Epidemiology and Management of Phytophthora Root and Crown Rot of Almond in California

Project No.: **15-PATH15-Adaskaveg/Browne**

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Objectives:

I. Evaluate the in vitro toxicity of new fungicides against *P. cactorum* and *P. niederhauseri* and establish baseline sensitivities.
II. Evaluate oxythiapiproline, mandipropamid, fluopicolide, and ethaboxam for the management of root of almond in greenhouse studies and compare efficacy to the registered mefenoxam and potassium phosphite.
   A. Treat plants inoculated with *P. cactorum* or *P. niederhauseri,* evaluate for incidence of root infection, and enumerate soil populations of the pathogen
   B. Evaluate for phytotoxicity and measure plant growth
III. Evaluate the above fungicides and selected mixtures for the management of root rot of almond in field studies and compare efficacy to the registered mefenoxam and potassium phosphite.
   A. Establish almond orchards on Hansen and Nemaguard rootstocks and inoculate root ball at planting time with *P. cactorum* or *P. niederhauseri.*
   B. Apply treatments semi-annually, evaluate for incidence of root infection, and enumerate soil populations of the pathogen.
   C. Evaluate trees for phytotoxicity and measure plant growth.

Interpretive Summary:

Phytophthora root rot and crown rot of almond can be caused by several species of *Phytophthora* including *P. cactorum, P. cryptogea*, *P. megasperma*, and the recently described *P. niederhauseri* that is present at high incidence at some locations. The disease is widely distributed and may cause high losses in newly planted orchards. The severity and rate of disease development depends in part on the rootstock and the species of *Phytophthora* involved, but the disease is most severe in soils with poor drainage that are waterlogged. Depending on the species, *Phytophthora* species survive as chlamydospores, oospores, and/or hyphae in plant debris in the soil. Under proper conditions, hyphae start growing or

chlamydospores and oospores germinate to produce sporangia that contain zoospores - the main infective propagules. The zoospores are motile in water, they are attracted by root exudates, and infect feeder roots. Management of root rot includes the use of tolerant rootstocks, irrigation management, and the use of mefenoxam and phosphonate (e.g., potassium phosphite, fosetyl-Al) fungicides. Several new fungicides including mandipropamid, fluopicolide, ethaboxam, and oxythiapiproline with high activity against *Phytophthora* species have recently become available. These fungicides all have different modes of action (different FRAC groups) and their potential usage on almond will allow for possibly better disease control and fungicide resistance management. Respective registrants are supporting almond registration. The effectiveness of these fungicides for the management of Phytophthora root rot of almond is being evaluated in comparison to mefenoxam and potassium phosphite in greenhouse and field studies.

Materials and Methods:

I. **Evaluate the in vitro toxicity of new fungicides against selected *Phytophthora* species occurring on almond.** Isolates of *P. cactorum* and *P. niederhauseri* were cultured on V8C agar. In vitro sensitivities were determined using the spiral gradient dilution (SGD) method as described previously (Forster et al., Phytopathology 94:163-70. 2004). Mycelial inoculum for the SGD plates was grown on cellophane strips. Fungicide solutions were applied to 15-cm V8C agar plates with a spiral plater using the exponential deposition mode. Mycelium-covered strips were then placed radially along the fungicide concentration gradient. Effective fungicide concentrations where 50% growth inhibition is observed was determined after 3-4 days of incubation using a computer program.

II. **Evaluate oxythiapiproline, mandipropamid, fluopicolide, and ethaboxam in greenhouse studies for the management of Phytophthora root of almond and compare to mefenoxam and potassium phosphite.** Greenhouse studies on effective fungicide rates were conducted on potted, ca. 12-month-old plants with Hansen rootstocks on Nonpareil scions. Trees were inoculated with *P. cactorum*-infested oat seeds and then treated with fungicide rates that were calculated per pot surface. Treatments included mandipropamid (Revus), oxathiapiproline (Orondis), and mefenoxam (Ridomil Gold) (Syngenta Crop Protection), fluopicolide (Presidio) and ethaboxam (V-10208 - Valent USA), and potassium phosphite (Prophyt - Luxembourg). After 6-10 weeks, feeder roots were plated onto selected agar for *Phytophthora* isolation and the incidence of root colonization was assessed. Additionally, soil populations of *Phytophthora* sp. were determined by soil plating onto selective media using standard protocols. Plants were also evaluated for signs of phytotoxicity from each of the treatments. Data were analyzed using analysis of variance and multiple mean separation methods of SAS ver. 9.4.

III. **Evaluate oxythiapiproline, mandipropamid, fluopicolide, and ethaboxam in field studies for the management of Phytophthora root of almond and compare to mefenoxam and potassium phosphite.** For field studies, an orchard was established at UC Davis. Rootstocks planted were Hansen and Nemaguard with Nonpareil as the scion. Roots of plants were inoculated at planting time with *P. cactorum*-infested oat seeds. A randomized complete-block design with 2 trees per each of 10 replications per treatment was used. Fungicides (oxythiapiproline, mandipropamid, fluopicolide, ethaboxam, mefenoxam, potassium phosphite, and selected mixtures) at recommended rates were applied to trees after 4 weeks. This will be repeated semi-annually. To evaluate treatment efficacy, tree size and vigor were evaluated. Root samples were taken at selected time intervals after treatment to determine the severity of *Phytophthora* infection and soil populations were determined to measure the effect of the treatments. Data were analyzed using analysis of variance and multiple mean separation methods of SAS ver. 9.4.

Results and Discussion:

Results for all three objectives are pending at the time this report was prepared. The first data collection for greenhouse and field studies will be in September 2016. In initial in vitro assays, activity of the new fungicides against *Phytophthora* species was generally much higher as compared to the previously registered mefenoxam and phosphonate fungicides. Oxathiapiprolin has activity at the parts per billion level. This indicates that low usage rates should provide high activity. Because the fungicides represent new modes of action, rotation of these products in semi-annual applications will be an effective fungicide resistance management program. In other crops, resistance in other *Phytophthora* species to phosphonate fungicides (FRAC 33) has been reported by us. With widespread and indiscriminant usage of phosphite products (fungicides and fertilizer blends), we expect resistance also to occur in *Phytophthora* populations on almond in the future. Additionally, phosphite residues may remain a problem with some trading partners due to a wide range of residues obtained with different use patterns and differences in regulatory agencies reviews of these fungicides (e.g., exempt in the US but not in the EU). The new fungicides under evaluation are effective against phosphonate-resistant populations, will have MRLs established in the EU, and should be commercially available in 2019.