Managing the Elusive Potato Black Dot Pathogen, *Colletotrichum coccodes*

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Colletotrichum coccodes, the soil-borne fungus that causes black dot of potato is known as an elusive pathogen (Johnson 1994). This is for several reasons. First, infections are latent. Infections of roots, stolons and below-and aboveground stems can occur relatively early in the growing season and affect a large percentage of potato plants in fields by mid-season, but disease symptoms or signs of the pathogen (microsclerotia) may not become evident until plants begin to senesce near time of harvest. Likewise, tubers become infected in the field and may not develop obvious symptoms or microsclerotia until storage (Hamm and Johnson 2012). The disease does not spread from tuber to tuber in commercial storage, but latent infections become symptomatic and lesions may expand in size on tubers. Second, disease symptoms are often not discrete and can be confused with Verticillium wilt, natural senescence, nitrogen deficiency, and other disorders. As a consequence, identifying the disease and evaluating the effects of the disease in research plots and grower fields is difficult. Third, the effect for the disease on potato yield does not appear to be consistent. This implies variables, both biotic and abiotic, are not fully understood that interact with the pathogen and potato. Consequently, timely observations on disease development and environmental factors are needed to quantify the effect of the disease on yield. Fourth, the disease is not satisfactorily managed.

A cause or result of plant stress

Small, black microsclerotia characteristically develop on infected and colonized below- and aboveground stems, stolons, and roots when infected tissues senesce or infected plants are stressed (Johnson and Miliczky 1993b). For example, young, immature microsclerotia are shown in Figure 1 on the belowground stems of Ranger Russet collected from a stressed plant at initial plant flowering in a commercial field in the Columbia Basin. The question arises: is the potato disease black dot a cause of plant stress, a result of plant stress or a combination of both? As partial answer: *C. coccodes* is not an aggressive saprophyte and is not able to initially colonize dead potato tissue in the field. Aggressive saprophytes outcompete *C. coccodes* for substrate on dead and dying potato tissue under field conditions. However, *C. coccodes* is very effective at latently infecting and colonizing host tissue while the host is alive (Nitzan and Johnson 2006). *C. coccodes* infects and colonizes the host tissue without competition from saprophytes while the potato host is alive. Symptoms are not evident because infections are latent. As the host dies, *C. coccodes* already has control of the colonized tissue and microsclerotia develop as the host tissues senesce. This is called prior colonization. The answer then to the stated question may be a combination of both: black dot is a cause of plant stress and disease development is also promoted by plant stress. The next question is: how much stress does *C. coccodes* cause the potato crop during the latent infection phase. As a partial answer, yield reductions of 30% have been attributed to black dot, indicating that *C. coccodes* is an important yield constraint (Johnson 1994).

Because infections by *C. coccodes* and plant stresses are important factors in the development of black dot and subsequent yield reduction, both the pathogen and plant stress need to be managed to produce a health potato crop. An understanding of potential sources of infection and causes of plant stress is then important in managing potato black dot.

Source of infection

In addition to soil-borne inoculum, infection of potato by *C. coccodes* can be caused by tuber-borne and air-borne inoculum. Soil-borne and tuber-borne inoculums are the main inoculum sources in the Columbia Basin. Soil-borne inoculum generally has a greater disease causing potential than tuber-borne inoculum (Dung et al. 2012, Nitzan et al 2008). However, infected seed tubers can be an important source of infection for roots, stolons, and daughter tubers. The fungus colonizes belowground tissues progressively away from an infected seed piece at a rate of 1 mm per day (Ingram and Johnson 2010).

Air-borne infection may be an important contributor to the initial development of the disease. Lesions develop on foliage from air borne inoculum and are dark brown to black and are similar in appearance to early blight, except concentric rings within the lesion do not develop. A high potential for foliar infection is present in the Columbia Basin because wounds from blowing sand provide entry avenues for the fungus. Sprinkler irrigation may disseminate conidia and microsclerotia via water splashing, and provide moisture that is needed for germination and infection (Johnson and Miliczky 1993a).

