## AN ABSTRACT OF THE THESIS OF

Meghan Canfield Arbogast for the degree of Master of Science in Botany and Plant Pathology presented on March 12, 1998. Title: Response of Potato Cultivars to Moisture Deficit Stress and *Verticillium dahliae*.

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Mary L. Powelson

Six potato cultivars that differed in resistance to Verticillium wilt were grown in field plots under three different amounts of applied water in the presence or absence of inoculum of *Verticillium dahliae*. From emergence to vine kill, amount of applied water was varied by utilizing a line source irrigation system. Amount of applied water x cultivar interaction was significant for severity of foliar senescence, as measured by relative area under the senescence progress curve (RAUSPC). With a decrease in amount of applied water, RAUSPC values increased in five of the six cultivars. Percent increase in RAUSPC values increased in five of the six cultivars. Percent increase in RAUSPC values was 48 and 8% for cv Katahdin compared to an average of 107 and 88% for the other cultivars when amount of applied water was decreased by 56 and 59% in 1996 and 1997, respectively. Inoculum density x cultivar interaction was also significant for RAUSPC in four of the six cultivars. With an increase in inoculum density of *V. dahliae* from 0 to 50 or 0 to 100 CFU/g soil in 1996 and 1997, respectively the average increase in RAUSPC values of the four susceptible cultivars was 32 and 24%. For cvs Katahdin and Ranger Russet, however, average percent increase in RAUSPC was 11 and 10% in 1996 and 1997, respectively. Population size of *V. dahliae* in stem apices of cv Katahdin

in both years and Ranger Russet in 1997 was significantly lower than that of the other four cultivars. The small population size corresponded with the low RAUSPC values. In contrast, susceptibility to Verticillium wilt was associated with sensitivity to a mild moisture deficit stress in Russet Burbank and Shepody as measured by RAUSPC. In addition, apical stem populations of *V. dahliae* were correspondingly larger in these cultivars. Neither aerial biomass or tuber yield was affected by inoculum density of *V. dahliae*, but amount of applied water had significant effect on both variables. With a decrease in amount of applied water, aerial biomass and yield of all tuber classes was reduced. Lack of an effect of *Verticillium* on aerial biomass and tuber yield in both years was attributed to the relatively cool and short growing season. Resistance to Verticillium wilt of potato was related to tolerance to a season long mild moisture deficit stress. Conversely, susceptibility to this disease was associated with sensitivity to a moisture stress.

# Response of Potato Cultivars to Moisture Deficit Stress and *Verticillium dahliae*.

by

Meghan Canfield Arbogast

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APPROVED:

Redacted for Privacy

Major Professor, representing Botany and Plant Pathology

Redacted for Privacy

Chair, Department of Botany and Plant Pathology

Redacted for Privacy

Dean of Graduate School

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Meghan Canfield Arbogast, Author

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## CONTRIBUTION OF AUTHORS

Dr. Mary L. Powelson and Ms. Marlys R. Cappaert were involved in the design, analysis, and writing of the manuscript. Dr. Cliff Pereira assisted in the interpretation of data.

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## LIST OF ABBREVIATIONS

CFU = colony forming units

RAUSPC = relative area under the senescence progress curve

cv = cultivar

## Response of Potato Cultivars to Moisture Deficit Stress and *Verticillium dahliae*

## CHAPTER I.

### Introduction

Fungal vascular wilt pathogens cause disease in cultivated crops and indigenous plants throughout the temperate regions of the world. Agriculturally, many of these fungal-caused diseases have emerged as significant factors since the onset and extensive practice of monocultures. Currently, many agronomic crops, primarily products of modern plant breeding, typically possess a narrower gene pool than that of pre-Mendellian crops. This type of agriculture is thought to contribute to many fungal saprophytes and epiphytes becoming pathogenic. Crops with such genetic similarity, bred for purposes other than host defense mechanisms, have presumably allowed the few fungi that become pathogenic by random mutation to proliferate in high numbers, and thus become epidemic (Green, 1931).

The focus of my thesis research is the response of potato cultivars to the fungal wilt pathogen *Verticillium dahliae* Kleb., the causal agent of Verticillium wilt of many plants, including cauliflower, cotton, eggplant, green ash, maple, potatoes, and tomatoes. My research is on the impact of soil moisture on the development of Verticillium wilt in several potato cultivars. Research has shown that in the cv Russet Burbank disease is severe in wet soils and suppressed in dry soils. This relationship has been fine-tuned and incorporated into management strategies for Verticillium wilt in the Columbia Basin of the Pacific Northwest and the central sands of Wisconsin. Based on this relationship, I wanted to assess whether the effects of moisture on disease development held true in other cultivars. With this information, I could investigate whether a cultivar that is tolerant to a moisture deficit stress is also resistant to Verticillium wilt. My primary objective was to determine if resistance to Verticillium wilt and tolerance to moisture deficit stress are related. The implication for disease control is that tolerance to moisture deficit stress could be used as a tool to screen potato germplasm for resistance to Verticillium wilt.

