Effect of Plant Stress on Development of Potato Black Dot

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Roots, stolons, tubers, below ground stems and foliage of potato are all infected and colonized by the soil borne fungus *Colletotrichum coccodes.* Infected tissues characteristically develop small black sclerotia as they senesce, giving the name 'black dot' to the disease on infected potato plants. Black dot is common in most potato growing areas in the world and may cause up to 30% yield reduction.

In the Columbia Basin of central Washington, *C. coccodes* can be isolated relatively early in the growing season from below- and above-ground potato stems and from a high proportion of plants by mid-season. Stem infections are initially latent in that disease symptoms often do not become evident until late in the growing season and sclerotia generally do not develop until plants begin to senesce and die. Leaves low in the canopy on infected plants may turn chlorotic and drop before plant senescence. Initial infections are latent, but the fungus rapidly expands within stem tissues during senescence and also during times of plant stress. The internal colonization of stems has a greater affinity towards the roots, stolons and tubers than towards the foliage.

Infection of potato plants by *C. coccodes* can be caused by soil-borne, tuber-borne or air-borne inoculum. Soil-borne and tuber-borne inocula are the main inoculum sources in the Columbia Basin. Soil-borne inoculum has recently been shown to have a greater disease-causing potential than tuber-borne inoculum. Air-borne infection may be an important contributor to the initial development of the disease. A high potential for foliar infection is present in the Columbia Basin because wounds from blowing sand provide entry avenues for the fungus and sprinkler irrigation may disseminate conidia and sclerotia via splashing, and contribute the needed moisture for inoculum germination and infection.

Potato roots and stolons are susceptible to infection from soil-borne inoculum. Lesions on below-ground plant parts may resemble those caused by Rhizoctonia. The cortical tissue is invaded 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. Sclerotia develop in infected tissues. Lesions develop on foliage from air borne inoculum and are dark brown to black and similar in appearance to early blight, except concentric rings within the lesion do not develop. Infection of potato tubers by *C. coccodes* results in the development of lesions on the tuber surface, characterized by the production of small, black sclerotia. 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 sclerotia of black dot, or conidia (spores) of *Helminthosporium solani*, the causal agent of silver scurf.

Effect of Rotation on Incidence of Black Dot

The black dot fungus can be initially isolated from tubers in the field when tubers are about 3 inches in diameter. Incidence of tubers with the black dot fungus increases as the growing season progresses (Fig. 1). In a study in 2009, detection of the black dot fungus increased sharply at approximately 130 days in field. Black dot symptoms were not present on tuber's periderm collected from the field before tuber maturation, indicating that the tubers were latently infected in the field. In studies in the Columbia Basin the 2008 and 2009 growing seasons, incidence of black dot significantly decreased as the number of years between potato crops increased (Figs. 2, 3, 4). A sharp decline in incidence of black dot occurred at three years out of potato production (Fig. 3 & 4). Black dot and silver scurf decreased 10% and 6%, respectively, per increasing year between potato crops (Fig. 3). The black dot fungus was detected in fields out of potato for 10 and 15 years, but incidence of detection of the fungus was generally low after 6 or more years out of potato production (Figs. 2, 3, 4). Black dot also significantly increased as the number of previous potato crops increased (Fig. 5). Both factors, years between potato crops and number of previous potato crops, accounted for a large proportion of disease incidence for black dot ($P < 0.0001$, $R^2 = 0.87$) with 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 increases colonization of potato roots by the black dot fungus. In recent 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. Plants were then destructively sampled at 1, 2 and 3 weeks after inoculation and roots were assayed for *C. coccodes*. Nitrogen treatments were arranged as a Latin square design with three replicates and two subsamples per replicate. 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. 6). When potassium was tested, greatest root colonization occurred at the lowest level of potassium (0 mg MgK) 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. 7). 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. 8).