Potato roots and stolons are especially susceptible to infection. Lesions on below-ground plant parts may resemble those caused by Rhizoctonia. The cortical tissue is invaded and rotted, causing a sloughing of the periderm. As stems dry, cortical tissue is easily scaled away and an amethyst color may be common inside the vascular cylinder. Microsclerotia develop in infected tissues. Infection of potato tubers results in the development of lesions on the tuber surface, characterized by the production of microsclerotia. Symptoms are commonly observed at the stem end of the tuber and the lesions can appear silvery to brown, generally with a poorly defined margin. In contrast, silver scurf lesions are silver, with a clearly defined margin. Confirmation of these two diseases requires examining tubers with a hand lens or microscope to observe the characteristic black microsclerotia of black dot, or conidia (spores) of *H. solani* (Hamm and Jonson 2012).

Effect of Rotation on Incidence of Black Dot

Short rotations between potato crops cause plant stress in that inoculum of *C. coccodes* and other soil-borne pathogens are often increased and impact the crop. In a study in the Columbia Basin, incidence of black dot on tubers of Norkotah was higher when the crop was rotated 1 to 3 years out of potato than for longer rotations (Fig. 2). Incidence of black dot decreased significantly as the number of years between potato crops increased. *C. coccodes* was detected in fields out of potato for 10 and 15 years, but incidence of detection of the fungus was low after 6 or more years out of potato production (Fig. 2). Black dot also increased significantly as the number of previous potato crops increased (Fig. 3). Both factors, years between potato crops and number of previous potato crops, accounted for a large proportion of disease incidence for black dot ($P < 0.0001$, $R^2 = 0.87$) using multivariate analysis. Weed hosts may account for long term persistence of the fungus in soil.

Effect of Nutrient Stress on Black Dot Development

Plant stress from nutrient deficiency or imbalance may also increase colonization of potato roots by the black dot fungus. In controlled experiments, Russet Burbank plants produced in tissue culture were grown in a hydroponic solution in growth chambers under temperature and light conditions favoring potato growth. Plant nutrients were supplied at a level where there were no deficiencies or toxicities except for nitrogen. Nitrogen (ammonium nitrate and ammonium phosphate) was supplied at 5, 40, 160, and 640 ppm to create plant stress from a nitrogen deficiency and excess. Established plants were inoculated with a spore suspension of *C. coccodes* and allowed to grow. Nitrogen treatments were arranged as a Latin square experimental design with three replicates and two subsamples per replicate. Plants were then destructively sampled at 1, 2 and 3 weeks after inoculation and roots were assayed for *C. coccodes*. Infection severity was assessed by plating roots on modified potato dextrose agar and then determining the extent of infection. The experiment was expanded to test for the effects of potassium (0, 10, 80, and 160 mg K/l potassium nitrate) and phosphorous (0.032, 0.128, 1.00 and 8.2 ml phosphoric acid/liter) on black dot development.

Colonization of root systems was greatest at the lowest level of nitrogen (5 ppm). Root colonization decreased as nitrogen concentration increased to 160 ppm, which was the optimum level of N, and then increased as nitrogen increased to 640 ppm (Fig. 4). When potassium was tested, greatest root colonization occurred at the lowest level of potassium (0 mg K) and decreased as potassium concentration increased to 80 mg (the optimal level of K) and then slightly increased as potassium concentration increased to 160 mg Mg K (Fig. 5). The same pattern was seen when phosphorous was tested. The greatest root colonization occurred at the lowest level of phosphorous (0.032 ml) and then decreased as phosphorous concentration increased to the optimal level of P (1.00 ml) (Fig. 6). In summary, potato roots were more extensively colonized by the black dot fungus when plants were stressed by both a lack and excess of nitrogen, potassium and phosphorous than when optimum levels of each nutrient were available to plants.

