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Potential Management of Verticillium Wilt of Potato with Rotation Crops

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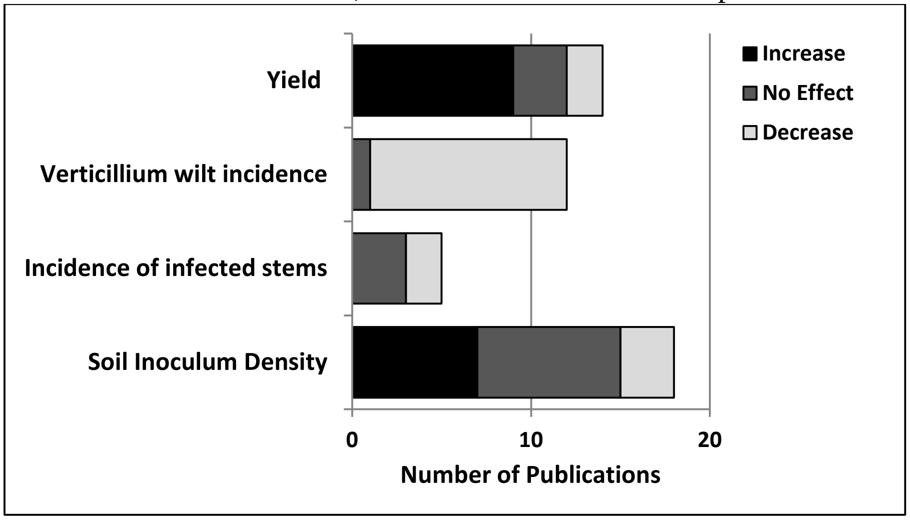
Verticillium wilt of Potato is a Problematic Disease with Limited Management Solutions

Verticillium wilt causes yield losses of potato in temperate production regions worldwide. Management tactics for Verticillium wilt of potato are limited because the pathogen that causes this disease, *Verticillium dahliae*, has a broad host range and produces long-lived survival structures called microsclerotia. Current management tactics include soil fumigation, use of moderately resistant potato cultivars, optimization of irrigation regimes, and crop rotation. Crop rotation is widely utilized to increase soil organic matter and manage soilborne plant pathogens; however, the effectiveness of crop rotation in reducing Verticillium wilt has been inconsistent (Larkin et al. 2011; Subbarao et al. 2007; Wheeler et al. 2012) and important questions remain to be answered.

How Effective is Crop Rotation in Managing Verticillium Wilt?

Published research articles on the effects of crop rotation on Verticillium wilt of various crops including potato were reviewed and results were compiled to detect general patterns among studies (Fig. 1). An increase in yield and decrease in the incidence of Verticillium wilt after crop rotation despite the concurrent maintenance or increase of soil levels of *V. dahliae* was reported in most studies. The discrepancy between increased yields and increased soil levels that can potentially infect future crops could be explained by various factors, including spatial and temporal differences of *V. dahliae* populations among and within fields, delayed detection of *V. dahliae* from decomposing infested plant debris, lengths of rotations between potato crops, new introductions of *V. dahliae* into fields, and asymptomatic infection of rotation crops that result in maintenance or increased inoculum of the pathogen in the soil after crop rotation. Asymptomatic infections of rotation crops are not well understood (Malcolm et al. 2013) and may contribute to the maintenance or increase in soil inoculum.

Figure 1. Effects of crop rotation of yield, incidence of Verticillium wilt, incidence of infected stems, and soil inoculum from 25 published research articles.