Effect of Water Stress on Black dot Development

Plant stress from over irrigating increases the severity of black dot on potato plants. The effects of water levels from irrigation on black dot development in potato were investigated under a greenhouse environment in 2009. Two separate trials were completed using certified G2 Umatilla Russet potato seed that was assayed free of black dot. 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. Each treatment and irrigation level was replicated eight times (n = 48 plants). The irrigation levels were defined as 1). High – plants were watered to keep the soil surface moist; 2). Medium – surface of soil was allowed to dry but plants never exhibited wilt symptoms; 3). Low – plants were irrigated only when 50% of leaflets showed loss of turgor. Due to excessive irrigation of plants receiving high irrigation 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 irrigation 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 added high treatment of irrigation 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 (root DSI), density of sclerotia on stems and infection of progeny tubers were all negatively affected by black dot at the high water irrigation treatment in both trials (Figs. 9, 10). Plant height, SPAD chlorophyll, tuber number and yield were not affected by *C. coccodes*.

Conclusions and Management of Black Dot

Incidence of tubers in which the black dot fungus can be detected increased as the growing season progressed. Tubers were latently infected in the field and disease symptoms of blemishes and lesions and disease signs of sclerotia became evident in storage. Incidence of black dot significantly decreased as the number of years between potato crops increased. 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. Severity of black dot was greater when plants were stressed by excessive irrigation water than when plants were optimally watered.

No single management tactic will successfully reduce the effects of black dot on potato growth. Therefore several tactics must be integrated to successfully manage the disease. Lengthening the time between potato crops reduces the effect of soil borne inoculum and can be a helpful disease management tactic. Data from recent studies suggest that more than four years out of potatoes are needed to appreciably reduce the effects of the disease from soil borne inoculum. Incidence of infected tubers decreased 10% per year out of potatoes after the first three years in a field study in the Columbia Basin in 2009. An application of a strobilurin 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.

Even though soil borne inoculum has a higher potential to cause severe disease than tuber borne inoculum, potato seed lots with a high incidence of black dot should be avoided. Recent research demonstrated that *C. coccodes* grows from infected seed piece to roots, stolons and tubers at a rate of approximately 1 mm/day. The fungus can easily colonize roots and stolons, and reach daughter tubers from an infected seed piece during a long growing season. Reducing plant stress is an important management tactic for black dot. A balanced plant nutrition program is important in reducing the effects of black dot on plant growth. Adequate nutrients may especially be important into the bulking phase of plant growth. Plant stress from over irrigation should be avoided. Not only does water saturated soil favor spread and development of *C. coccodes*, but oxygen is displaced in the soil which is needed for oxidative respiration by roots. Other causes of plant stress including 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.

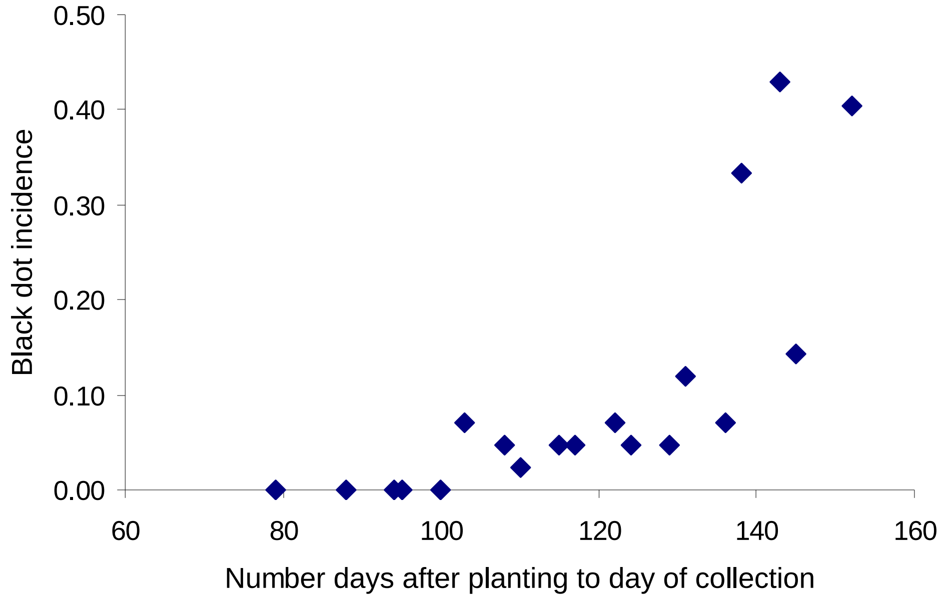

Figure 1. Incidence tubers with the black dot fungus for four fields during the growing season.

