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Supplemental irrigation and cultivar effects on potato tuber diseases

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Abstract

Supplemental irrigation can improve potato growth and tuber yield under deficit rainfall conditions, but may also impact potato tuber diseases. The comparative effects of irrigation on tuber disease incidence were quantified on four cultivars. Surface sprinkler irrigation was applied in July and August of each year, based on tensiometer or moisture block readings, with the goal of maintaining soil water to the required treatment levels. Black scurf (*Rhizoctonia solani*), black dot (*Colletotricchum coccodes*), silver scurf (*Helminthosporium solani*) and comm- on scab (*Streptomyces scabei*) diseases were quantified on potato tubers randomly sampled at harvest and stored at 7.2 C. The incidence of tuber diseases varied among irrigations and significant treatment effects (*P<0.05*) were observed for black dot, black scurf and silver scurf diseases across years. The highest levels of black dot and black scurf disease incidences were recorded on the irrigation treatments of artificial drought and Tiaug60 in 1996 and Eaug50 and Non-irrigated check in 1997, respectively. Disease incidence differed significantly (*P<0.05*) among cultivars and years, and was generally greater on Superior and Shepody than on Atlantic and Russet Burbank. This study showed that supplemental irrigation may selectively impact tuber disease incidence, depending on treatment and application scheduling, while varying cultivar susceptibility may increase tuber disease levels.

Keywords: Supplemental irrigation, cultivars, tuber diseases, Maine

Introduction

Soil-borne and tuber diseases are diverse and ubiquitous in potato growing regions of the world. Tuber black scurf (*Rhizoctonia solani* Kuhn), black dot (*Colletotricchum coccodes* (Wallr.) S.J. Hughes), silver scurf (*Helminthosporium solani* Durieu & Mont.) (Syn. *Spondylocladium atrovirens* Harz.), and common scab (*Streptomyces scabei*) are the most important potato tuber diseases in some potato production areas (Adams et al., 1987; Adams and Stevenson, 1990). In addition to their direct effects on tuber quality, their presence can increase inoculum potential for subsequent planting seasons.

The relative importance of tuber diseases has been attributed to the increase in utilization of potatoes for fresh and table stock or packed markets, which have resulted in high demand for potatoes with good quality tuber appearance. Although estimates of losses associated with tuber diseases from diverse potato production regions are limited (Lees and Hilton, 2003), the effect of these diseases on quality of tubers and pathogen dissemination on seed or table stock potatoes has increased grower awareness and sensitivity to their potential effects. In other cases, these diseases have attracted industry attention due to potential rejection of potatoes destined for processing or table stock markets (Secor, 1994; Ostrysko and Banville, 1992).

Research has been conducted on soil-borne and tuber diseases such as black scurf, silver scurf, black dot, and common scab with emphasis on their prevalence, disease management and potential impacts (Carling et al., 1989; Johnson and Miliczky, 1993; Larkin and Honeycutt, 2006). In some of the previous research, cropping systems approaches (cultivars, crop rotation, soil amendments) have been utilized as management options to reduce the incidence or severity of tuber-borne diseases and enhance soil nutrient status or organic matter content of potato soils (Olanya et al., 2006; Peters et al., 2004, Honeycutt et al., 1996). Pathogen infection of potato plants and symptom development in relation to cultivar susceptibility has also been investigated for management of stem canker and black scurf disease caused by *R. solani* (Olanya et al., 2009).

Table 1. Monthly rainfall totals and average air temperatures at Aroostook Research Farm, Presque Ilse, ME (1994-1997).

	1994	1995	1996	1997
	Total Monthly rainfall (mm)			
May	115	58	101.3	138.2
June	118	39	93.4	61.5
July	81	61	130	74.2
August	32	61	65.3	112.5
September	92	56	101.3	63.5
	Average monthly air temperature (C)			
May	10	11.2	10.6	…….
June	18.3	18.0	14.8	18.4
July	21.1	21.3	16.1	21.2
August	17.7	20.6	16.7	…….
September	12.6	13.0	…….	…….

