Flowering and Bulb Quality of Liliaceous Species in Response to Mycorrhizal Fungi©

Carolyn F. Scagel and R.G. Linderman
USDA-ARS, Horticultural Crops Research Laboratory, 3420 NW Orchard Street, Corvallis, Oregon 97330

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. There is little available information describing the benefits of inoculation with mycorrhizal fungi on different aspects of productivity and flowering of liliaceous bulb crops except onion (Giovannetti and Riess, 1980; Tawaraya et al., 1999), and little information describing the effects of mycorrhizal fungi on flowering (Byla and Koide, 1998; Johnson et al., 1982). Members of the Liliaceae form mycorrhizal associations with vesicular-arbuscular mycorrhizal fungi (VAMF) (Ames and Linderman, 1977). This paper presents results from several inoculation experiments with VAMF on bulb, corm, and flower production in several liliaceous plant species.

CULTURAL METHOD

Bulbs of the liliaceous plant *Triteleia laxa* 'Koningin Fabiola' (syn. *Brodiaea laxa* 'Queen Fabiola' [wild hyacinth]), *Zephyranthes candida* (white rain lily), *Habranthus robustus* [syn. *Zephyranthes robusta* [pink fawn lily]), *Z. sulphurea* (yellow zephyr lily), *Sparaxis tricolor* (harlequin flower), and *Freesia* hybrids, were inoculated with spores and root fragments of the VAM fungus *Glomus intraradices* by placing inoculum beneath bulbs in pasteurized (60°C 30 min^{-1}) or nonpasteurized soil. Plants were fertilized with liquid fertilizer as needed through their production cycles.

PLANT GROWTH AND FORM

Timing of Development. The number of days it takes for stems and flowers to emerge after planting a bulb or corm influences the length of the crop cycle. We found that inoculation with VAMF decreased the number of days until stem emergence for *T. laxa, H. robusta, Z. candida, Z. sulphurea* (Fig. 1), and *Freesia* (White and Blue). The number of days until stem emergence of *S. tricolor* and yellow *Freesia* was not influenced by inoculation with VAMF. Inoculation with VAMF decreased the number of days until flower emergence for *T. laxa, Sparaxis,* and *Z. sulphurea* (Fig. 1). Inoculation with VAMF increased the number of days until flower emergence for *Freesia,* but had no effect on flower emergence for *Z. candida* and *H. robusta*. Any change in the number of days until stem emergence suggests that although reserves in bulbs and corms are important for growth after planting, inoculation with VAMF can still influence initial plant growth. Change in the timing of plant development could be a result of differential carbon partitioning or nutrient acquisition between plants with or without VAMF.

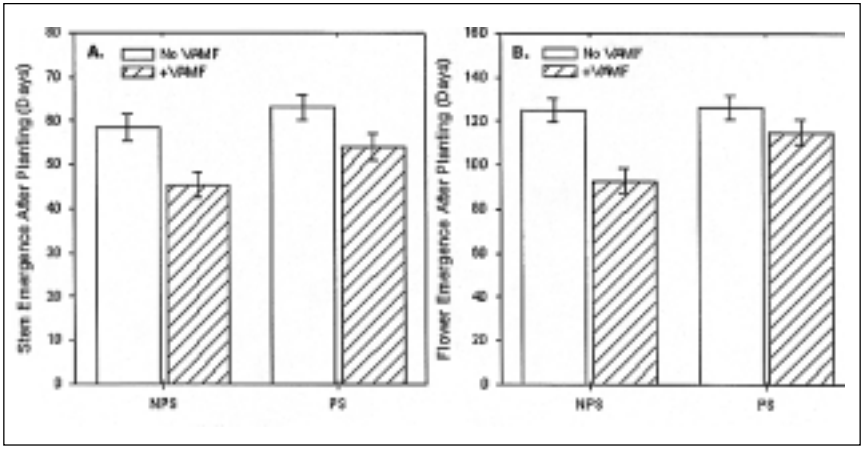

Figure 1. Number of days until stem (A) and flower (B) emergence of *Zephyranthes sulphurea* (yellow zephyr lily) after planting in nonpasteurized (NPS) or pasteurized (PS) soil. No VAMF= no inoculum; +VAMF=VAMF (*Glomus intraradices*) spores and colonized root fragments in a sandy loam-based carrier incorporated into soil (1 : 166 (v/v). Means based on 20 replicate bulbs per treatment. Bars on data points represent LSDs.