Effect of Water Stress on Black dot Development

Water saturated soil from over-irrigation depletes soil oxygen which plant roots need for cellular respiration. Crop plants are subsequently stressed and become more susceptible to pathogens such as *C. coccodes*. For example, severity of black dot increased when Umatilla Russet plants were stressed from excessive irrigation during two trials in a greenhouse study. The first trial had 2 oz seed pieces planted in 2 gal pots of greenhouse mix soil with a pre-plant 16-16-16 NPK. One of three irrigation levels was applied to each pot and each irrigation level contained a pot where soil was infested with inoculum of *C. coccodes* or not infested. The 6 treatments were replicated eight times (n = 48 plants). The irrigation levels were defined as 1). High water – plants were watered to keep the soil surface constantly moist; 2). Medium water – surface of soil was allowed to dry but plants never exhibited wilt symptoms; 3). Low water – plants were irrigated only when 50% of leaflets showed loss of turgor. Due to excessive irrigation of plants receiving high water, there was typically 200 – 400 ml of drainage which depleted the nutrient reservoir of these plants. To remove the nutrient factor among irrigation levels, NPK was added to the high water treatment to maintain similar nutrient reservoirs between treatments. Nutrient levels were monitored both by chlorophyll meter and petiole assays. The second trial had the same treatments as the first except an additional high water treatment was added that received no extra nutrients and thus was susceptible to effect of nutrient leaching. Each treatment was replicated four times in the second trial. Weight of roots, density of sclerotia of *C. coccodes* on stems, density of sclerotia on roots as measured with a disease severity index (DSI) and incidence of infected progeny tubers were used to determine effect of irrigation on incidence and severity of the disease.

Root weight, density of sclerotia on roots (DSI), density of sclerotia on stems and infection of progeny tubers were all negatively affected by black dot at the high water treatment in both trials (Figs. 7, 8). Severity of black dot was greater when plants were stressed by excessive irrigation water than when plants were optimally watered (Cumming and Johnson 2014). Plant height, SPAD chlorophyll, tuber number and yield were not affected by *C. coccodes*.

Conclusions and Management of Black Dot

Several control tactics must be integrated to successfully manage potato black dot. Crop stress must be managed for successful black dot management. Sources of crop stress include short rotations between potato crop, soil nutrient imbalance, and improper irrigation practices. Lengthening the time between potato crops reduces the effect of soil-borne inoculum of *C. coccodes* and other pathogens. Data from the Columbia Basin indicate that more than five years out of potatoes are needed to substantially reduce the effects of the disease from soil-borne inoculum. However, incidence of infected tubers decreased 10% per year out of potatoes after the first three years in 2009 (Johnson and Cummings 2015). An application of a strobilurin or an effective black dot fungicide at 40-62 DAP can significantly reduce black dot sclerotia in upper and lower stems and tubers which may reduce soil inoculum in subsequent years (Cummings and Johnson 2008, Nitzan et al. 2005).

Potato seed lots with a high incidence of black dot and excessive tare dirt should be avoided. Physical surfaces that contact freshly cut tubers should be cleaned of grime and tare dirt regularly during the seed handling and cutting processes. Fields should be selected for planting with well-drained soil. Soil compaction and over irrigation should be avoided. Adequate nutrients may especially be important just before and during the bulking phase of plant growth. Young plants need to be protected from blowing sand which may increase the incidence of foliar infections should be avoided. Co-infection with other pathogens, especially the Verticillium wilt fungus will increase damage in many potato cultivars. Consequently black dot management also includes managing Verticillium wilt and other potential causes of early crop death.

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Figure 1. Immature microsclerotia of *Colletotrichum coccodes* seen as black specks between the second and third nodes from the left on a belowground stem of Ranger Russet collected at initial flowering.