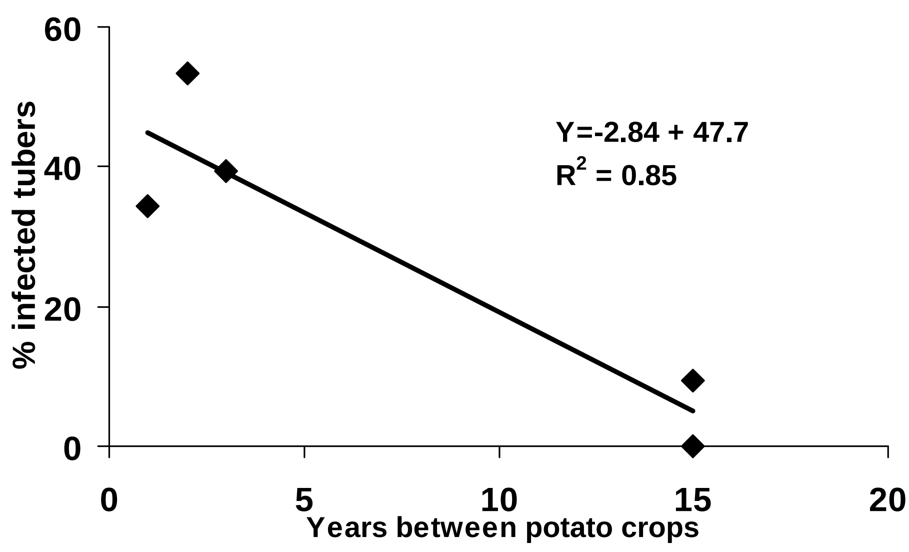

Figure 2. Percent progeny tubers that assayed positive for *Colletotrichum coccodes* in fields in the Columbia Basin with different potato rotations in 2008.

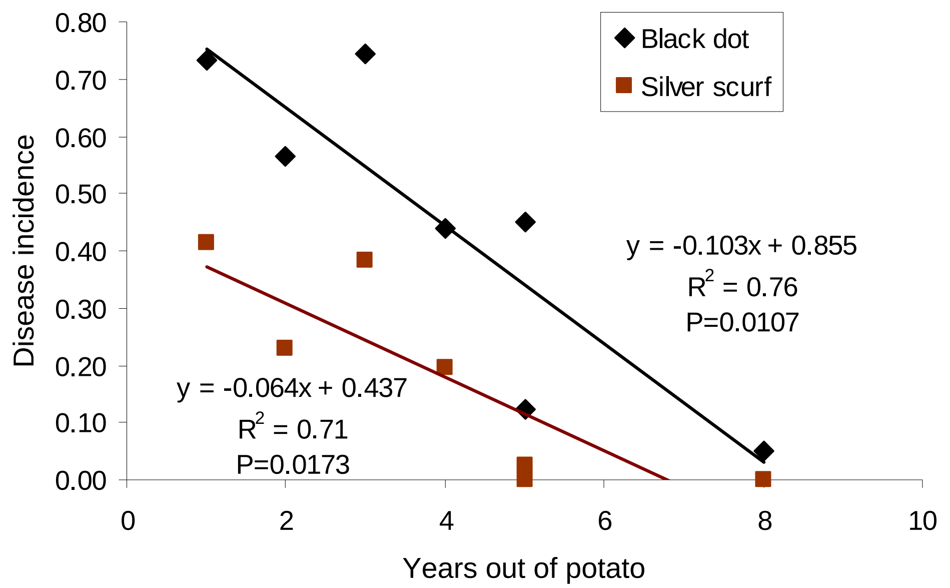

Figure 3. Incidence of black dot and silver scurf on potato tubers from seven fields from commercial storage relative to number of years potatoes were out of rotation.

