Abstract. Disbudded ‘Brooks 56’ Rosa multiflora Thunb. plants were grown in 0.01 or 0.1 Steiner solutions and inoculated with indigenous vesicular–arbuscular mycorrhizal fungal (VAMF) species, Glomus fasciculatum (Thax. sensu Gerd.) Gerd. and Trappe. Inoculation resulted in a significant increase in both fresh and dry weight of the *R. multiflora* plants. Increasing the Steiner solution from 0.01 to 0.1 resulted not only in a significant decrease in the rate of VAMF infection, but also in a significant increase in the fresh and dry weight of the mycorrhizal plants.

The amount of plant tissue (roots) in the world infected by vesicular-arbuscular endomycorrhizal fungi (VAMF) exceeds that infected by any other group of fungi (8, 9). The fungi are found primarily in the cortex of the living plant root (8) but can also colonize organic fragments (25), weed seeds (24), and other ecological niches that may provide appropriate environments, such as portions of dead insects. The mycorrhizal–root association is recognized as a symbiotic interaction (4, 8). Recent research suggests that this relationship can be manipulated to improve economical use of superphosphate fertilizers and increase exploitation of less-soluble rock phosphate (1, 4, 9). Mycorrhizal fungi increase both water and nutrient uptake by increasing the volume of soil explored (11). The fine mycorrhizal roots with increased surface area and length per unit weight are able to draw both water and inorganic phosphorus (P) from a greater volume of soil and increase plant uptake (6, 7, 12, 16).

In general, VAMF are more prevalent in plants grown in low-fertility soils (3, 9, 11) than in those grown in fertile conditions. A balanced high-mineral nutrition may reduce the degree of infection, whereas a low or unbalanced nutrient supply may increase it (3, 11, 13). Graham et al. reported that foliar application of P inhibited VAMF infection of onion, demonstrating that P concentration in the host plays an important role (10). Nitrogen, complete fertilizer, and bacterial fertilizer can also reduce mycorrhizal infection in the field (11). The drouthy, infertile soils of East Texas support one of the 2 major centers of field rose bush production in the United States—worth an estimated $15 million (23). Although much is known about specific elemental leaf tissue levels needed for optimum growth (26), few data have been published concerning specific fertilizer requirements for field roses in Texas or the United States; however, Seeley and Davidson (21) found that roses require more P than is needed by peach and apple trees and other horticultural crops.

Little information is available on the occurrence of mycorrhizal fungi in *Rosa* spp., and no information is available on responses of roses to VAMF. Malloch and Malloch (15) reported roots of 3 Rosaceous plants to be endomycorrhizal, but other Rosaceae, including *Rosa acicularis* Lindl., completely lacked mycorrhiza. They concluded that the mycorrhizal status of the Rosaceae may be correlated with subfamily, i.e., the 4 species of Rosoideae they examined were weakly or nonmycorrhizal and 2 species of the Maloideae showed well-developed endomycorrhizae.

Paterson et al. (18) were the first to show that commercial rootstock plants of *R. multiflora* (subfamily Rosoideae) grown in East Texas were heavily infected with *G. fasciculatum*. Furthermore, it was found that the use of methyl bromide in field soil fumigation experiments significantly reduced VAMF infection in both root and soil samples of *R. multiflora* (‘Brooks 56’) understock (18). This reduction of VAMF may affect mineral uptake and growth of *R. multiflora*. The following study was designed to investigate the effects of 2 levels of a nutrient solution and an indigenous VAMF on the nutritional uptake and growth of *R. multiflora* understock grown under hydroponics.

Four uniform, disbudded 20-cm *R. multiflora* understock hardwood cuttings were planted in each of sixty-four 15-cm cans placed in eight 27 × 61-cm metal containers filled with extra-coarse silica sand. Four 5-mm holes were punched in the bottom of each can. Four of the large metal containers were subirrigated for 15 min with a 0.01 aerated Steiner solution and 4 with a 0.1 aerated Steiner solution (22) to a height of 5 cm and then drained 5 times a day with a soxhlet

### Table 1. Influence of VAMF and nutrient solution concentration on fresh and dry weight and % VAMF infection (percentage) of *R. multiflora* understock.