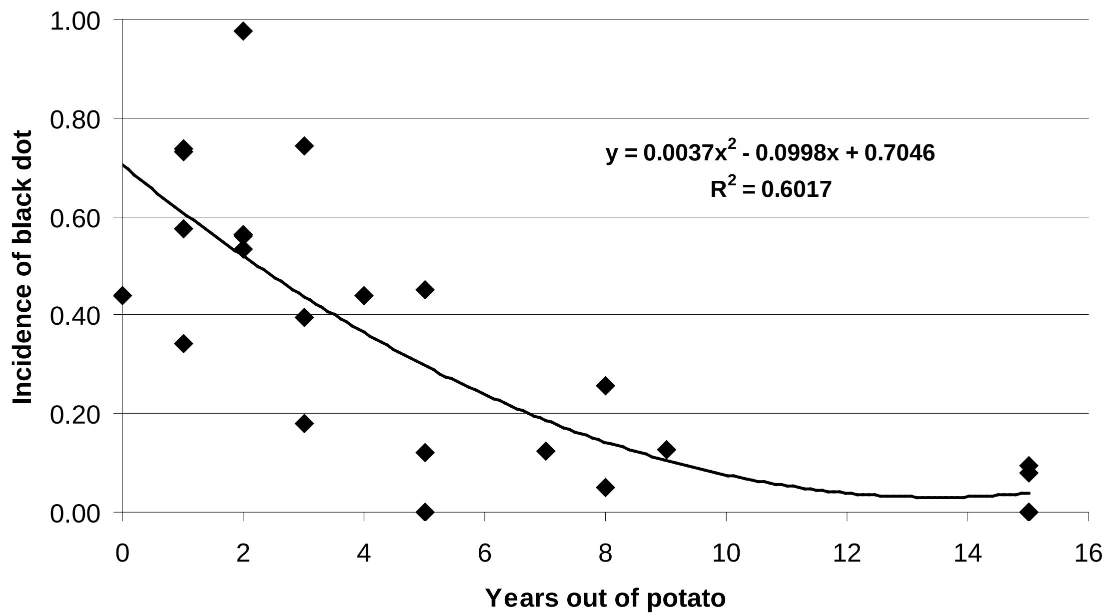

Figure 2. Incidence of black dot on tuber periderm of Russet Norkotah tubers relative to year out of potato production for 24 fields from 2008 to 2011 in the Columbia Basin WA.

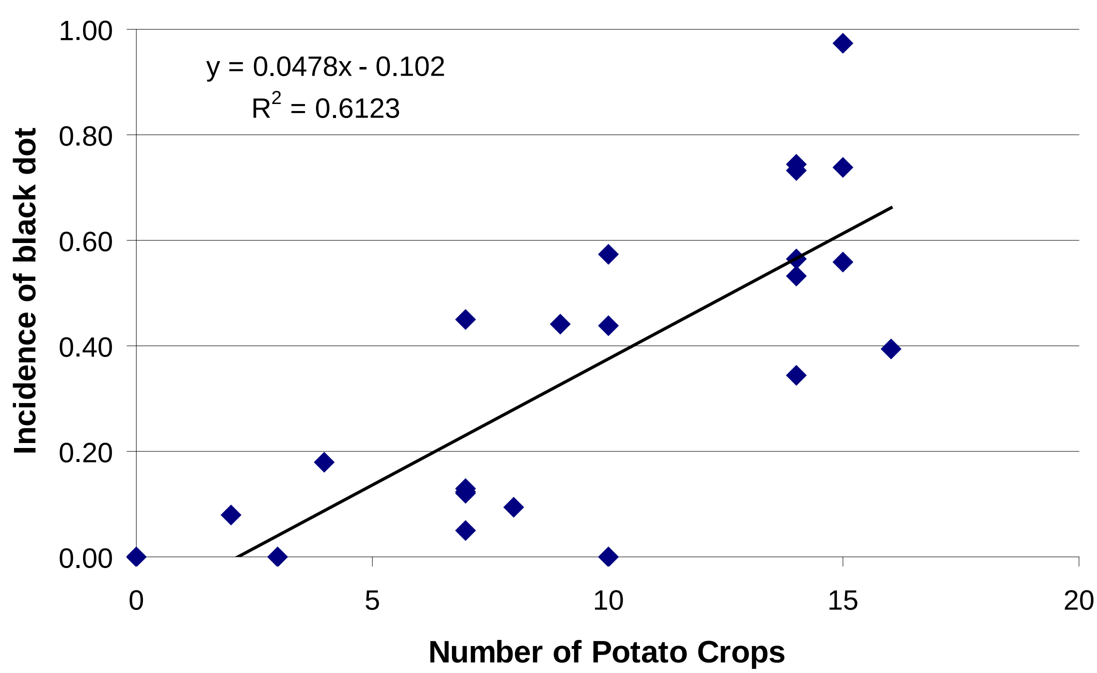

Figure 3. Incidence of black dot lesions on tuber periderm relative to the number of potato crops for twenty three fields from 2008 to 2011 in the Columbia Basin WA.