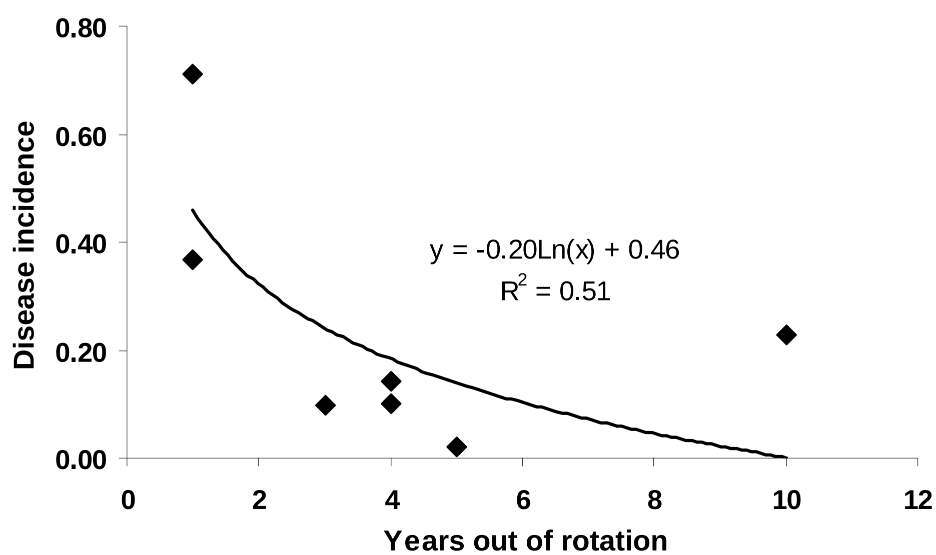

Figure 4. Black dot incidence on potato tubers out of commercial storage compared to number of years potatoes were out of rotation.

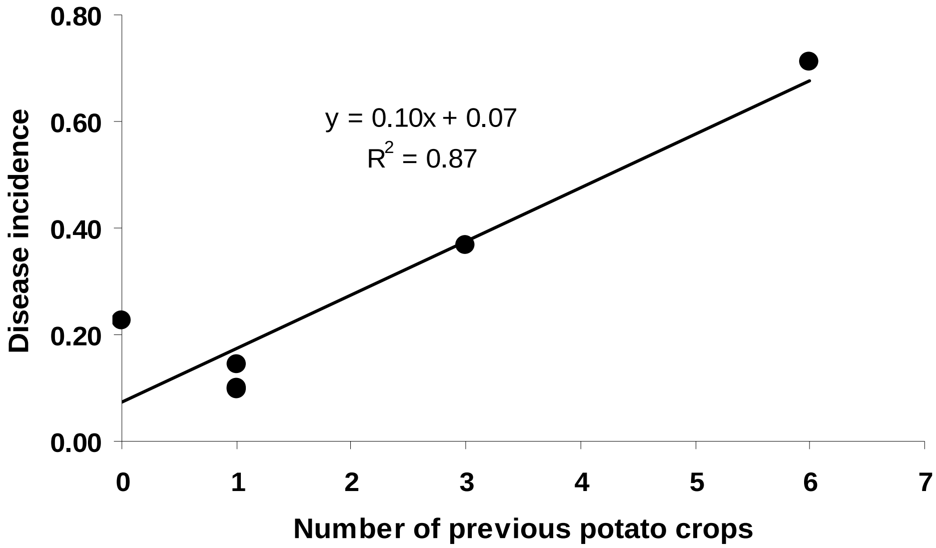

Figure 5. Black dot incidence on potato tubers out of commercial storage compared to number of previous potato crops grown.

