

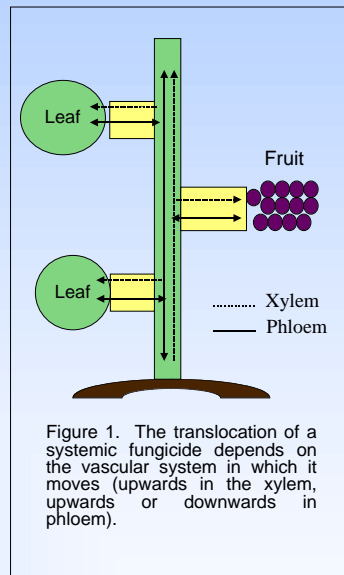
Introduction

Grapevine downy mildew, caused by the oomycete *Plasmopara viticola*, is controlled primarily by the timely application of fungicides, and knowledge of their physical modes of action can improve efficacy and efficiency. The physical mode of action of a fungicide describes how timing or placement affects its efficacy, such as whether the fungicide moves systemically, or whether it possesses pre- or post-infection activity. Thus, physical mode of action may be an important consideration in deciding when and how a particular fungicide can best be deployed.

Beyond locally-systemic movement (e.g., translaminar movement from adaxial to abaxial leaf surfaces) longer-distance systemic movement requires xylem or phloem transport. Most systemic fungicides are xylem-mobile, meaning they follow the upward movement of water and mineral nutrients in the transpiration stream (Fig. 1). Fosetyl-al is phloem mobile, moving up or down in the plant with transport of photosynthates (Fig. 1).

Although metalaxyl has shown systemic movement in many plant systems (1), the nature and effects of its movement vary. In tomato (2), metalaxyl applied to the lower leaves or stem only partially controlled disease in upper leaves. In grapevine seedlings, metalaxyl controlled downy mildew by translaminar systemic movement (3), by systemic movement from stems to leaves, and within leaves, but not from leaf to leaf (2).

It has long been assumed that metalaxyl is not translocated to developing grape clusters from leaves in quantities sufficient to suppress downy mildew. However, the only experimental data on systemic movement are restricted to juvenile, non-fruiting plants (seedlings). In preliminary experiments in a mature fruiting vineyard, we found evidence of substantial translocation from leaves to berries. Our objective was to investigate long-distance systemic movement of metalaxyl in mature fruiting grapevines.

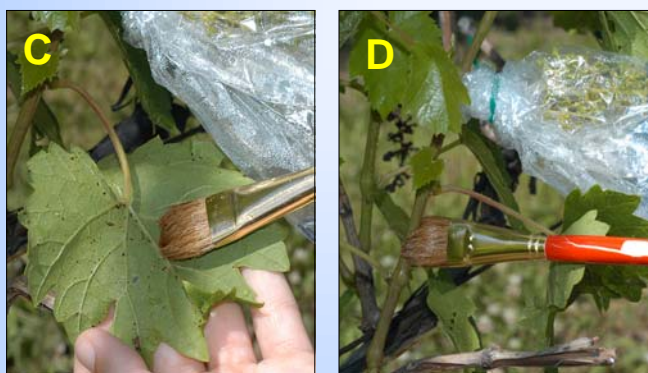


Materials and Methods

We inoculated clusters of *Vitis vinifera* cultivars 'Chardonnay' and 'Riesling' and *V. labrusca* cultivar 'Niagara' at susceptible growth stages with a suspension of *P. viticola* sporangia (1×10^5 sporangia / mL) (Fig. 2A), and placed wet plastic bags on the clusters to keep the surface wet overnight for infection to occur (Fig. 2B).



The next day, with the cluster still bagged, we applied the fungicide selectively to the leaves (Fig. 2C) stem (Fig. 2D), or both ("whole shoot"), using a paintbrush. The concentration of metalaxyl was 288 mg active ingredient per liter.



After two weeks, we assessed disease development on the inoculated fruit clusters. To induce sporulation, we placed wet plastic bags over the clusters overnight, and we assessed disease symptoms the following morning by estimating the percentage of cluster surface sporulating (Fig 2E, F).

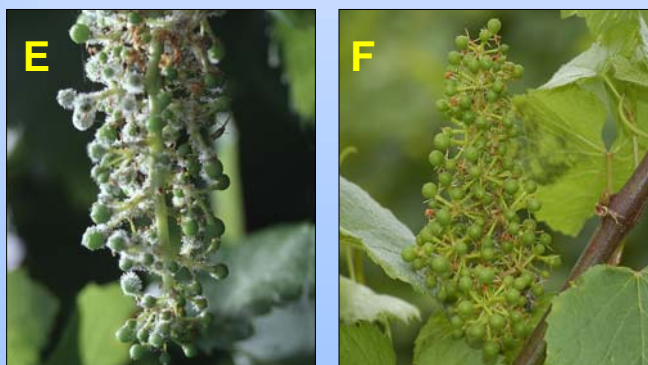


Figure 2. Cluster inoculation (A, B), fungicide application (C, D), and disease assessment (E, diseased; F, healthy).