Irrigation management and water application can have beneficial effects on potato crop development under drought stress conditions. Due to the sensitivity of potato to water stress, careful water applications are required to optimize tuber yield under deficit rainfall regimes. Irrigation requirements often differ with locations, soil types, cultural practices and cost considerations (Starr et al., 2008). Therefore, for optimum potato production; the timing, amount, frequency and duration of irrigation applications are scheduled to alleviate water stress. Sprinkler or overhead irrigations are used to optimize potato production or enhance crop profitability under certain growing conditions in Maine, and approximately 20% of the potato crop in Maine is produced with some supplemental irrigation (Dalton et al., 2004).

Although supplemental irrigation and water management have been successfully utilized to optimize potato production, the effects of water application on crop diseases may vary. Several research showed that irrigation application may enhance microclimate humidity of crops, leading to development of some diseases (Rotem et al., 1970; Olanya et al., 2007, 2009). Water application has been reported to enhance soil saturation or promote excessive wetness which may be favorable for the spread and development of some soil-borne pathogens. For example, the occurrence and severity of white mold, late blight and other foliar potato diseases with soil-borne components were reported to be influenced by moisture-related climatic factors (Rotem and Palti, 1969). Alternatively, irrigation has also been found to decrease crop susceptibility to some diseases, through its indirect effect on plant vigor or crop growth and development at critical periods (Rotem et al., 1970; Lapwood et al., 1973).

Relatively little research has documented the combined effects of supplemental irrigation and cultivars on the incidence of potato tuber diseases in the humid Northeastern United States. Therefore, this study was conducted to evaluate the independent and interactive effects of irrigation and cultivars on the incidence of selected potato tuber diseases.

Materials and methods

Site description and plot establishment

This study used experimental plots that were established at the University of Maine's Aroostook Research Farm in Presque Isle, Maine, from 1994 to 1997. The field site was established in 1991, and previously cropped to potato. The details of a related research are provided in Porter et al. (1999). The soil at the experimental site is a Caribou gravelly loam (fine-loamy, mixed, frigid isotic Haplorthods). Average air temperature and monthly rainfall totals were monitored and are summarized in Table 1.

Irrigation experiments (1994-1995)

Irrigation experiments were established during the 1994-1995 and 1996-1997 production years. The experiment was a split-plot arranged in a randomized design with four replications. The irrigation treatments were the main plots, each measuring 18.2 x 18.2m. Overhead sprinklers with plastic pipes were used for all experiments. Buffer zones (3 to 5m wide) were maintained around each plot to isolate irrigation treatments and minimize interplot interference with water applications. The irrigation treatments were: (1) non-irrigated check where natural rainfall occurred, (2) rain-out shelter or shelter irrigation in which natural precipitation or irrigation water was excluded from the plots to increase drought stress over ambient conditions, (3) reduced irrigation (fewer or smaller applications) from tuber initiation to mid-bulking with a goal of maintaining 50% plant available water in plot soil (PAW), (4) moderate irrigation treatment was conducted from tuber initiation to mid-bulking with a goal of maintaining soil moisture at 65% PAW, (5) frequent irrigation from tuber initiation to mid-bulking with a goal of maintaining soil moisture at 80% PAW, and (6) excessive irrigation was applied to field plots from tuber initiation to mid-bulking with a goal of maintaining soil moisture at 90% PAW.

Irrigation experiments (1996-1997)

In 1996-1997 the same experimental design was utilized except that irrigation treatments were different. The treatments were: (1) emergence to early August at 30% soil moisture (Eaug30) and the amount of water irrigated onto the plots was 1.14 cm per application, (2) emergence to early August at 50% soil moisture (Eaug50) at 2.29 cm per application, (3) tuber initiation to late August at 40% soil moisture (Tiaug40) at 1.71 cm per application, (4) tuber initiation to late August at 60% soil moisture (Tiaug60) at 2.86 cm per application, (5) artificial drought (Art drought) in which irrigation water was applied from late July to late August at 30% soil