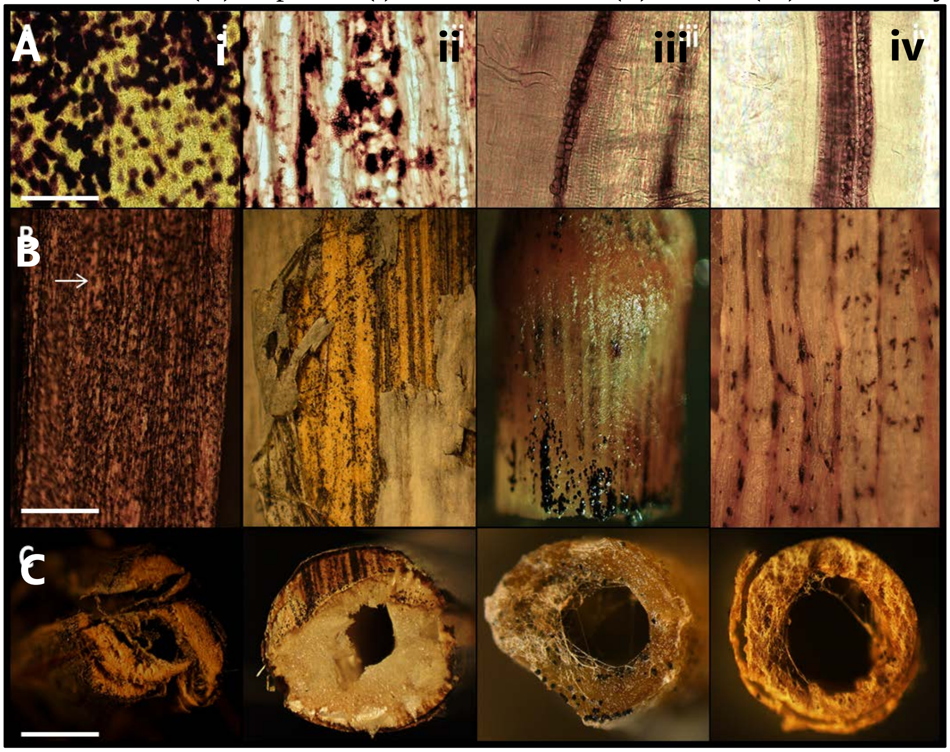


Are rotation crops infected by strains of *Verticillium dahliae* that infect potato?

Rotation crops were grown in soil infested with different strains of *V. dahliae* and the level of the fungus was estimated from stems, roots, and soil in the greenhouse to determine if rotation crops are infected by *V. dahliae*. Brown mustards 'Pacific Gold' and ISCI 99, white mustard 'Martigena', arugula 'Nemat', Austrian winter pea, sweet corn 'Marvel', spring wheat 'Alpowa', barley 'Baroness', and sudangrass were planted in soil infested with different strains of *V. dahliae* in two experiments. Eight different strains of *V. dahliae* from five hosts and four vegetative compatibility groups (VCG) were used (Dung et al. 2013). Microsclerotia of at least one strain were observed on each crop (Fig. 2) and all crops were asymptomatically infected during at least one experiment (Figs. 3 and 4). Stem levels were generally, but not always, greater in potato than rotation crops. For example, stem levels of strain 155 and strains 381 and VMD-4 were greater in arugula and Austrian winter pea than potato, respectively (Fig. 4a). Root and soil levels were similar among rotation crops and all *V. dahliae* strains were detected from the roots and soil of all rotation crops (Fig. 4b and c).

Stems of various rotation crops were collected from 21 fields in the Columbia basin of Washington with history of Verticillium wilt and tested for *V. dahliae* to validate results from greenhouse experiments. Stems from eight of the 21 fields were infected with *Verticillium* spp. and incidence of infected stems ranged from 1 to 2% in the grasses to 67% in a field of brown mustard (Fig. 5). Strains of *Verticillium* were identified as either *V. dahliae* or, in the case of strains from sunflower, *V. isaacii* based on DNA sequence data from multiple genetic regions. Additionally, genetic diversity and the prevalence of one of two mating-types (both mating-types are necessary for sexual recombination) were detected among strains from rotation crops (data not shown). Research is currently being completed to determine if strains of *V. dahliae* from rotation crops differ genetically and in aggressiveness from strains from potato. This information will be useful in predicting risk of Verticillium wilt and in differentiating between strains with potentially differing levels of aggressiveness to potato.

Figure 2. Formation of the microsclerotia, the small black speck-like survival structures of *Verticillium dahliae*, in vascular tissues (**A**), on stems (**B**), and stem cross-sections (**C**) of potato (**i**), brown mustard (**ii**), wheat (**iii**), and barley (**iv**).



Are rotation crops and *Verticillium dahliae* affected by asymptomatic infections?

Although rotation crops were asymptomatically infected, differences in biomass of stems and roots were detected from some crops infected with specific stains of *V. dahliae* (data not shown). For example stem height and weight of sweet corn was greater in plants infected with strain 461 than the non-inoculated controls. Conversely, stem and root weight of barley was less in plants infected with strain VD5 VSP699 than the non-inoculated controls. Additionally, at least one strain of *V. dahliae* grew slower under laboratory conditions when recovered from barley than the same strain from potato (data not shown). Greenhouse experiments are currently being completed to determine if this difference in growth translates to a difference in aggressiveness on potato.