Plant Form. Differences in plant form between plants with and without VAMF can influence marketability and also affect flowering, bulb production, and bulb quality as a result of differences in photosynthesis. We found that inoculation with VAMF increased leaves and total leaf area on *Sparaxis* (Fig. 2), *Z. candida*, *H. robusta*, and *Freesia*, but had no effect on the number of leaves of *T. laxa* or *Z. sulphurea*. Leaf area per leaf was only higher in *Zephyranthes* spp.

Partitioning. In bulb and corm crops, optimal cultural practices for the vegetative growth may not necessarily result in optimal flower production due to differential partitioning between vegetative and reproductive structures. In our studies when plants of *Sparaxis* started to flower, their leaf production decreased more when grown in pasteurized soil, but their flower production was not influenced by inoculation with VAMF (Fig. 2).

FLOWER AND BULB PRODUCTION

Flowers. The total number of flowers produced per plant is important for cut flower and container production of bulbous and corm crops. Total flower production on *T. laxa* (Fig. 3), *Sparaxis* (Fig. 2), *Z. sulphurea*, and *Freesia* (Fig. 3) was highest on plants inoculated with VAMF, but it was not influenced by inoculation with VAMF on *Z. candida* and *H. robusta*.

Bulbs. The number of daughter bulbs produced and the weight per bulb are important productivity and quality characteristics of bulb and corm production. We found that the number of daughter bulbs produced in *S. tricolor* and *Freesia* was highest in plants inoculated with VAMF (Fig. 4). Furthermore, the average weight per bulb was higher in *Freesia*, *Zephyranthes* spp., and *T. laxa* bulbs inoculated with VAMF, but VAMF inoculation had no effect on the weight of *Sparaxis* bulbs.