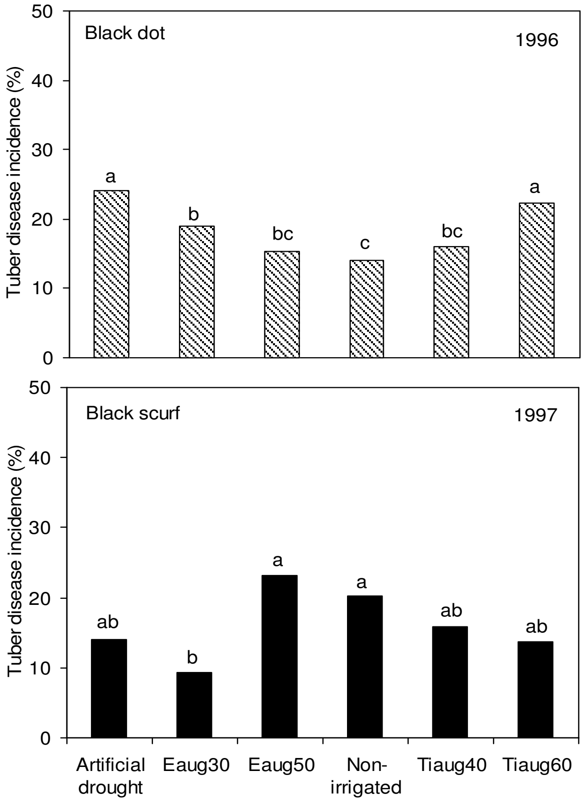

Fig 1. Effect of supplemental irrigation on the percent incidence of black dot (*Colletotrichum coccodes*) and black scurf (*Rhizoctonia solani*) on potato tubers. Data represent irrigation effects averaged across cultivars for each of the two diseases. The irrigation treatments represent Artificial drought – water was applied from late July to Late August at 30% soil moisture, emergence to early August at 30% soil moisture – Eaug30, emergence to early August at 50% soil moisture–Eaug50, Non-irrigated (check), Tuber initiation to late August at 40% soil moisture–Tiaug40, and Tuber initiation to late August at 60% soil moisture–Tiaug60. Different letters represent significant differences in average disease incidence among irrigation treatments in each year.

moisture and 1.14 cm per application, and (6) non-irrigated check in which no irrigation water was applied.

Cultivars and potato tuber diseases (1994-1995 and 1996-1997 experiments)

Cultivars were the sub-plots in this experiment and each plot measured 9.1 x 9.1 m. Four potato cultivars (Superior, Shepody, Atlantic and Russet Burbank), representing possible ranges of cultivar maturity classes and susceptibility to foliar and tuber diseases were used. The same cultivars were used during 1994 to 1995 and 1996-1997 irrigation experiments, and the incidences of soil-borne diseases on the cultivars were determined.

Foliar disease control

Foliar diseases in all plots were controlled by the application of mancozeb during 1994 and 1995. In 1996 to 1997, foliar disease management was controlled by the application of chlorothalonil. In all cases, fungicide applications were based on the recommended rates and schedules provided by the University of Maine Cooperative Extension Service.

Disease assessment

Incidence of black scurf, silver scurf, black dot and common scab was visually assessed after harvest (James, 1971). Two samples of at least 20 kg each consisting of approximately 200 potato tubers were randomly obtained from each treatment at harvest. Samples were stored at 7.2ºC and 90% RH until the grading period in December of each year. Each sample was washed on a commercial washer and then visually assessed for disease incidence by counting the number of tubers with symptoms typical of the disease evaluated and expressing it as a percentage of total tubers evaluated (50 tubers / replication). Black dot and silver scurf were differentiated based on observation of *Colletotrichum* sp. under dissecting scope immediately after washing of tuber samples. The presence of silver scurf was verified by microscopic observation of spores of *H. solani* obtained on two-sided tape. Tubers with black scurf or symptoms characteristic of *R. solani* sclerotia, and common scab were also identified. Potato tubers with and without symptoms were counted from a sample lot and weighed. The incidence of tuber diseases on potato tubers were then calculated on a number and weight basis.