Figure 3. Levels of *Verticillium dahliae* in potato, peppermint, native mint, white mustard, brown mustard ISCI 99, brown mustard 'Pacific Gold', sweet corn, wheat, and sudangrass. Incidence of infected stems: **A**, root levels (CFU/ 60 cm of root); **B**, and soil levels (CFU/g of soil); **C,** detected from plants of rotation crops grown in soil infested with two strains of *V. dahliae*. Boxplot hinges represent 1st and 3rd quartiles, whiskers extend to values within 1.5x the inter-quartile range, and circles represent outliers.

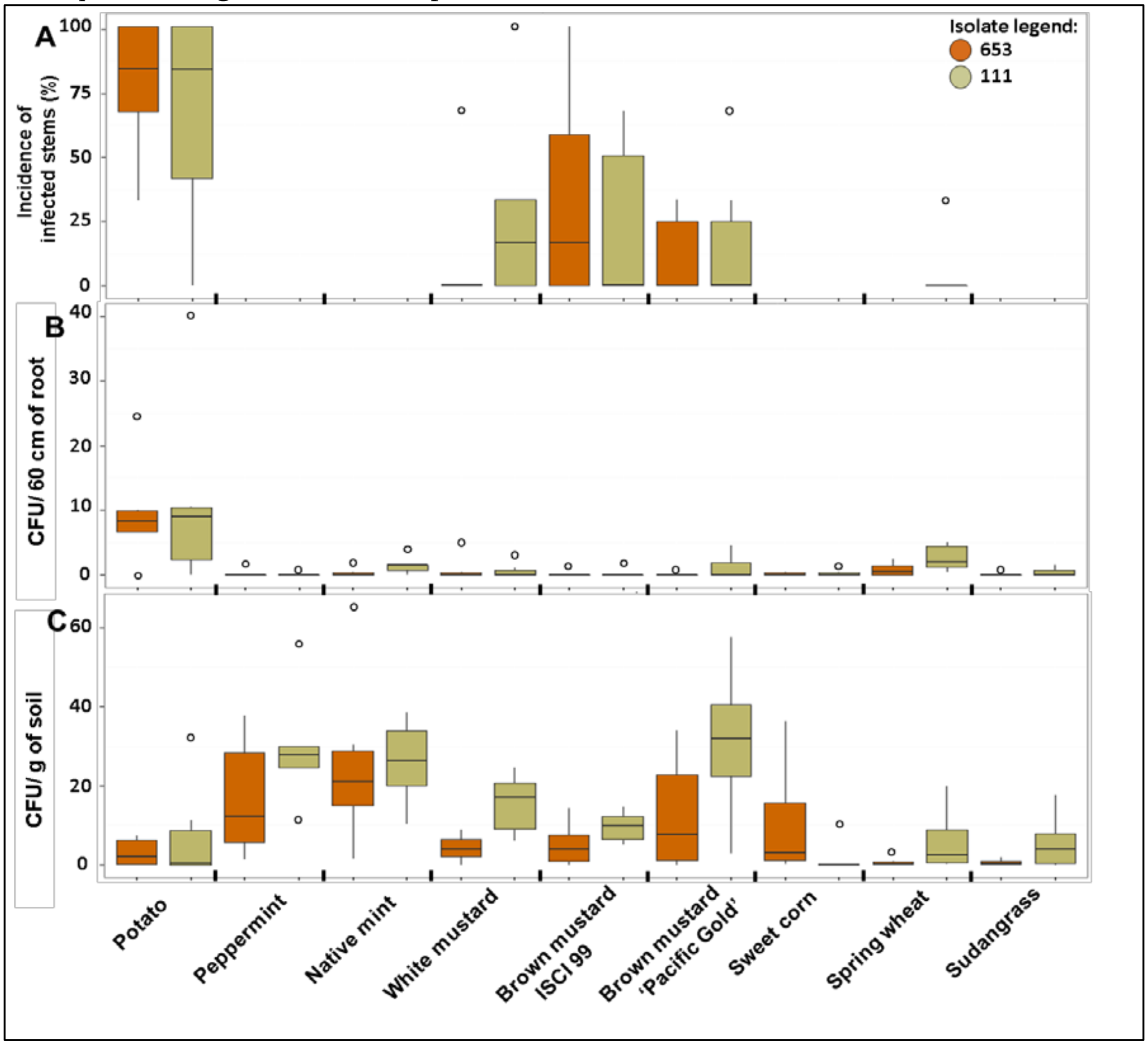


Figure 4. Levels of *Verticillium dahliae* in potato, peppermint, arugula, Austrian winter pea, barley, sweet corn, and sudangrass. Stem levels (CFU/g of stem): **A**, root levels (CFU/g of root); **B**, and soil levels (CFU/g of soil); **C,** detected from plants and soil of rotation crops grown in infested soil. Boxplot hinges represent 1st and 3rd quartiles, whiskers extend to values within 1.5x the inter-quartile range, and circles represent outliers.