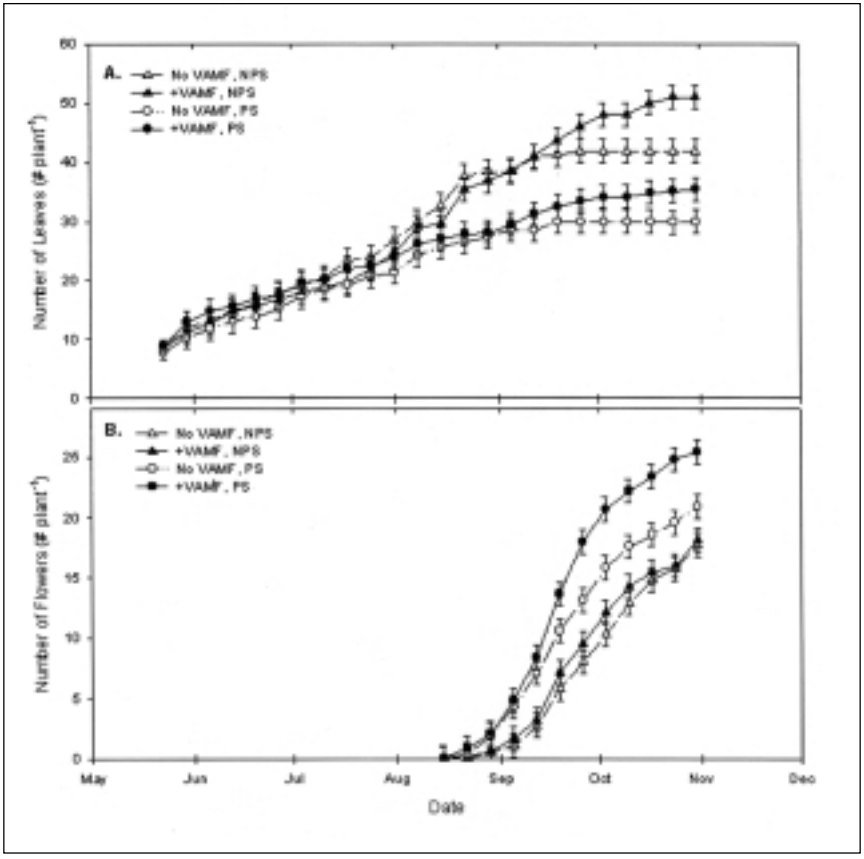

Figure 2. Number of leaves (A) and flowers (B) of *Sparaxis tricolor* (harlequin flower) grown in nonpasteurized (NPS) or pasteurized (PS) soil. No VAMF= no inoculum; +VAMF=VAMF (*Glomus intraradices*) spores and colonized root fragments in a sandy loam-based carrier incorporated into soil (1 : 166 (v/v). Means based on 20 replicate bulbs per treatment. Bars on data points represent LSDs.

BULB COMPOSITION AND CARRY-OVER EFFECTS

Mineral Nutrients. VAMF are reported to cause changes in mineral nutrition in inoculated plants. We found that differences in P, N, K, Ca, Zn, and S content between bulbs inoculated or not with VAMF varied with cultivar tested and whether or not the soil had been pasteurized (Table 1). In *Freesia*, *T. laxa*, and *Zephyranthes*, where bulb weights were highest if inoculated with VAMF, increases in mineral content were a result of increased uptake or nutrient recycling, while decreases were a result of dilution or decreased uptake.

Nitrogen Storage Compounds. Nitrogen-containing compounds, such as proteins and amino acids, are important for initial growth of several perennial crops and may therefore play a role in bulb quality. We found that protein and amino acid content of bulbs of *Zephyranthes* spp., *S. tricolor*, and *Freesia* were higher in bulbs inoculated with VAMF than non-inoculated bulbs (Table 1).

Table 1. Bulb composition in different liliaceous species in response to inoculation with the VAM fungus *Glomus intraradices*.

	Habranthus	*Zephyranthes*			*Freesia*			
Factor	*Triteleia*[1]	Pink	White	Yellow	*Sparaxis*	Blue	White	Yellow
P (%)	=/+[2]	=/=	=/=	+/+	=/=	-/-	-/-	-/-
N (%)	=/+	-/-	-/-	-/=	+/+	-/-	-/-	-/=
K (%)	+/=	+/=	+/=	+/+	=/=	=/=	=/=	=/=
Ca (%)	-/=	-/-	-/-	=/=	=/+	+/+	+/+	=/+
Zn(ppm)	=/+	=/+	=/+	=/+	=/-	-/=	-/=	-/-
S (%)	=/=	-/-	-/-	+/=	-/-	=/=	=/-	-/+
Protein (%)	-/-[2]	+/+	+/+	+/+	+/+	+/+	+/=	-/=
Amino Acids (%)	-/-	+/+	+/+	+/+	+/+	-/-	=/+	+/=
Starch (%)	+/=	+/+	+/+	+/+	+/-	+/+	+/+	+/+
Simple Sugars (%)	=/=	+/=	+/+	+/+	-/=	-/-	+/-	-/-

[1] *Triteleia* = *T. laxa* 'Koningin Fabiola'; Zephryanthes = *Z. candida* (white), *Z. sulphurea* (yellow), *Habranthus robusta* (pink); Sparaxis = *S. tricolor*; Freesia= *Freesia* hybrids 'Blue', 'White', 'Yellow'.

[2] An "=" indicates no significant difference between inoculated and non-inoculated plants, a "+" represents a significant increase in response to inoculation with VAMF; and a "-" represents a significant decrease in response to inoculation with VAMF. The first symbol in a cell represents the response in nonpasteurized soil, the second symbol in a cell represents the response in pasteurized soil.