Data analysis

Data on black scurf, silver scurf, black dot, and common scab incidences were analyzed separately and combined using the GLM prodedures of SAS (SAS Institute Inc., Cary, NC). Means were separated using the least significant difference (P= 0.05). Prior to analysis, incidence data were subjected to tests for normality of variances using the Shapiro-Wilk test of residuals (SAS Institute Inc., Cary, NC).

Results

Effects of Irrigation on potato tuber diseases

Analysis of variance for 1994-1995 experiments revealed that there was no significant effect of irrigation on the incidence of potato tuber diseases (Table 2). In the 1996-1997 experiments, there were significant ($P<0.05$) irrigation effects observed for some tuber diseases such as black dot in 1996 and black scurf in 1997 (Table 2,

Fig. 1). The average incidence of black dot ranged from 15 to 24% in 1996. The lowest value of the disease incidence was recorded in the non-irrigated treatment, while the treatment where water was applied at tuber initiation in early August at 60% soil moisture depletion and artificial drought had the highest black dot incidence (Fig. 1). The mean incidence of black scurf ranged from 9.4 to 23.3%. The lowest disease value was detected in irrigation treatment of early August at 30% soil moisture depletion (Eaug30) and the numerically highest incidence of black scurf was recorded on irrigation treatment initiated in early August at 50% (Eaug50) soil moisture depletion (Fig. 1).

Effects of cultivars on potato tuber diseases

Variation in the average incidence of tuber diseases was detected among cultivars (Table 2, Figs. 2 and 3). The ranking of cultivars in terms of tuber susceptibility to various diseases was not consistent. During 1994 and 1995, significant cultivar effects were detected for the mean incidence of silver scurf and black dot (Fig. 2). The incidence of silver scurf was consistently and significantly ($P<0.05$) greater on Shepody and Superior cultivars than Atlantic or Russet Burbank (Fig. 2). The incidence of black dot on tubers ranged from 6.65 to 24.64% across cultivars (Fig. 2). Among cultivars, the incidence of black scurf was generally greater in 1997 than in 1996 cropping year (Fig. 3). The incidences of silver scurf and black dot diseases were generally greater on Shepody and Superior than on Russet Burbank cultivar (Fig 3). Cultivar differences in the levels of black scurf disease were also observed (Fig. 3).

Effects of irrigation by cultivar on potato diseases

The interaction of irrigation by cultivar was significant ($P<0.05$) for black dot disease in 1996. The incidence of black dot was relatively greater on Shepody and Superior than Russet Burbank cultivar subjected to irrigation treatments consisting of Artificial drought (Artdr), Eaug50, Tiaug40 and Tiaug60 (Fig. 4). At these irrigation treatments, the average incidence of black dot ranged from 9 to 29, 10 to 21, 9 to 20 and 10 to 26%, respectively.

Discussion

Irrigation treatments led to increases or decreases in the incidence of black dot in 1996 and black scurf in 1997. This suggests that some of the irrigation treatments may selectively affect tuber-borne diseases. Differences in black dot incidence were recorded in 1996, implying that water applications may affect black dot incidence depending on treatment and timing of application. Our results are consistent with previous research which showed that water application early in the season decreased infection of potato plants and tubers by the black dot pathogen (Read and Hide, 1988). This was attributed to moderate soil moisture which was conducive for black dot infection and disease development. In contrast, Adams and Stevenson (1990) showed that excessive soil moisture may lead to swollen lenticels in potato tubers and increased susceptibility to tuber-borne infections. However, this increase may have variable effects on soil-borne pathogens. Overhead irrigation and microclimate have been shown to vary black dot development on potato, depending on the initiation of water application (Raniere and Crossant, 1959; Adams et al., 1987).