# CHAPTER 2.

## Literature Review

### Biology of *Verticillium dahliae*

The fungal wilt pathogen *Verticillium dahliae*, a widespread species of *Verticillium*, is responsible for losses in many trees, ground covers, shrubs, vines, vegetable and field crops (Powelson and Rowe, 1993). Globally, this organism is a problem in many parts of western and eastern Europe, Australia, and the Pacific Northwest, north central states, Florida and California of the United States.

*Verticillium dahliae* survives in soil primarily as microsclerotia, but it also survives as clusters of hyaline cells and various types of mycelium (Schnathorst, 1981). Because of the heterogeneity of resting structures and their associated physiological differences, germination in a population of resting structures does not occur simultaneously, but rather over time. Germination is stimulated by root exudates of both host and nonhost plant species. Hyalinated and lightly pigmented peripheral cells of microsclerotia are thought to be the first to germinate, followed by the more highly melanized microsclerotia (Schreiber and Green, 1962). Once germination has occurred, infectious hyphae directly penetrate the roots. Areas of differentiation, and possibly root hair zones and epidermal tissues that have been ruptured by the emergence of lateral roots are points of infection (Garber, 1973). Once inside the root, the hyphae grow intercellularly and intracellularly through the cortex and the endodermis until they penetrate the xylem. In the xylem, the fungus colonizes the vessel elements by production of conidia. Conidia are dispersed from one vessel to another through the pits to aerial portions of the plant in the transpiration stream. If the spores become lodged, they often germinate, penetrate the obstruction, and produce more spores (Garber, 1973).

**Disease physiology.** Once the xylem has been colonized, conidia and mycelia cause physical barriers to transpiration flow. Fungal metabolites such as polysaccharides interfere with translocation as well (Caroselli, 1954). Hydrolyzing enzymes and growth regulating compounds produced by the fungus also may damage host cells. The molecular weight of any such compound influences the process as well; high molecular weight compounds plug the xylem nearer the base of the plant, while low molecular weight compounds are transported to the smaller vascular elements near the top of the plant where they plug petioles and leaf blades (Hodgson, et al., 1949).

Fungal hydrolytic enzymes can damage the host vascular system by weakening cell walls, releasing cell wall constituents, or vessel wall pieces that can assist in plugging the water conducting elements. Damage to the pit membranes can be extensive enough to allow vessels to collapse. Fungal pectolytic enzymes and polyphenoloxidase release phenolic substrates from the host tissues, resulting in vascular discoloration in the xylem or roots, and dark melanin pigments that accumulate in host cells. These pigments also may be released into the xylem, contributing to vascular occlusion (Green, 1981).

Plant growth regulators may contribute to the pathogenesis of *V. dahliae*. *Verticillium*-infected tomato plants were shown to accumulate auxin, perhaps as a result of hyperplasia of xylem and pith parenchyma, which in turn may contribute to collapse of xylem vessels (Pegg and Selman, 1959). Ethylene and indole-acetic acid were implicated in premature defoliation, activation of dormant buds, adventitious root formation, and epinasty associated with fungal wilt diseases (Green, 1981). Therefore, wilting of the host is ultimately a result of decreased solute movement through the xylem due to fungal propagules and/or host degradation products inhibiting transpiration, and/or to the interaction of the *V. dahliae* with the host. Stomatal conductance and translocation of photosynthates are thus compromised, and thus, host productivity is limited (Bowden and Rouse, 1991).

**Symptoms.** Visual symptoms of Verticillium wilt in annual crops usually begin after colonization of the vascular tissue. Initial symptoms are foliar chlorosis, followed by necrosis and finally, defoliation. Unilateral wilt is often a symptom when the fungus is restricted to one side of the plant. This symptom is more noticeable in the early stages or in mild cases of the disease. Other visual symptoms include shortened internodes and reduced leaf development, resulting in stunted growth. Overall, the symptoms are similar to normal plant senescence; however, in *Verticillium*-infected annual plants, senescence occurs prematurely, reducing yields significantly (Powelson and Rowe, 1993; Rowe, et al., 1987). In perennial crops, such as olive and maple trees, the disease can be highly damaging. Over several years the disease may kill the plant (Schnathorst, 1981).