Results

A previous study of metalaxyl translocation in grapevine seedlings did not reveal evidence of significant leaf-to-leaf movement. However, using mature grapevines in our study, translocation of metalaxyl from leaf and stem tissue into clusters reduced severity of downy mildew to trace levels despite the high susceptibility at the development stages inoculated.

Niagara clusters inoculated at prebloom or bloom developed no disease when metalaxyl was applied to the whole shoot 12-18 hours after infection (Table 1). When metalaxyl application was delayed until 48 hours after infection, only trace levels of disease developed. Control clusters had high disease levels, ranging from 67.5 to 81.9 percent. Similarly, inoculated Chardonnay clusters developed no disease when metalaxyl was applied to the entire shoots at 12 or 42 hours after inoculation (Table 1). Non fungicide-treated clusters were highly infected.

Metalaxyl was translocated from both stem and leaf tissue to Chardonnay and Riesling berries, reducing disease by 92 -100% compared to the unsprayed controls (Figure 3).

Parallel studies with azoxystrobin indicated no translocation from stems or leaves into the clusters.

| Variety | Year | Timing of metalaxyl application | Vine stage | Disease Severity (Sprayed) | Disease Severity (Unsprayed) |
|------------|------|---------------------------------|------------|----------------------------|------------------------------|
| Niagara | 2002 | 12 | Prebloom | 0.0 (0.0) | 71.4 (16.23) |
| Niagara | 2002 | 48 | Bloom | 1.0 (0.61) | 67.5 (10.31) |
| Niagara | 2003 | 18 | Prebloom | 0.0 (0.0) | 73.8 (10.43) |
| Niagara | 2003 | 18 | Bloom | 0.0 (0.0) | 81.9 (3.13) |
| Chardonnay | 2002 | 12 | Prebloom | 0.0 (0.0) | 73.1 (7.11) |
| Chardonnay | 2002 | 42 | Bloom | 0.0 (0.0) | 18.8 (2.28) |

Table 1. Disease severity on inoculated, metalaxyl-treated shoots compared to inoculated, non metalaxyl-treated controls. Clusters were inoculated at prebloom or bloom, and metalaxyl was applied to the whole shoot at the indicated number of hours post-inoculation.

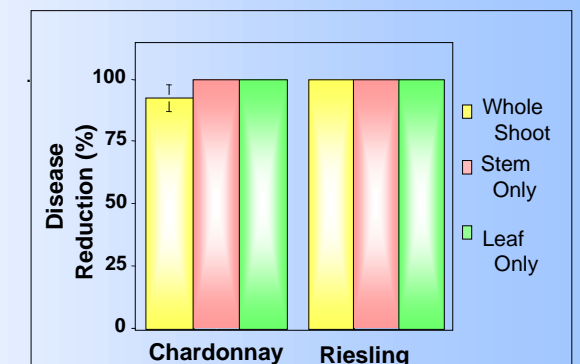


Figure 3. Percent disease reduction by application of metalaxyl on different plant parts, as compared to inoculated, non-fungicide-treated controls. Riesling and Chardonnay clusters were inoculated at prebloom. The following day, metalaxyl was applied to the whole shoot, stem only, or leaves only.

Discussion

Knowledge of the physical mode of action of fungicides can help to develop guidelines for the intelligent use of compounds based upon their unique properties. A fungicide that translocates efficiently from leaves to fruit has significant advantages for control of grapevine diseases. The dense canopies of certain vineyards (Fig. 4), coupled with the "shingling" effect of grapevine leaves, make the fruit cluster a challenging target for fungicide applications. Although foliage comprises the main target for fungicide applications, and is the principal infection court for the epidemic, grapevines can withstand some loss of photosynthetic leaf area without loss of yield or crop quality. However, direct infection of the cluster causes economic loss. Grape clusters deep inside the canopy may still receive substantial protection by metalaxyl applied to leaves and shoots which then translocates to fruit.

In the absence of resistance, metalaxyl is widely regarded as perhaps the most effective fungicide ever developed for management of grapevine downy mildew. It appears that in addition to its high innate efficacy, its unique ability to translocate from leaves and stem tissue into grape berries may be an important factor in its performance in the field.



Figure 4. The dense canopy of many grapevines, especially *Vitis labrusca* grapes native to North America, prevents direct contact of fungicides with the fruit clusters in the interior of the canopy.

References

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