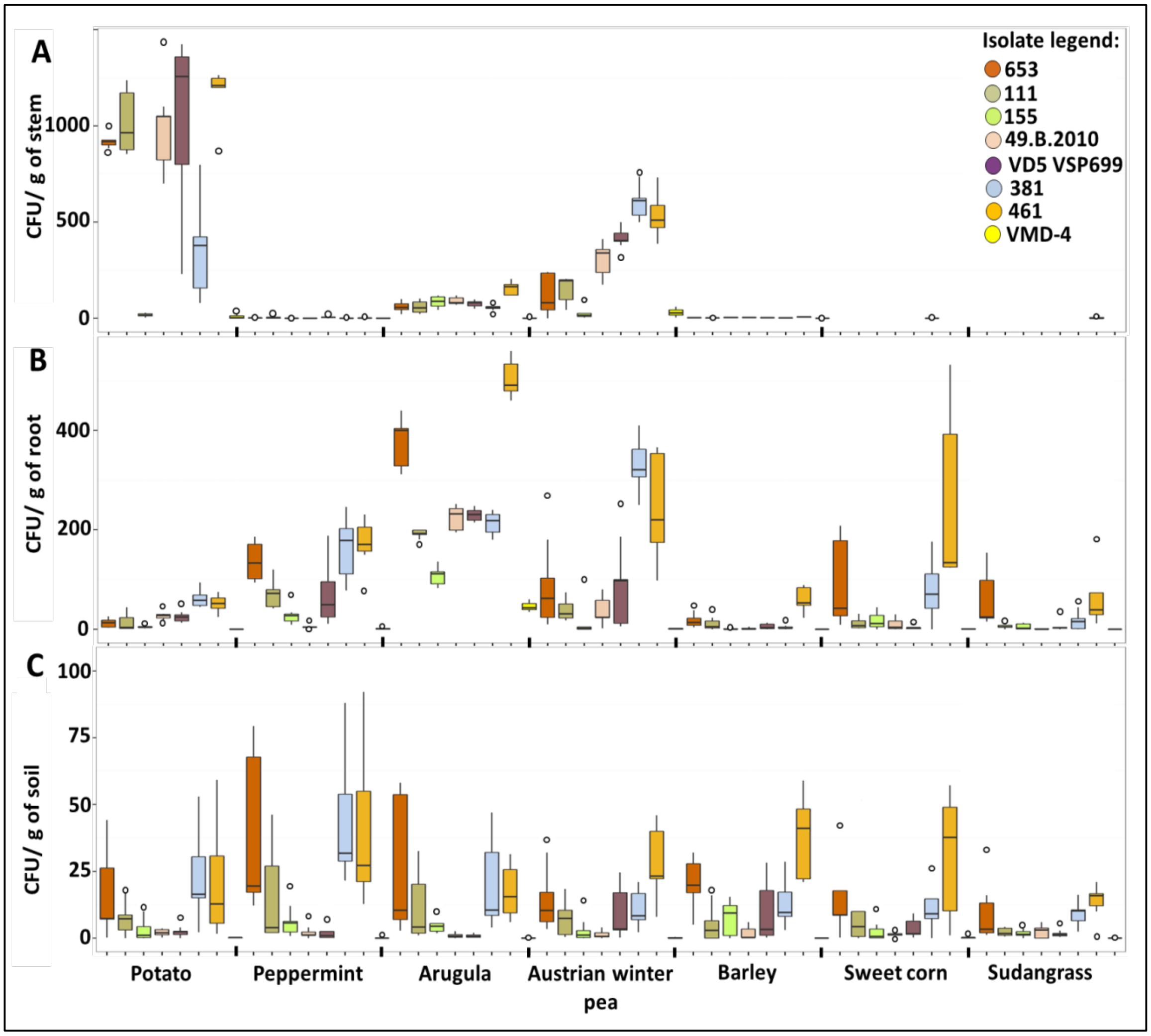
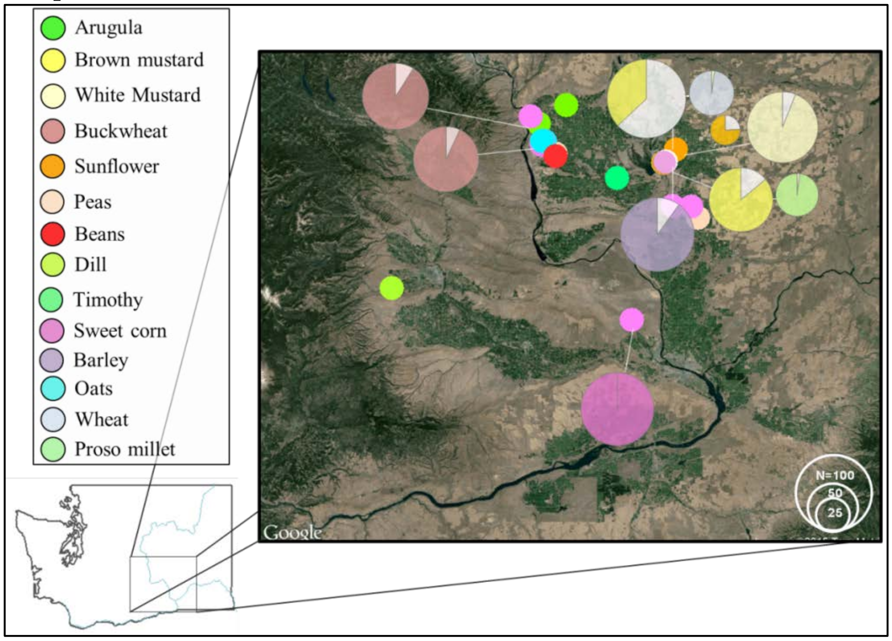