**Inoculum survival and dispersal.** As the plant senesces the fungus becomes saprophytic and colonizes all the tissues of the plant. During this phase, microsclerotia are produced on or within the host tissue. As the host dies and crop refuse is dispersed into the soil, the microsclerotia are released. Soil inhibitors impose dormancy, or, fungistasis on these propagules. Survival of microsclerotia in the absence of a susceptible host is dependent on this fungistasis (Schnathorst, 1981). *Verticillium* survives for many years as microsclerotia or a parasite on living roots of weed hosts, volunteers and nonhost plants (Schnathorst, 1981). Spread of *V. dahliae* is primarily by movement of infected potato seed tubers, planting stock, plant debris, or infested soil (Rowe, et al., 1987).

## Environmental Influences

Verticillium wilt is more of a problem in temperate compared to tropical regions of the world. A general temperature range of 21-27 C will support disease caused by most *V. dahliae* isolates, whereas temperatures of 28-30 C suppress disease development. Host plants and *Verticillium* alike vary in their responses to soil moisture. Irrigation has an affect on the pathogen by lowering soil temperatures and providing moisture for infection. In seasons when the temperatures are cool, the transpiration rate is not accelerated; thus, disease is not likely to be severe. However, if temperatures are high enough to increase transpiration, and soil temperatures are in the range of 21-27 C, irrigation allows more rapid transport of conidia through the plant, accelerating disease. Schnieder (1948) reported that in *V. dahliae* infected guyule, disease incidence was 77% of the plants that were watered weekly; in plants that were irrigated every 2 or 4 wk or nonirrigated, disease incidence was 62, 42 or 8%, respectively. Leyendecker (1950) obtained similar results in irrigation studies with cotton. In potatoes, Verticillium wilt was more severe under wet than dry soil conditions (Cappaert, et al., 1994; Havorkort, et al., 1990). In a study on yellow poplar, Morehart and Melchior (1980) determined the effect of extreme moisture conditions on expression of disease in saplings infected with *V. albo-atrum*. When saplings were exposed to either periodic drought by withholding water for 3-wk intervals or to high moisture by flooding, wilt was more severe in infected trees stressed by low moisture than in trees subjected to flooding. Inoculated trees exposed to the flood treatment remained symptomless. Furthermore, *V. albo atrum* was not recovered from aerial portions of the trees suggesting that the pathogen had not been dispersed to the upper canopy. Morehart and Melchior (1980) suggested that flooding negatively affected the virulence of *Verticillium* while in the roots, thus preventing disease development. Aerenchyma tissue may develop in response to low soil oxygen that could prevent the transport of *Verticillium*.

Because some symptoms of pathogen-induced water deficits and abiotic drought stress are similar, research has been done to better understand the host, pathogen, and soil moisture relationships of Verticillium wilt. The following examples, in particular, are key works that explain why an understanding of these interactions is critical to disease management. In a very extensive project, Nelson (1950) tested the reaction of peppermint to various soil moisture levels in the presence of *V. albo-atrum*. In tank tests, soil moisture maintained at 80-85% field capacity either prevented infection, or the plants were tolerant, harboring the pathogen, but exhibiting no symptoms, unless temperatures reached 26-28 C. When the soil was saturated, however, severity of wilt increased. At the other extreme, when soil was dried to 70% field capacity, again infection and development of wilt were enhanced. When tested in the field, the most severe disease occurred when soil temperature was high (22-28), and moisture was medium to very high (60-80% field capacity).

Pennypacker et al. (1991), explored the effect of abiotically induced drought on alfalfa plants resistant to *V. albo-atrum*. Her purpose was to assess whether drought acclimation mechanisms might influence plant response to the combined pathogen and drought stresses. By gradually intensifying drought, the plants would have a chance to acclimate, which may influence the host response to the pathogen. Two resistant alfalfa clones were evaluated for resistance to colonization by *V. albo-atrum* following three 28 day growth periods. The first growth period was watered normally. The second and third growth periods were well watered at the beginning, followed by a drying down of the soil. Following the second growth period, the plants were watered, and colonization by *V. albo-atrum* measured subsequently. One clone showed a corresponding surge in vascular colonization by *V. albo-atrum*, whereas the other clone did not, alluding that there are different resistance mechanisms to *V. albo-atrum* in these clones. When the clones were droughted during the third growth period and re-watered, colonization was suppressed in both clones.

In similar works, Haverkort et al. (1990) measured stomatal conductance, transpiration and net photosynthesis on potatoes infected with *V. dahliae* to assess host physiological responses to disease and moisture deficit stress. Measuring responses to the pathogen alone 1 mo post emergence, stomatal conductance, transpiration, and net photosynthesis were decreased. Next, three drought treatments were imposed: 1) water was withheld until the wilting point, 2) half the amount of transpired water was withheld from the time of treatment 1 to the end of the season, and 3) water was withheld for 4 days prior to measurements of physiological parameters. Drought treatments reduced stomatal conductance, transpiration and photosynthesis. More importantly, an interaction of pathogen and drought occurred such that *V. dahliae* reduced transpiration, and those plants were affected less from the early season drought, than plants droughted in the absence of *V. dahliae*. These works demonstrate the complexity of fungal wilt pathogen, host, and moisture interactions.

