It's a plus for VAMF!

by Rick Knowles and D.A.J. McArthur*

3Interactions between potatoes and this fungi are positive.

There is a mutually beneficial, or symbiotic, relationship between plants and some fungi which infect their roots. This infection usually increases the ability of a plant to explore a given volume of soil for water and minerals, thus enhancing the efficiency of nutrient acquisition and overall nutritional status of the plant. In return, the plant provides carbohydrate to support growth of the fungus and mycorrhizal root systems. The organisms known as Vesicular-arbuscular mycorrhizal fungi or VAMF, have the greatest effect on plant phosphorus (P) nutrition, although uptake of other essential nutrients is also enhanced by the symbiotic relationship.

Although VAMF are found everywhere in natural environments, and about 95 percent of all vascular plants are potentially mycorrhizal, the intensive cultural practices common on today's agricultural lands have significantly reduced the diversity of VAMF and in some cases totally eliminated them from the soil. Reintroducing select species of VAMF to the soil may thus benefit production. Potential benefits include enhanced plant growth and yield, improved natural disease resistance, decreased fertilizer requirements and improved water uptake by VAMF-infected plants.

Despite a wealth of information on growth responses of horticultural crops to inoculation with VAMF, very little is known about their interaction with the potato plant. This is surprising because, on a world-wide basis, potato is one of the most important food crops. The results of an eight year study on the nutritional status of plants in commercial potato fields of southern Alberta strongly suggest that P deficiency is a major limiting factor to yield. Moreover, many studies have concluded that P supply is critical, especially during the early tuber growth and tuber bulking phases. Phosphorus deficiency toward the end of a growing season often limits photosynthesis, tuber-filling capacity, and thus yield. The use of VAMF in potato production may provide an effective means to counteract the negative effects of reduced P availability at critical times during the season.

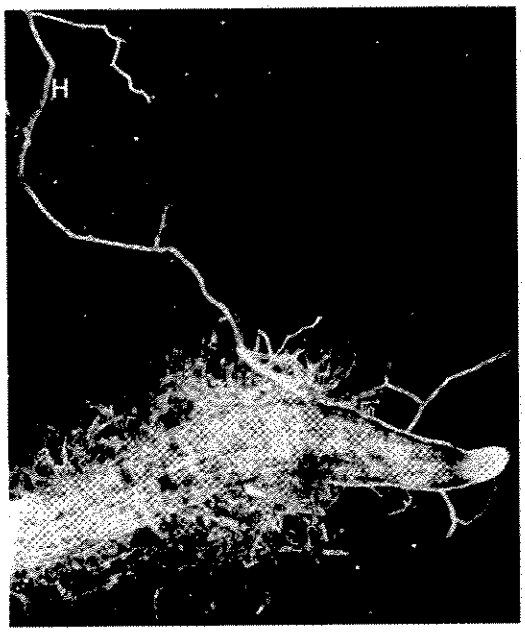

Photo 2. *A VAMF-infected potato root showing the relative lengths of root hairs and external hyphae of the fungus.*

Photo 4. *The effect of VAMF on leaf area of plants grown with medium levels of P at 84 days after planting.*

Our studies have demonstrated that potato is highly susceptible to infection by VAMF. When spores of VAMF were added to soil in which potato plants were growing, the spores germinated, producing hyphae which grew toward the plant's roots (see Photo 1). Upon contacting a root, hyphae produced a clamp-like structure which allowed entry of the fungus through the epidermis. Once inside, internal hyphae grew between and within cells of the roots. Hyphae external to roots extend well beyond a zone of nutrient depletion that can develop around potato roots. This is evident (see Photo 2) where the external hyphae were much longer than the nutrient-absorbing root hairs. These external hyphae scavenge nutrients from soil more quickly than roots. Minerals acquired by external hyphae are then transported to the root. This is done through a tree-like structure which is a terminal, highly branched