<table>
<thead>
<tr>
<th>Steiner solution Conc.</th>
<th>Fresh wt/4 plants (g)</th>
<th>Dry wt/4 plants (g)</th>
<th>Infection (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>VAMF</td>
<td>VAMF</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Dead</td>
<td>Live</td>
<td>Avg</td>
</tr>
<tr>
<td>0.01</td>
<td>25</td>
<td>33</td>
<td>29 B*</td>
</tr>
<tr>
<td>0.1</td>
<td>54</td>
<td>64</td>
<td>59 A</td>
</tr>
<tr>
<td>Avg</td>
<td>39 b</td>
<td>48 a</td>
<td></td>
</tr>
</tbody>
</table>

*Mean separation between VAMF treatments or between concentrations by F test at 5% (lower case letter) or 1% (upper case letter).*

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Table 2. Influence of Steiner solution concentration and VAMF on elemental leaf concentrations of
R. multiflora foliage.

<table>
<thead>
<tr>
<th>Steiner solution concn.</th>
<th>R. multiflora Roots (10 g)</th>
<th>Dry wt (%)</th>
<th>Dry wt (μg g⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.01</td>
<td>Autoclaved</td>
<td>1.63</td>
<td>0.27</td>
</tr>
<tr>
<td>0.01</td>
<td>Live</td>
<td>1.54</td>
<td>0.16</td>
</tr>
<tr>
<td>Avg</td>
<td></td>
<td>1.41</td>
<td>0.16</td>
</tr>
<tr>
<td>0.1</td>
<td>Autoclaved</td>
<td>1.21</td>
<td>0.18</td>
</tr>
<tr>
<td>0.1</td>
<td>Live</td>
<td>1.55</td>
<td>0.19</td>
</tr>
<tr>
<td>Avg</td>
<td></td>
<td>1.38</td>
<td>0.18</td>
</tr>
</tbody>
</table>

*Mean separation in a column by F test at 5% (lower case letter) or 1% (upper case letter).

apparatus (5). One-half of the 32 cans in each Steiner concentration in each replication were inoculated with 10 g R. multiflora/‘Kordes Perfecta’ understock roots from a commercial rose production field infected with the indigenous endomycorrhizal fungus, G. fasciculatum, and one-half with 10 g of root inoculation autoclaved 20 min at 121°C (18). Infection of roots used for inoculation purposes was 43% of their total length, as determined by rating 90 one-cm root pieces cleared and stained by the method of Phillips and Hayman (19). An average of 140 adhering extramatrical spores per 10 g of root inoculum were included with the inoculum. Spore numbers were determined by the wet-sieving and decanting procedure (24).

Nineteen weeks after planting, fresh and dry weight determinations were made on the R. multiflora understock. R. multiflora foliage from all treatments was dipped in a deterrent solution, rinsed in distilled water, dried, ground, and analyzed for 9 elements using an adaptation of the procedure described by Parkinson and Allen (17); i.e., N using the ammonia electrode; P̂ using colorimetric procedures; K by flame photometry; and Ca, Mg, Zn, Fe, Cu, and Mn by atomic absorption spectrophotometry.

The use of 10 g R. multiflora roots infected with G. fasciculatum increased the fresh weight and gave a significant increase in the dry weight of disbudded ‘Brooks 56’ R. multiflora understock (Table 1). Increasing the concentration of the Steiner solution from 0.01 to 0.1 decreased the percentage of VAMF root infection significantly (Table 1). Use of the 0.1 solution gave a significant increase in both the fresh and dry weight of multiflora understock (Table 1).

When the 0.1 Steiner solution was used, there was a significant increase in foliage K in comparison with the 0.01 concentration (Table 2). Neither the two concentrations of Steiner solution nor the use of VAMF inoculum had a significant effect on the elemental concentrations of N, P, Ca, Mg, Cu, or Zn in R. multiflora foliage (Table 2). Foliar content of N, P, K, and Cu for plants grown in both nutrient concentrations were below optimum when compared to standards reported by White (26). Magnesium and Mn tissue levels could be considered optimum and Fe and Zn levels high using these same standards (26).

Although plant growth (Table 1) was increased by the use of live VAM inoculum in combination with 0.1 Steiner and lower infection rates of G. fasciculatum with virtually no change in leaf tissue nutrient content (Table 2) when compared to the 0.01 Steiner treatments, the VAMF may have increased this growth of R. multiflora plants by some means other than aiding nutrient uptake. VAMF has been demonstrated to increase photosynthesis and decrease soil-plant liquid flow resistance in Bromus inermis (2) and to increase stomatal conductance and lower leaf water potentials in Glycine max (20) and Citrus jamhiri (14).

Literature Cited