Control of Verticillium Wilt

Factors contributing to the difficulty in controlling this disease are the pathogen's ability to tolerate dry conditions and antagonistic soil factors, the prolonged period of time over which microsclerotia germinate and infect a host, and the length of time microsclerotia can survive in the soil between cropping seasons.

**Chemical control.** Verticillium wilt in potato is effectively controlled by soil fumigation with metam sodium or methyl bromide-chloropicrin (Davis, 1985; Erwin, 1981). Their environmental impact, however, is not fully known, and other control methods are currently being explored.

**Cultural control.** Cultural practices including crop rotation, plow down of green manures, fertility, and timing and amount of applied water have been shown to be effective strategies for control of Verticillium wilt in potato. Crop rotation is effective if rotations are long enough to reduce populations below the economic threshold. This is often not economically feasible, because microsclerotia have been known to survive for up to 16 yr. The plow-down of green manures has been investigated as one approach to reduce inoculum levels during non-crop years. This technique has had mixed results, with some research showing reduction in disease severity following two or three consecutive years of a green manure (Davis et al., 1996), whereas Cappaert and Powelson, (1997) have shown no reduction in the disease. Incorporation of broccoli residue has been effective in reducing inoculum levels of *V. dahliae* and suppressing disease in cauliflower fields in California (Subbarao and Hubbard, 1996).

Adjustments in scheduling in irrigation to make the soil less conducive to disease have proven successful with the potato cultivar Russet Burbank (Cappaert et al., 1994).

By imposing a mild drought between emergence and tuber initiation, severity of Verticillium wilt was significantly reduced, and yields were maintained.

Solarization reduced *V. dahliae* inoculum levels with increased yields in potato fields in Idaho and the effect lasted for two cropping seasons (Davis and Sorensen, 1986). To date, this method of disease control is not widely used, but may have potential value in the warmer potato producing regions of the world.

Propane flaming of mint and potato stubble is an effective tactic to reduce inoculum of *V. dahliae* (Hardison, 1976). Burning of mint fields is practiced in Oregon as one approach to managing wilt (McIntyre and Horner, 1972). In potato, however, it took 3-yr before inoculum levels were decreased enough to exert significant control; therefore it is not considered an effective control method (Easton et al., 1975).

**Host resistance.** To date, no commercial potato cultivars are immune to this disease. Cultivars that have moderate to high levels of resistance, such as Ranger Russet, Reddale, Century Russet, and Katahdin, have been released (Corsini and Pavek, 1996; Corsini, et al., 1985, Davis, 1985;). Transgenic potato plants with genes inserted for resistance to Verticillium wilt are currently being screened in the Pacific Northwest and Wisconsin (Powelson, personal communication).

# CHAPTER 3.

## Response of Six Potato Cultivars to Amount of Applied Water and *Verticillium dahliae*

Meghan C. Arbogast, Mary L. Powelson, and Marlys R. Cappaert

## Introduction

Verticillium wilt, caused by the soilborne fungus *Verticillium dahliae* Kleb, is a factor limiting potato production in both irrigated and nonirrigated production areas of the world. The disease results in premature senescence of the foliage; the earlier the onset of senescence, the greater the yield reduction. Yield losses of up to 50% have been reported (Davis and Sorensen, 1983; Powelson, 1979; Rowe and Riedel, 1976).

This disease is controlled by soil fumigation, long term crop rotations, and modification of cultural practices such as fertility (Davis and Everson, 1986) and irrigation (Cappaert et al., 1994; Davis and Everson, 1986). Both soil solarization (Davis, 1985; Davis and Sorensen, 1986) and plow down of green manures (Davis et al., 1996) have been reported to suppress this disease. A few resistant cultivars with market acceptance have been released (Corsini and Pavek, 1996; Corsini et al, 1985; Corsini et al., 1988; Davis, 1985).

Two environmental factors that influence the severity of Verticillium wilt are temperature and moisture. When air temperatures are in the range optimum for colonization of the vascular tissue by *V. dahliae,* disease can be severe (Francl et al., 1990). The relationship between soil moisture status and disease severity in agronomic and horticultural species, however, has been variable. For example, severity of wilt symptoms has been associated with amount of applied water, frequency of irrigation, and drought episodes. Cappaert et. al. (1992) working with potato, and El-Zik (1985) with cotton, showed that with an increase in amount of applied water, disease severity was increased. With guyule, disease was more severe under frequent versus less frequent irrigations even though amount of applied water was the same at each irrigation event

(Schnieder,1948). In contrast, the severity of Verticillium wilt in maple was higher under a constant soil moisture deficit stress than under optimum soil moisture conditions (Caroselli, 1957). When mint was grown in soil at 70 compared to 85% field capacity, disease ratings were higher (Nelson, 1950).