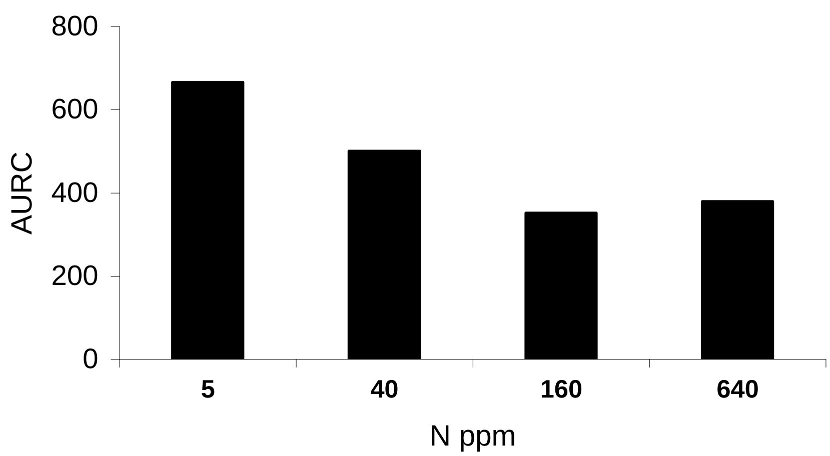

Figure 6. Root colonization curve for black dot (AURC) on RB grown in hydroponic culture with various levels of nitrogen.

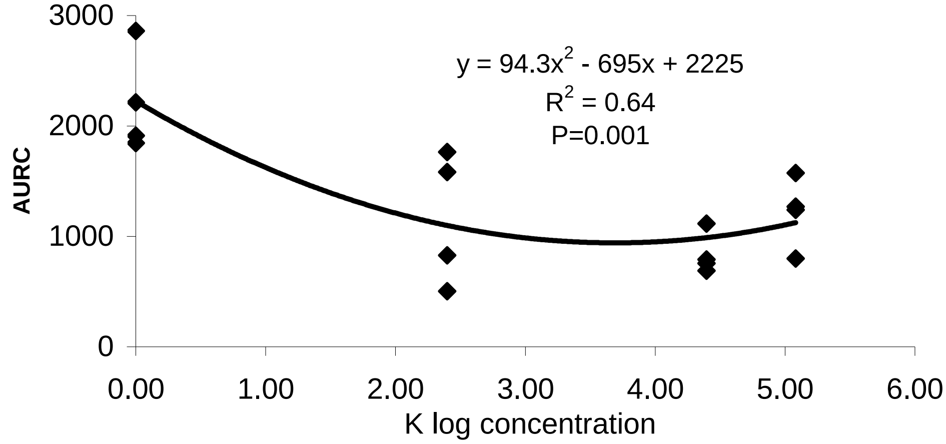

Figure 7. Root colonization curve for black dot (AURC) on RB grown in hydroponic culture with various levels of potassium. Non-transformed values of K were 0, 10, 80 and 160 mg.

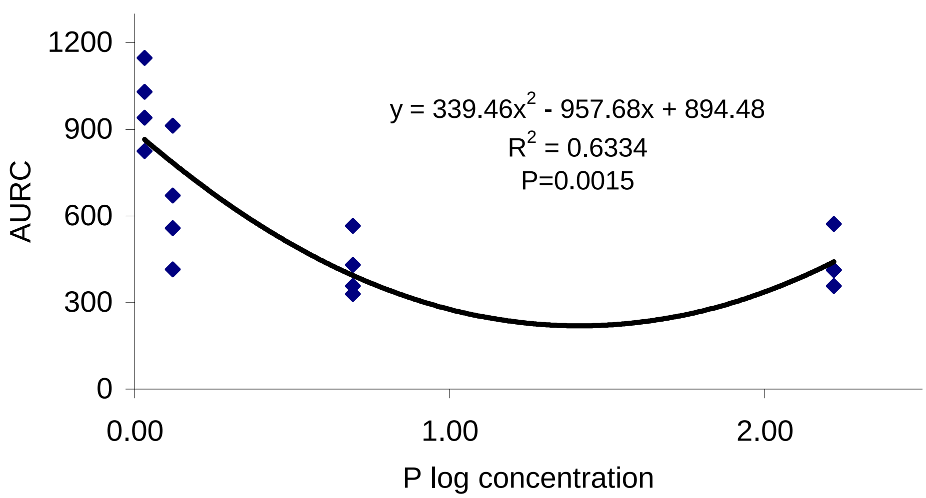

Figure 8. Root colonization curve (AURC) for black dot on RB grown in hydroponic culture with various levels of phosphorous. Non-transformed values of P were 0.032, 0.128, 1.00 and 8.20 ml.