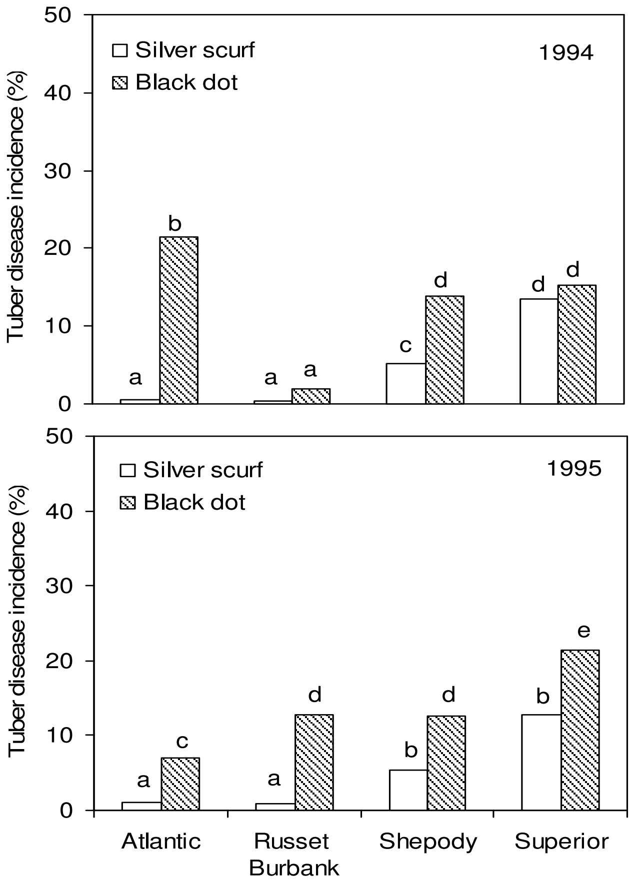

Fig 2. The effects of cultivars on the percent incidence of potato tuber diseases in a long-term experiment. Field plots were subjected to supplemental irrigation during 1994 and 1995. Data represent cultivar reaction averaged across irrigation treatments. Different letters for the same disease on cultivars represent significant differences ($P<0.05$) in mean disease values based on Fisher's LSD statistics.

Table 2. Analysis of variance on the effects of supplemental irrigation and cropping cultivars on potato tuber disease incidence

Source of variation									
Irrigation x cultivar (1994-1995)	df	Black scurf		Silver scurf		Black dot		Common scab	
Irrigation[w]	5	.3534		.5957		.1131		……[Z]	
Rep	3	.2390		.1975		.0340*		……	
Rep x irrigation	15	.2815		.4411		.6546		……	
Cultivar[x]	3	.1099		.0001**		.0007**		……	
Irrigation x cultivar	15	.7963		.8543		.6442		……	
Year	1	.8984		.8761		.6478		……	
Irrigation x year	5	.3685		.0359*		.5828		……	
Cultivar x year	3	.0366		.9437		.0001**		……	
Irrigation x cultivar x year	15	.2186		.1888		.9767		……	

Irrigation x cultivar (1996-1997)	df	Black scurf		Silver scurf		Black dot		Common scab	
		1996	1997	1996	1997	1996	1997	1996	1997
Irrigation[y]	5	.6025	.0235*	.4657	.9035	.0297*	.9828	.3179	.1590
Rep	3	.0672	.0643	.2005	.1086	.5458	.0870	.4149	.0704
Rep x irrigation	15	.5434	.2488	.2488	.5048	.4040	.1014	.9797	.0650
Cultivar	3	.0620	.0001**	.0001**	.0001**	.0001**	.0001**	.0922	.064
Irrigation x cultivar	15	.7926	.8880	.1281	.3105	.0545*	.0613	.4529	.3010

[W]Irrigation treatments consist of intermittent, frequent, moderate, rain-out shelter, reduced and non-irrigated in 1994 and 1995

[X]Potato cultivars Atlantic, Russet Burbank, Shepody and Superior were used

[Y]Irrigation treatments were: artificial drought, early august 30% soil moisture, early august 50%, non irrigated, tuber initiation to 40% soil moisture, and tuber initiation to 60% soil moisture depletion were applied in 1996 and 1997.

[Z]Data could not be analyzed due to very low or zero disease values.