Early dying (Verticillium wilt) in potato cv Russet Burbank can be suppressed if water is managed prior to tuber initiation (Cappaert et al., 1994). When water was applied at 75% of estimated consumptive use (ECU) (mild moisture stress) prior to tuber initiation the disease was significantly less severe compared to the 150% ECU and yields were maintained (Cappaert et al., 1994). Studies on the effect of a range in soil moisture levels on Verticillium wilt in other potato cultivars, however, are lacking. Based on the response of cv Russet Burbank to a mild moisture stress, our working hypothesis is that cultivars that are tolerant to a season long mild moisture deficit stress will be resistant to Verticillium wilt. The objectives of our research were two fold: 1) to evaluate potato cultivars for reaction to a moisture deficit stress and Verticillium wilt, and 2) to determine if responses to a moisture deficit stress and Verticillium wilt are similar across cultivars.

## Materials and Methods

**Field plots.** Field plots were established at the Central Oregon Agricultural Research Center in Crook County (941 m elevation; 90- to 100-day growing season; Madras, fine-loamy, mixed, mesic, Xerollic Duragid, Aridisol) on 10 May 1996, and 14 May 1997. Treatments were six potato (*Solanum tuberosum* L.) cultivars, three amounts of applied water, and two levels of *V. dahliae* inoculum. The experimental design was a split-plot randomized block with amount of applied water as the main plot and cultivar x *V. dahliae* inoculum as subplots. Each factorial set of treatments was replicated six times.

**Inoculum production.** Single spore isolates of *V. dahliae* from symptomatic potato plants collected from Umatilla County in 1995 were grown on potato dextrose agar. The plates were flooded with sterile water, and 200 µl aliquots of the conidial suspension were pipetted into tubes with 9 ml of Czapex Dox broth. The broth was shaken in the dark at 22 C at 60 rpm for 48-72 hr. Rye grain was autoclaved for 40 min and approximately 1 liter was placed in mushroom spawn bags (Northwest Mycological Consultants, Corvallis, OR). Bags were closed, autoclaved for 80 min and cooled to 22 C in a laminar flow hood. One tube of the *V. dahliae* spore suspension was added to each bag. The bags were closed with plastic zip ties, and stored in the dark at 22 C. The rye grain was shaken every 2 days until most of the grain was covered with microsclerotia of *V. dahliae*. The colonized rye grain was spread on greenhouse benches, air-dried, and then ground in a J. B. Hammermill. Inoculum density of *V. dahliae* was determined by diluting the ground rye in sterile greenhouse soil, and plating the mixture onto Sorensen's modified NP-10 medium (Sorensen et al., 1991) with an Anderson air sampler (Butterfield and DeVay, 1977). Appropriate amounts of the colonized rye grain were added to sterile greenhouse soil so that the resulting inoculum density in field plots would be ~50 or 100 CFU/g of soil in 1996 and 1997, respectively.

**Seed stock.** Seed tubers were purchased from certified seed potato growers in the United States. The cultivars, Katahdin, Ranger Russet, Red La Soda, Russet Burbank, Shepody, and Viking, represented a range in maturity, tuber quality, resistance to Verticillium wilt, and drought tolerance (Table 1).

Table 1. Maturity class and reaction to drought and Verticillium wilt in six potato cultivars.

| Cultivar | Maturity class | Drought reaction | Verticillium wilt reaction |
|---|---|---|---|
| Katahdin | late [a] | Moderately tolerant [a] | resistant [a] |
| Ranger Russet | medium-late [b] | -- [c] | resistant [a] |
| Red La Soda | early-medium [a] | sensitive [a] | -- [c] |
| Russet Burbank | late [a] | sensitive [a] | moderately resistant [a] |
| Shepody | medium-early [b] | sensitive [a] | susceptible [a] |
| Viking | medium [a] | moderately tolerant [a] | susceptible [a] |

[a] Mosley and Chase, 1993
[b] James, personal communication
[c] reaction not published

**Plot establishment.** Seed tubers were cut into seed pieces weighing 43 to 71 g. Seed pieces were planted in plots of three 6.0 m long rows. Row width was 86 cm and seed pieces were spaced 34 cm apart within the rows. Area between plots was planted to Russet Burbank to avoid flooding. At planting, about 50 (1996) or 100 (1997) g aliquots of *V. dahliae* inoculum were banded along side the seed pieces of the center row of the *Verticillium*-infested plots.