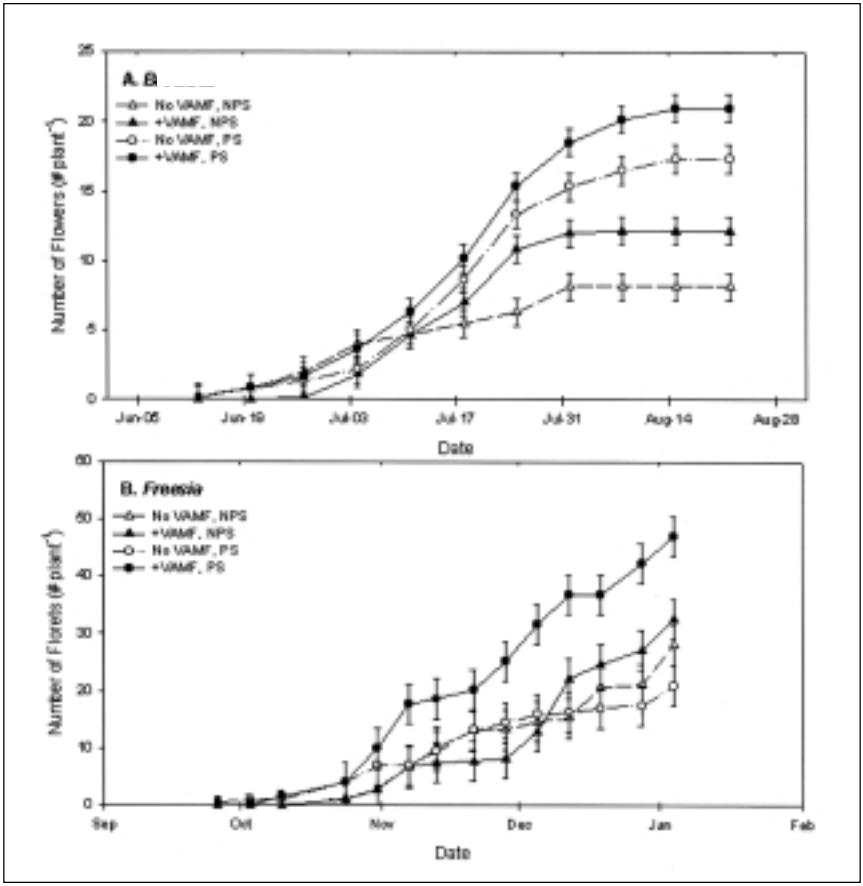

Figure 3. Number of flowers of *Triteleia laxa* 'Koningin Fabiola' (A) and *Freesia* hybrids (yellow) (B) grown in nonpasteurized (NPS) or pasteurized (PS) soil. No VAMF= no inoculum; +VAMF=VAMF (*Glomus intraradices*) spores and colonized root fragments in a sandy loam-based carrier incorporated into soil (1 : 166 (v/v). Means based on 20 replicate bulbs per treatment. Bars on data points represent LSDs.

Starch and Simple Sugars. Starch and simple sugars are known sources of stored energy in bulbs. Starch and simple sugar content of *Zephyranthes* spp., *S. tricolor*, and *Freesia* was higher in bulbs inoculated with VAMF than non-inoculated bulbs (Table 1).

Carry-over Effects. Growth and flowering of bulbs and corms are highly correlated with cultural conditions during the prior year's growth. Flower production of *T. laxa*, *Zephyranthes* spp., and *S. tricolor* (Fig. 5) was higher in plants 1 year after inoculation than plants that were not inoculated during the prior season's growth.