Significant at *P<.05* and ** significant at *P <. 01*. The irrigation effects were tested by reps*irrigation error term. All other effects were tested by pooled error term.

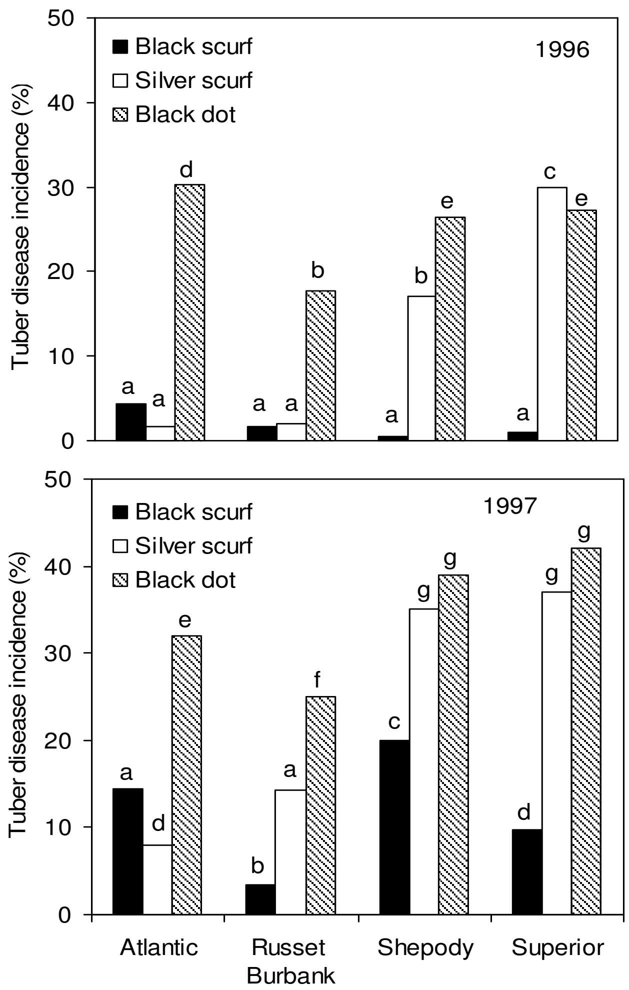

Fig 3. Effects of potato cultivars on tuber disease incidence (%) in 1996 and 1997. Data refer to cultivar effects averaged across irrigation treatments for black scurf, silver scurf and black dot. Different letters for the same disease on cultivars represent significant differences (*P<0.05*) in mean disease values based on Fisher's LSD statistics.

The previous findings are consistent with our study even though irrigation effect on the disease was observed for some of the treatments.

Soil moisture may also have favorable effects on the development of black scurf disease. Previous research showed that lower temperatures and increased soil moisture were favorable for stem canker infection and subsequently black scurf incidence (Hide and Firmager, 1989). Overhead irrigation has also been reported to alter potato canopy microclimate and thereby impacting potato disease development (Adams & Stevenson, 1990). The variation in the incidence of black scurf disease on potato, observed in our study may not be conclusively explained by soil moisture conditions conducive for infection or disease development, since high incidence of black scurf was recorded in the irrigation treatment initiated from crop emergence to early August at 50% soil moisture depletion and noted in the non-irrigated treatment. It is also possible that other factors such as variation in soil-borne inoculum levels may have contributed to disease variation among irrigation treatments. However, we did not quantify soil-borne inoculum in this study.

There is limited recently published documentation on the effect of supplemental irrigation on the incidence or severity of silver scurf disease on potato. In this study, the mean incidence of silver scurf on tubers was not significantly affected by the irrigation treatment. Even though infection of potatoes by *H. solani* may occur in field or storage resulting from soil-borne or seed-borne inoculum, warmer soil temperatures and moderate soil moisture were noted to be conducive for plant infection under field conditions (Lennard, 1980), while warmer ambient temperatures and high relative humidity were suitable for infections under storage conditions (Lennard, 1980). None of the environmental conditions (soil moisture and temperatures) were quantified in our experiments in order to make comparisons with the findings of other researchers.