Irrigation treatments were established with a line source irrigation system, so that a moisture gradient was created perpendicular to the irrigation line. Plots were parallel to the irrigation line and the center row of each plot was positioned at 2.3, 5.9, or 9.6 m from the line source. Amount of water applied to each distance was designed to supply 100, 75, or 50% estimated consumptive use (ECU). Irrigation was scheduled using crop water use calculations based on weather data collected on site, and adjusted when visual soil moisture observations indicated excessive soil dryness or wetness. Percent volumetric soil moisture was monitored weekly with a time-domain-reflectometer (Soilmoisture Equipment Corp., Santa Barbara, CA), and amount of applied water was measured in catch cans after each irrigation and precipitation event.

**Response variables.** Data were collected on the center row of each plot. When plants began showing foliar symptoms of chlorosis and necrosis, weekly assessments of percent foliar senescence per plot were made on a scale of 0 to 100%. When all cultivars had reached growth stage V, one stem from each plot in 1996 and three stems/plot in 1997 were harvested for aerial biomass determination. Samples were dried in ovens at approximately 100 C and then weighed. In addition, the top 10 cm of three (1996) and 10 (1997) plants were randomly collected from each plot. Leaves were removed; the remaining stem pieces were dried at 22 C for 3 mo and ground in a Wiley mill (mesh #20). The ground stems were plated with an Anderson Air Sampler (Butterfield and DeVay, 1977) onto Sorensen's Modified NP-10 medium (Sorensen et al., 1991) at 0.04 g per plate. Plates were incubated in the dark at 22 C for 7-14 days. The agar surface was rinsed under tap water and colonies of *V. dahliae* were counted with a stereomicroscope.

The center row of each plot was harvested by machine. Tubers were weighed and graded into yield components of U.S. No. 1's (<113 g, 113-170 g, 171-340 g, and >340 g), No. 2's and culls. Marketable tuber weight was calculated as the mean total weight per treatment minus the No. 2's and culls.

**Data analysis.** Degree-days after planting (DDAP, base=12.8 C ) was calculated by the methods of Baskerville and Emin (1969). Foliar senescence progress curves were generated based on mean percent senescence per treatment. Area under the senescence progress curve was calculated (Shaner and Finney, 1977) and the value divided by the number of degree-days over the senescence period, to generate the relative area under the progress curve (RAUSPC). This calculation adjusted for differences in maturity class. Values for aerial biomass and apical stem populations were natural logarithm transformed before analysis. Biomass, RAUSPC, apical populations, and graded tuber yield treatment means were analyzed by the general linear models (GLM) procedure by SAS, version 6.12 (SAS Inst., Cary, NC). To account for non-random assignment of irrigation treatments, the error term designated for the irrigation effect was block*irrigation. The Huyn-Feldt tests of sphericity were used to test the hypothesis that the irrigation treatments were not correlated and had equal variance. If the error term of the irrigation treatment main effect was greater than the error term of the block*irrigation treatment, a simple model was applied, and irrigation main effects were allowed. Treatment means were separated by Fishers protected least significant difference test.

## Results

**Irrigation treatments.** Irrigation treatments were initiated 143 and 171 DDAP in 1996 and 1997, respectively. Total amount of applied water for the season (irrigation plus precipitation) at 2.3, 5.9, and 9.6 m from the irrigation line was 61, 44, and 27 cm and 41, 31 and 17 cm in 1996 and 1997, respectively (Fig 1). Amount of applied water per irrigation event averaged 2.9, 1.9, and 1.2 cm and 1.9, 1.4, and 0.7 cm for each distance in 1996 and 1997, respectively. Average percent volumetric soil water within 24 hr of irrigation at 2.3, 5.9, and 9.6 m was 18, 11, and 4%, and 18, 12, and 6% in 1996 and 1997, respectively (Fig. 2). Plots furthest from the irrigation line averaged <10% volumetric soil water in both seasons. The permanent wilting point for a sandy-loam soil is 10% (Kramer, 1983a); therefore, a mild moisture-deficit stress was achieved in the plots furthest from the line source.