Figure 5. Distribution of asymptomatic infections of rotation crops in the Columbia Basin of Washington state. Color circles represent sampled fields. Pie-charts represent sampled fields that tested positive for *Verticillium* spp. where the size of the pie-chart is proportional to the sample size (n=25, 50 or 100) and the white sections of each chart represents the percent of samples from which *V. dahliae* or *V. isaacii* were detected.



Does cropping history affect stem infection of potato?

The effects of rotation crops on susceptible crops subsequently planted in the same soil were determined by planting potato and peppermint in infested soils where rotation crops were grown. Incidence of infected stems of potato and peppermint was restricted to plants grown in infested soils previously planted with potato and white and brown mustards (data not shown). Additionally, strain 653 was only detected from soils where both peppermint and native mint were grown whereas strain 111 was detected from soils where all crops were grown.

Conclusions

The published effects of crop rotation on Verticillium wilt differ and most studies report increases in yield despite the maintenance or increase of soil populations of the fungus that potentially can infect future potato crops. The observed difference can be explained by the asymptomatic and differential infection of rotation crops demonstrated in this study. All rotation crops tested were asymptomatically infected by at least one strain of *V. dahliae* and the resultant fungal populations differed among rotation crops depending on the crop and strain treatment combination. Most crops did not support the same levels of *V. dahliae* as potato but other crops supported the same or more levels than potato when infected with specific strains of *V. dahliae.* Stem infection in rotation crops from commercial fields was detected and the incidence of infected stems within each field was low compared to the greenhouse experiments. The survival structures of *V. dahliae*, microsclerotia, were observed on all infected rotation crops. Although no symptoms were observed, stem and root biomass of specific rotation crops were affected when infected with specific strains of *V. dahliae*. Growth of at least one strain of *V. dahliae* was also affected by infection of rotation crops and an experiment is currently being completed to determine if this difference in growth translates into a difference in aggressiveness on potato. The incidence of infected stems of potato and peppermint and soil levels were affected by cropping history and only potato and peppermint plants grown in soils where mustards and potato were grown were infected.

V. dahliae from rotation crops may contribute to soil inoculum, infect and cause yield losses in future crops. Future research is therefore needed to estimate the contribution of asymptomatic infection to soil inoculum, determine the distribution of asymptomatic infections in potato cropping systems, the genotypes and pathogenicity of strains from rotation crops, and the stability of infections over time.

Literature cited

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