ± 4.3b	A 63.1 ± 0.8c
Control	A 0.304 ± .030a	A 0.396 ± .027a	A 0.929 ± .049b	A 37.1 ± 1.3a	A 46.2 ± 0.8b	A 64.3 ± 1.4c

[z]Different upper case letters (within columns) indicate significant differences among commercial mycorrhizal inoculants at $P \le 0.05$. A = not significantly different from control; B = higher than control; C = lower than control.

[y]Different lower case letters (across rows) indicate significant differences among soil, nursery and sunshine potting mixes at $P \le 0.05$.

inoculated with most of the products (1, 2, 3, 7, 8, 9 and 10) (Fig. 1), but no differences in RGR were found thereafter among the three growing media (data not shown).

Mycorrhizal colonization did not enhance plant growth. Only the plants inoculated with the products that did not promote mycorrhizal colonization increased their growth responses relative to the non-inoculated controls. Plants inoculated with products 9 and 10 had greater shoot dry mass than the non-inoculated controls in the SSM, NM and SUN (Table 5).

The mycorrhizal plants inoculated with products 1, 3, and 4 were shorter than the controls in the SSM and with products 1, 2, 4, 5, and 6, in the SUN. The dry mass of the mycorrhizal plants was only negatively affected in plants grown in the SUN inoculated with product 1 and in those grown in the SSM inoculated with product 4 (Table 5).

As previously mentioned, it was difficult to remove the peat moss in the roots of plants grown in the SUN, and only the root:shoot ratios of the plants grown in soil and NM are reported. Significant differences were found in the root:shoot ratios of plants inoculated with different products. Plants inoculated with 3, 4, 5, 6, 8, 9 and control had higher r/s ratios than plants inoculated with 1, 2, 7 and 10 in both, NM and SSM. There were no significant effects of inoculants on the r/s ratio in either NM or SSM (data not shown).

The variation in the percentage of mycorrhizal colonization obtained with the different inoculants could be attributed to several factors, including inoculum viability or density, nursery conditions, and characteristics of the growing media.

Three out of ten products failed to promote mycorrhizal formation in all the conditions tested, which might be an indication of absence of viable propagules or low densities of propagules diluted in the inoculant carrier. More testing would be required to attribute these results to either the continuous absence of mycorrhizal propagules in a product line or to a bad inoculum batch.

Four products promoted up to 20–50 percent of AM colonization in at least one of the potting media, while three products promoted less than 10 percent. The different infectivities among the inoculants could be explained by their different inoculum densities. Other studies have shown a linear relationship between the amount of mycorrhizal inoculum applied and the percentage of root colonization until a pla-

teau is reached (6, 26). The number of propagules reported in the product labels varied widely and it was not standardized in the different treatments. All the inoculants were applied at the recommended rate.

It is a common trend to relate the 'strength' of commercial mycorrhizal inoculants with their propagule number. While the number of viable propagules in an inoculant influences infectivity, the levels of mycorrhizal colonization can also be controlled by the plant host (1), AM fungal aggressiveness, as well as by the different components of horticultural soilless mixes (12, 16). It has been reported that redwood shavings, some barks, certain peats, and soils with high organic matter content in general, can have inhibitory effects on root colonization by AM fungi (3, 14, 16, 22). We found significant differences in the infectivity of each mycorrhizal inoculant in the three growing media. Two products promoted higher values of AM colonization in the SUN, three in the NM and one in the SSM. The larger size of the plants grown in the SUN could be a confounding factor, but one product had lower AM colonization in the SSM than in the NM (plants with similar shoot and root dry mass) and some products had higher AM colonization in the SUN despite the increased root mass. Miller et al. (23) also found different percentages of AM colonization in plants grown in vermicompost, spent mushroom compost, yard waste compost, and processed manure fiber.

Despite the strong differences in nutrient content, the three growing media used in this study were suitable for mycorrhizal formation. The AM fungi present in the commercial mycorrhizal inoculants was not always specified, but the most frequent species was *Glomus intraradices*. This AM fungi has been chosen as the 'super strain' (30) for many commercial mycorrhizal inoculants because it is a highly infective species of herbaceous and woody plants in a wide range of conditions (10, http://www.invam.caf.wvu.edu). The different patterns in the mycorrhizal colonization promoted by the inoculants in the different potting mixes might be related to the adaptability of the AM fungi to their local conditions. There is increasing evidence that AM fungal performance is superior under the conditions in which the isolates originated (15, 30).

The presence of highly infective AM fungal inoculum does not necessarily indicate that it is always beneficial to plant growth. Mycorrhizal colonization negatively affected the
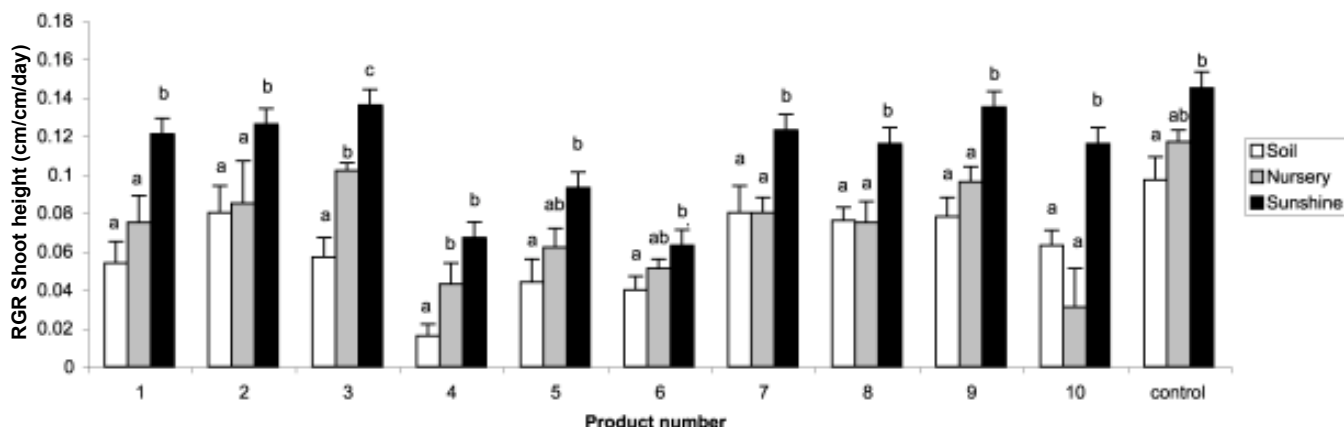
Fig. 1. Relative growth rate of the shoot height of corn plants inoculated with 10 commercial mycorrhizal inoculants (products 1–10) and non-inoculated control (control) ten days after transplanting. Plants were grown in soil:sand, and in nursery and Sunshine # 5 potting mixes. Different letters above bars indicate significant differences of each product within the different growing media at $P \leq 0.05$.

shoot height of the plants grown in the SUN. These growth depressions were not unexpected, due to the high nutrient levels in this medium (20). However, low response to mycorrhizal inoculation in the greenhouse is not necessarily a good predictor of the multiple benefits of mycorrhizae in natural conditions. Long term growth responses under field conditions may be more useful to determine the effectivity of the mycorrhizal inoculum.

Our results also illustrate how the multiple components in the mycorrhizal inoculants can confound the effects of mycorrhizal colonization. Only the plants inoculated with the products that did not promote mycorrhizal colonization improved the growth response of corn plants in this study, suggesting the presence of other growth promoting additives in the products. Plant nurseries should do preliminary tests to understand which AM strains and inoculants will perform in their potting mixes to assure the best fit of inoculum with their particular conditions.

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