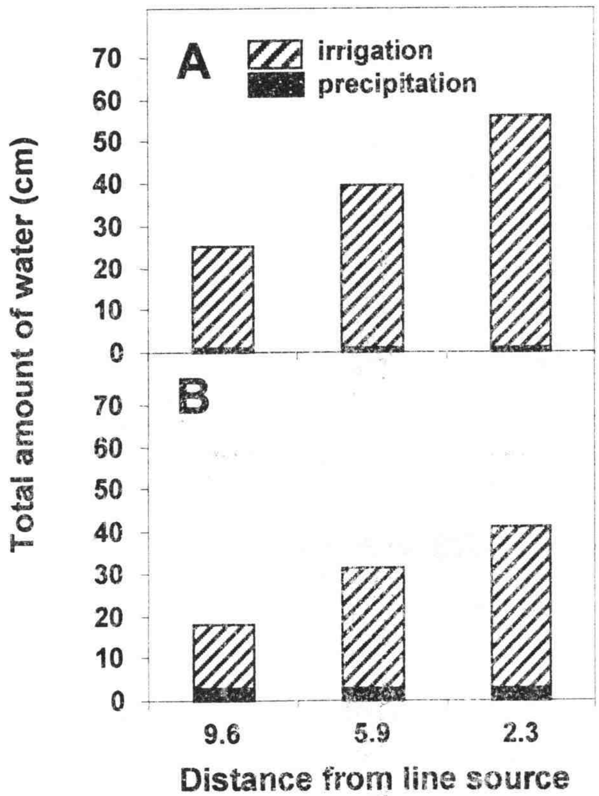


Fig. 1. Cumulative amount of applied water at three distances from an irrigation line source in **A**, 1996 and **B**, 1997. Amount of applied water was based on estimated consumptive use of potato. Bar segments indicate the total amount of water applied during the season and the portion that came from rain.

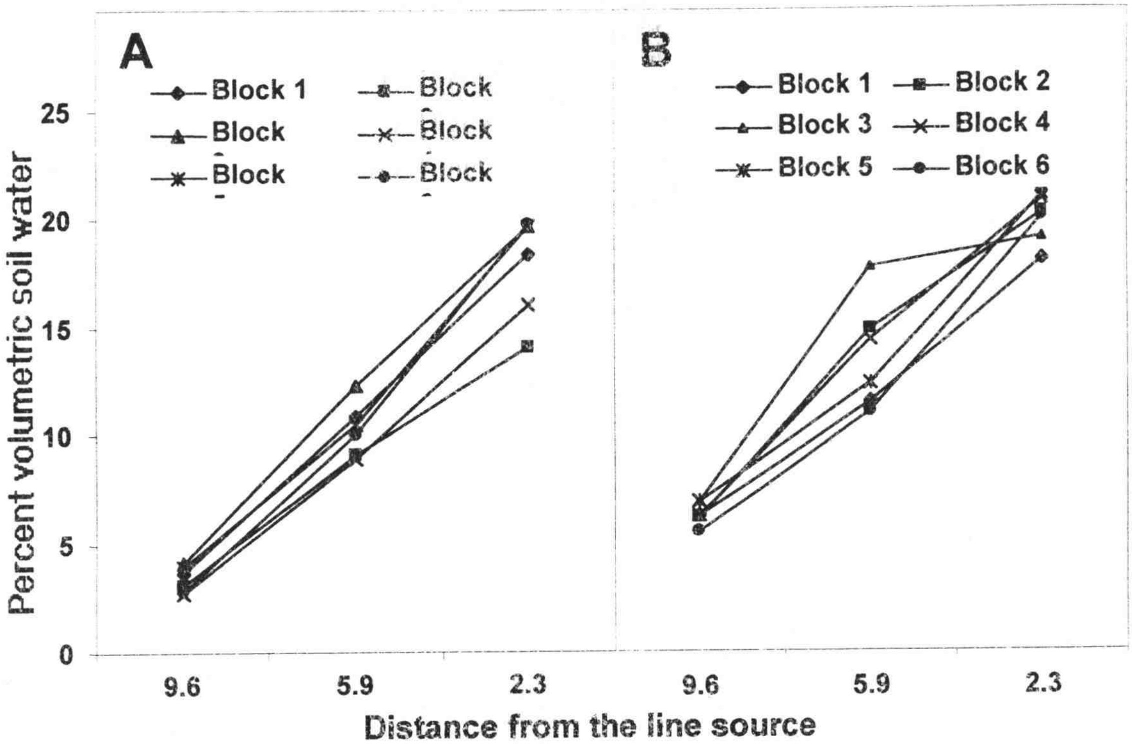


Fig. 2. Percent volumetric soil water measured at each of three treatment distances from an irrigation line source for six blocks in A, 1996 and B, 1997. Percent volumetric soil water was measured to a depth of 15 cm with a time-domain-reflectometer.