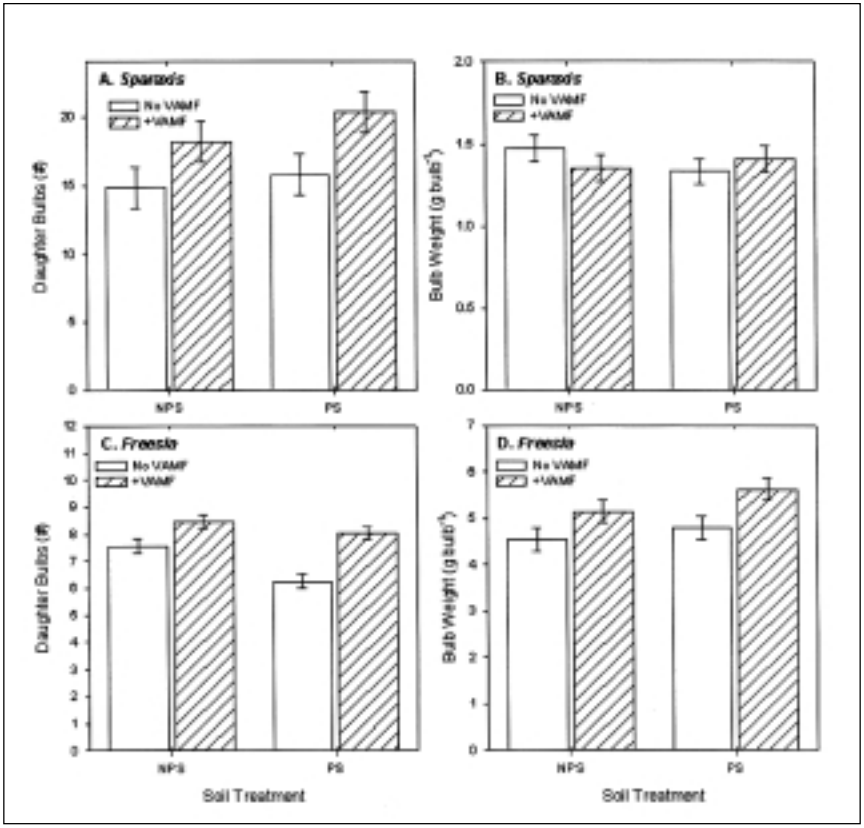

Figure 4. Number of daughter bulbs and weight per bulb of *Sparaxis tricolor* (A.& B) and *Freesia* (yellow) (C. & D.) grown in nonpasteurized (NPS) or pasteurized soil (PS). No VAMF= no inoculum; +VAMF= VAMF (*Glomus intraradices*) spores and colonized root fragments in a sandy loam-based carrier incorporated into soil (1:166 (v/v). Means based on 20 replicate bulbs per treatment. Bars on data points represent LSDs.

SUMMARY

The magnitude and type of response of liliaceous bulb and corm crops to inoculation with mycorrhizal fungi is highly dependent on the genus, species, and cultivar of plant as well as the soil environment. When using VAMF during the production of liliaceous plants, preliminary trials that assess the effect of inoculation on different aspects of productivity (e.g., flower or bulb production) and quality are required to achieve optimal benefits from inoculation.

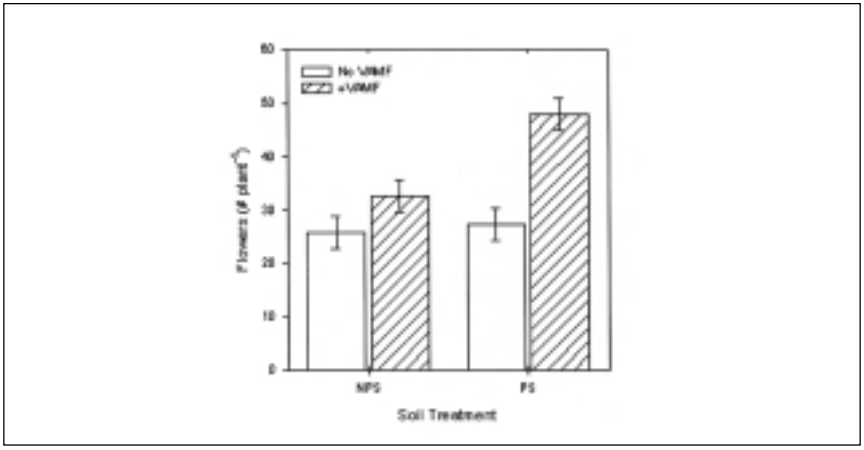

Figure 5. Number of flowers produced on *Sparaxis tricolor* plants one year after inoculation with VAMF and grown in non-pasteurized (NPS) or pasteurized soil (PS). No VAMF= no inoculum; +VAMF=VAMF (*Glomus intraradices*) spores and colonized root fragments in a sandy loam-based carrier incorporated into soil (1:166 (v/v). Means based on 10 replicate bulbs per treatment. Bars on data points represent LSDs.

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