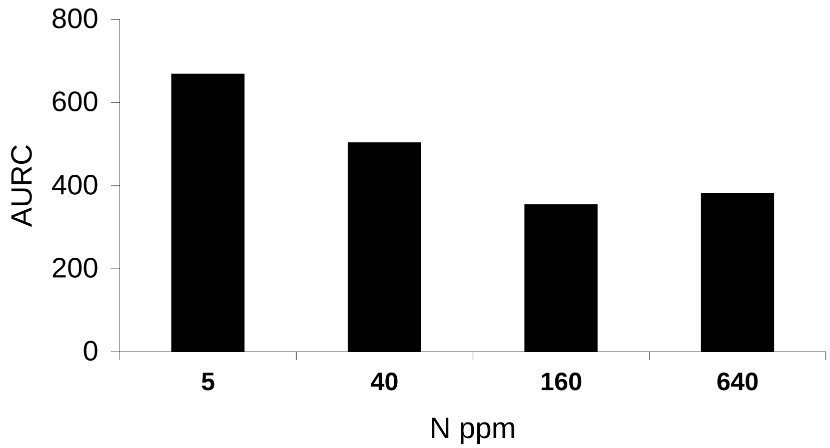

Figure 4. Root colonization curve for black dot (AURC) on RB grown in hydroponic culture with various levels of nitrogen.

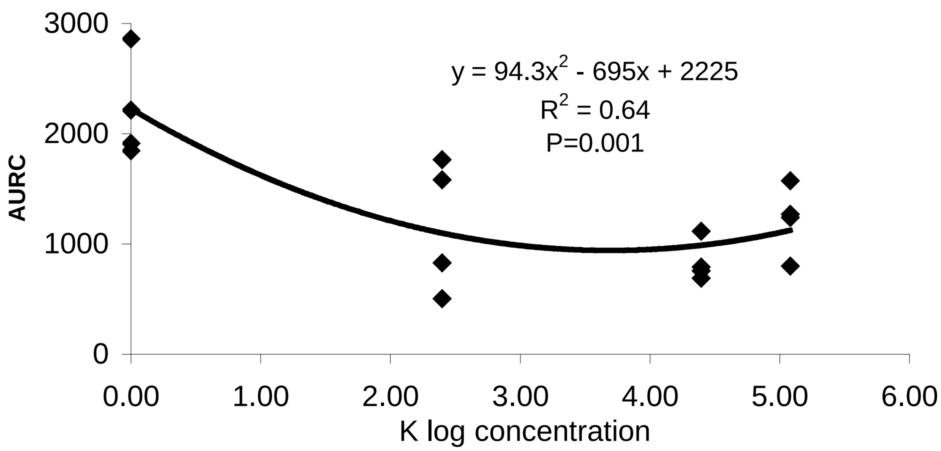

Figure 5. Root colonization curve for black dot (AURC) on RB grown in hydroponic culture with various levels of potassium. Non-transformed values of K were 0, 10, 80 and 160 mg.