No substantial effect of irrigation on common scab disease was detected in this study. This suggests that either the irrigation treatments described and utilized in this research were not effective or conducive for infection and pathogen development, or that natural inoculum levels may have been insufficient to detect significant irrigation effects on tubers in field plots. Previous research however, indicated that common scab infections of potato tubers were predisposed by dry weather, and that soil moisture deficits were correlated to disease, depending on moisture levels and the tuberization period (Lapwood et al., 1973). Our results could not be compared to the above findings since hardly any common scab disease was detected on potato tubers in 1994 and 1995 field experiments, and no significant irrigation effects on common scab were also detected in 1996 and 1997 years.

Significant variation in tuber disease incidence was detected among cultivars. The cultivars Shepody and Superior were more susceptible to silver scurf and black dot during the years of 1994 to 1997 than Russet Burbank. Similarly, Shepody was more susceptible to black scurf than the other cultivars in 1997. This suggests that the variations in disease levels may be due to the inherent differences in susceptibility of cultivars to the above diseases. Differences in susceptibility of potato cultivars to silver scurf, black scurf and black dot have been previously documented (Ostrysko and Bainville, 1992, Merida et al., 1994; Olanya et al., 2006).

The differences in susceptibility of cultivars to tuber diseases may also be attributed to maturity durations. The cultivars Superior and Shepody are early maturing compared to Atlantic and Russet Burbank.

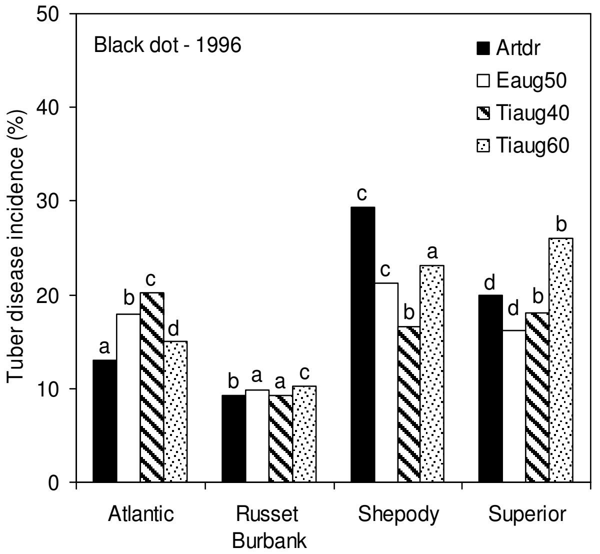

Fig 4. Supplemental irrigation and cultivar effect on the incidence (%) of black dot (*Colletotrichum coccodes*) disease during 1996. Irrigation treatments consist of water application at: emergence to early August at 50% soil moisture (Eaug50), tuber initiation to late August at 40% soil moisture (Tiau40) and tuber initiation to late August at 60% soil moisture – Tiaug60. Different letters for the same disease across cultivars for each irrigation treatment refer to significant differences ($P<0.05$) in disease based on Fisher's LSD statistics.

Early maturing potato cultivars have been noted to be generally more susceptible to various potato diseases due to earlier senescence and pathogen infection (Read, 1991). Therefore, cultivar maturity classes may be a factor in black dot incidence in that *C. coccodes* tend to colonize senescent plants rather than actively or vigorously growing potato plants. Similarly, the earlier maturing Norland cultivar was shown to have a higher incidence of silver scurf disease compared to Superior and the late maturing Russet Burbank (Merida et al., 1994).

We conclude that supplemental irrigation and cultivars may affect the incidence of potato tuber diseases. Disease increases (black scurf) may be aggravated by soil moisture conditions, but soil moisture may also be limiting for some diseases (common scab). The timing and frequency of irrigation in relation to tuber initiation and disease onset appears to be a determining factor for potato tuber disease development. Cultivar effects were significant for all diseases, suggesting that cultivar susceptibility is likely an important factor in potato tuber diseases. The cultivar maturity class is also a major predisposing factor to infection and development of many potato tuber diseases.

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