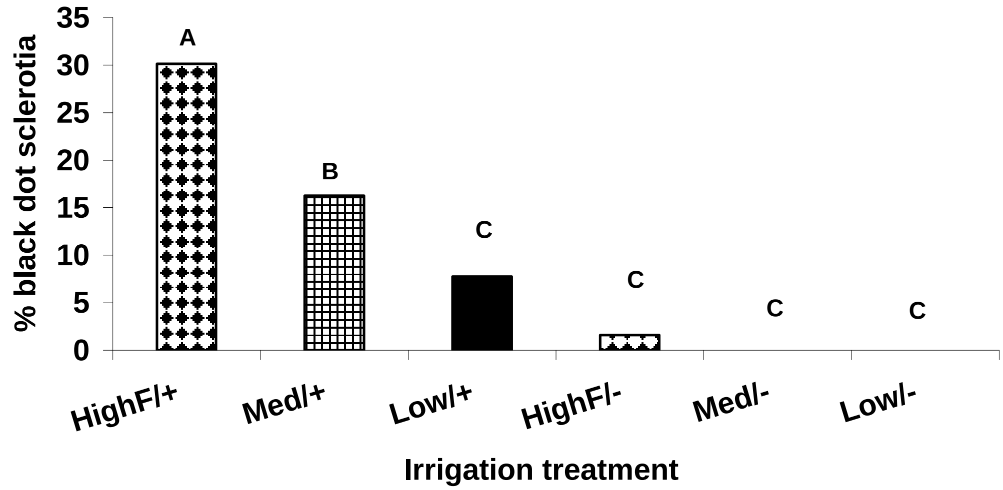

Figure 9. Percent of black dot sclerotia on potato stem in greenhouse with three levels of irrigation with (+) and without (-) soil infested black dot.

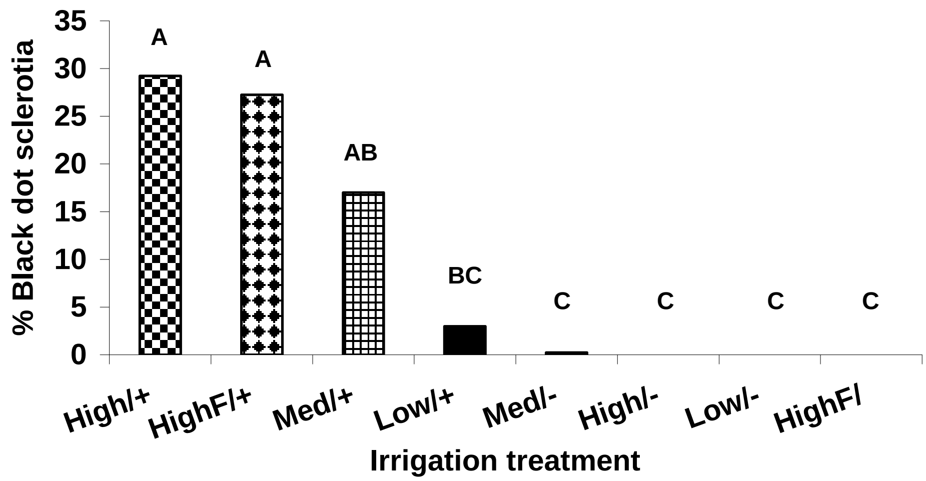

Figure 10. Percent of black dot sclerotia on potato stem in greenhouse with three levels of irrigation with (+) and without (-) soil infested black dot where the high irrigation had nutrients (F) or not.