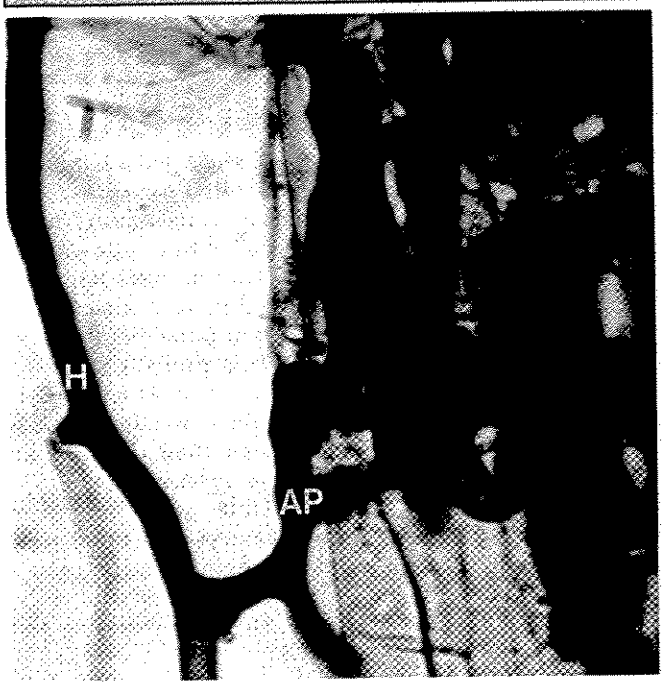

Photo 1. *A VAM hypha (H) is forming a clamp-like structure (AP) on the epidermis of a root.*

modification of a hypha that greatly increases the surface area of contact between the root cells and VAMF. The VAMF and the root exchange minerals and carbohydrate produced by the plant. The fungus converts the carbohydrate to lipid, which it uses as an energy source for further growth and development. The lipid is stored in spores and vesicles formed by the fungus inside of the root cells (see Photo 3).

Our controlled-environment studies have characterized the whole-plant growth responses of Russet Burbank potatoes to infection by various species of VAMF. As P supply increased, percent infection of roots by VAMF decreased. Plant leaf area development was very sensitive to P nutrition and VAMF infection. Leaf area increased 400 percent as supplemental P increased from low to adequate levels (as defined by *Alberta Potato Production Guide*). At low and medium levels of P nutrition, VAMF-infected plants produced (on average) 200 percent more leaf area than non-infected plants by 84 days after planting. Photo 4 shows the effect of VAMF on leaf area of plants grown with medium levels of P at 84 days after planting.

In all controlled-environment studies thus far, VAMF greatly enhanced the efficiency of P uptake from soil for plants growing under P stress. Plant tissues (including tubers) of VAMF-infected plants had significantly higher concentrations of P than those from non-infected plants. Moreover, the total amounts of N, P, K, zinc, iron, and magnesium were significantly higher in plants infected with VAMF, relative to non-infected plants, under low and medium levels of P nutrition. These studies thus demonstrate that VAMF effectively increase the nutrient-scavenging ability of potato plants.

In field studies over four years, under non-irrigated conditions, VAMF increased the yield of marketable Russet Burbank tubers by an average of 23 percent (4.3t/ha) over non-infected controls (see Table 1). These studies were conducted on soils containing marginally adequate levels of P for potato production under dryland conditions (as specified in the *Alberta Potato Production Guide*). As stated earlier, the effectiveness of VAMF at colonizing potato roots decreases with increasing soil P. Potato plants have a greater ability to resist infection by VAMF when grown with high levels of P. We are currently investigating the physiological and biochemical basis for this resistance response. The potential for utilizing VAMF in commercial potato production may depend on our ability to circumvent the plant's natural resistance response to infection when grown under higher levels of P nutrition. In addition, use of VAMF in production will depend on economic considerations as well as the availability of inoculum in a suitable form for application. ■

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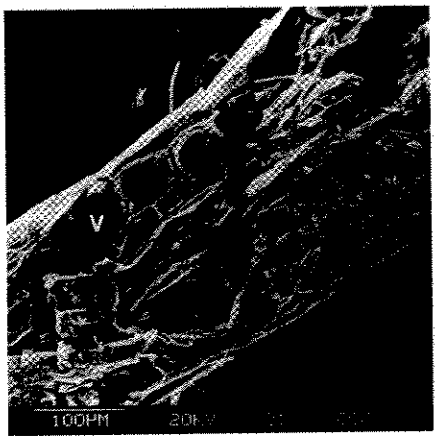

Photo 3. *A longitudinal section of a potato root shows VAMF in root cells and lipid storage in vesicles (V).*

Table 1. Marketable yield of Russet Burbank.

Year	Yield (t/ha) NM	Yield (t/ha) VAMF	VAMF yield increase (t/ha)	VAMF yield increase (percent)
1	18.8	23.9*	5.1	27
2	23.8	29.0*	5.2	22
3	21.8	24.4*	2.6	12
4	10.5	14.8*	4.3	41
Average	18.7	23.0*	4.3	23

*VAMF-induced increases in yield were significant at the 0.05 level for years one and four, 0.10 level for years two and three and 0.001 level for average over the four year study interval.