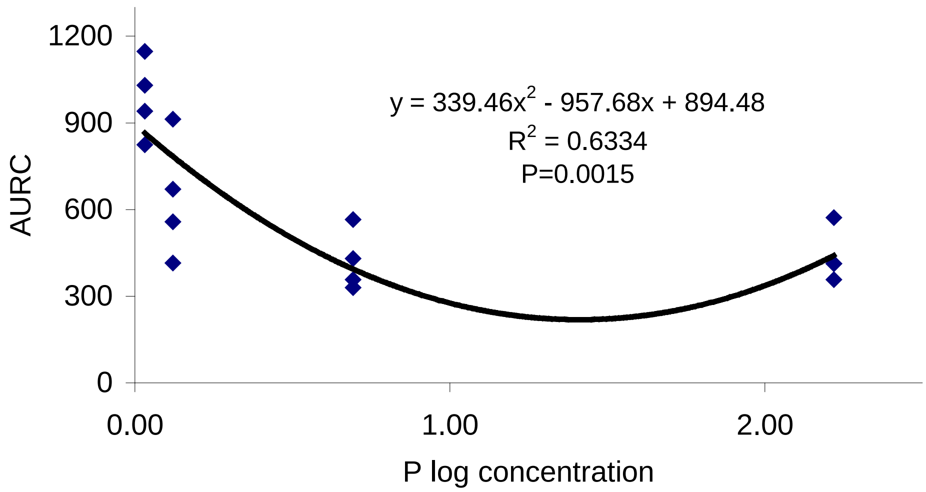

Figure 6. Root colonization curve (AURC) for black dot on RB grown in hydroponic culture with various levels of phosphorous. Non-transformed values of P were 0.032, 0.128, 1.00 and 8.20 ml.

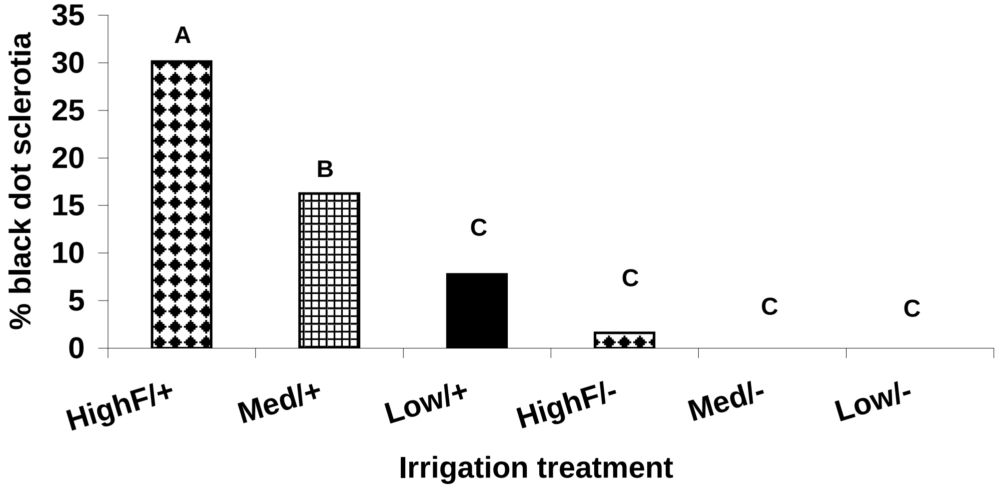

Figure 7. Percent of black dot sclerotia on potato stem in greenhouse with three levels of irrigation with (+) and without (-) soil infested with black dot.

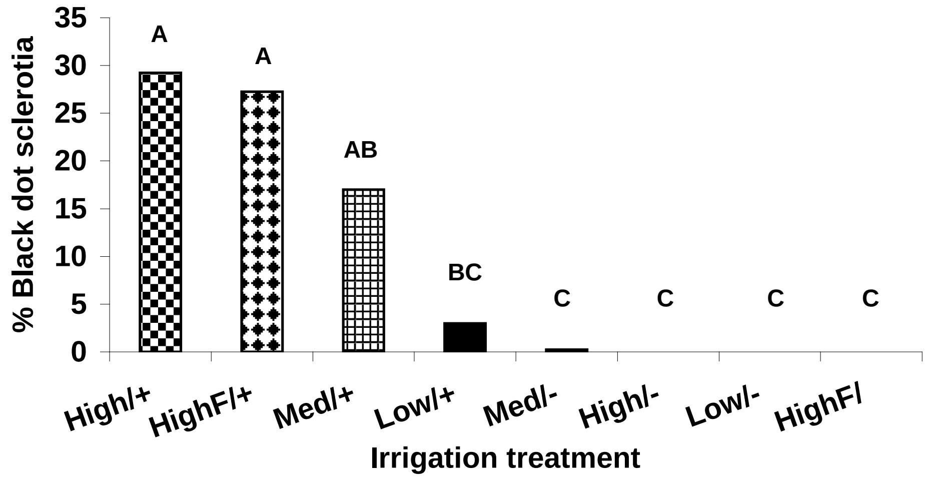

Figure 8. Percent of black dot sclerotia on potato stem in greenhouse with three levels of irrigation with (+) and without (-) soil infested with black dot where the high irrigation had nutrients (F) or not.