**Foliar senescence.** Amount of applied water x cultivar interactions were significant for RAUSPC in both 1996 ($P$=0.0009) and 1997 ($P$=0.0194) (Fig 3). In 1996, a decrease in amount of applied water had no effect on foliar senescence in cv Katahdin, but resulted in an overall increase in RAUSPC in the other five cultivars. Increases in RAUSPC ranged from 40 to 80% and 65 to 135% when amount of applied water was reduced from 61 to 44 cm (28%) and from 61 to 27 cm (56%). In 1997, a 24% reduction in amount of applied water had no effect on RAUSPC for cv Katahdin, Viking, and Ranger Russet, but had a significant effect on the other cultivars. The increase in RAUSPC ranged from 23 to 55% when amount of applied water was reduced from 41 to

31 (24%). When applied water was decreased by 59% (41 to 17 cm), RAUSPC was increased by 38 to 153% in all cultivars but Katahdin.

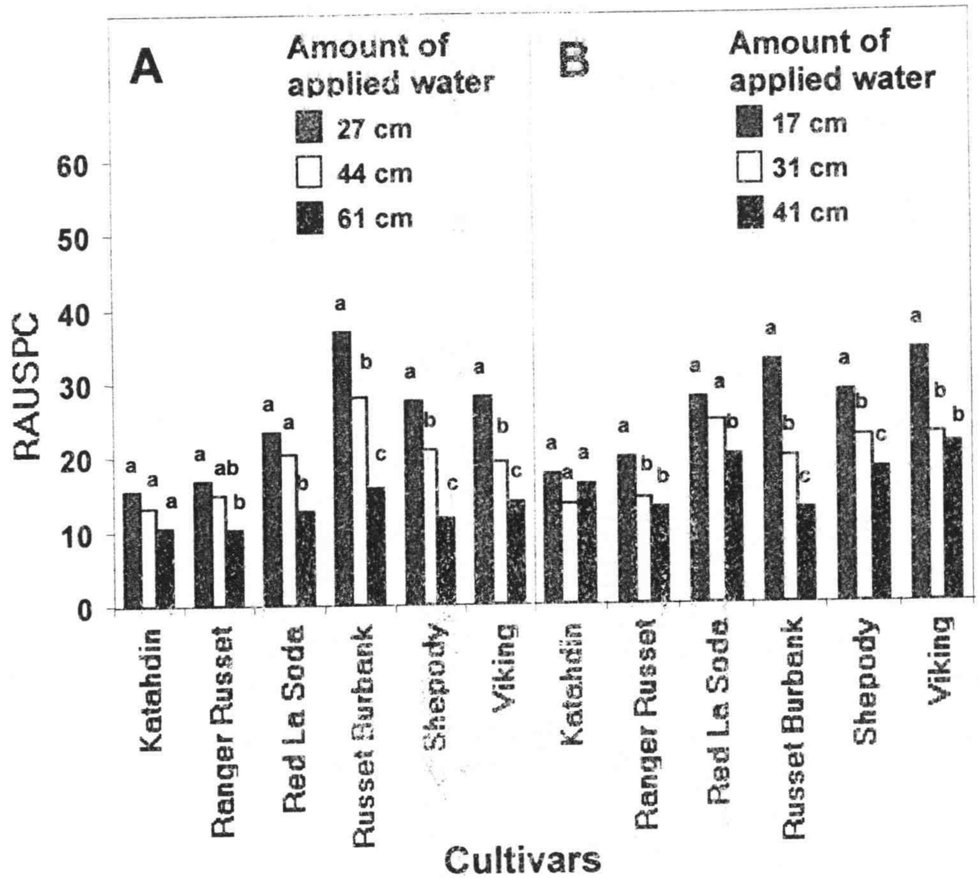


Fig. 3. Amount of applied water x cultivar interactions on relative area under the senescence progress curve (RAUSPC) of potato in **A**, 1996 and **B**, 1997. Within cultivar, bars with the same letter did not differ significantly according to Fisher's protected least significant difference (LSD) test ($P \leq 0.05$). Amount of applied water x cultivar interaction for **A**, $P$=0.0090 and **B**, $P$=0.0194.

Foliar senescence was significantly affected by an interaction between cultivar and inoculum density of *V. dahliae* ($P$=0.0194 and $P$= 0.0033 in 1996 and 1997, respectively)(Fig 4). Cvs Katahdin and Ranger Russet were resistant and cvs Russet Burbank and Shepody were susceptible to Verticillium wilt as measured by RAUSPC. RAUSPC values were 44 and 31% higher in 1996 ($P$=0.0001 and $P$=0.0244) and 61 and

19% in 1997 than they were in noninfested plots ($P$=0.0001 and $P$=0.0244), respectively. Response of cvs Red La Soda and Viking was inconsistent across years. In 1996, Viking was not significantly affected by inoculum density. In contrast, in 1997 inoculum increased RAUSPC values significantly ($P$=0.0113) by 19%. In cv Red La Soda, the RAUSPC value was 42% greater ($P$=0.0014) in the presence of *V. dahliae* inoculum in 1996, but was not affected by inoculum in 1997.

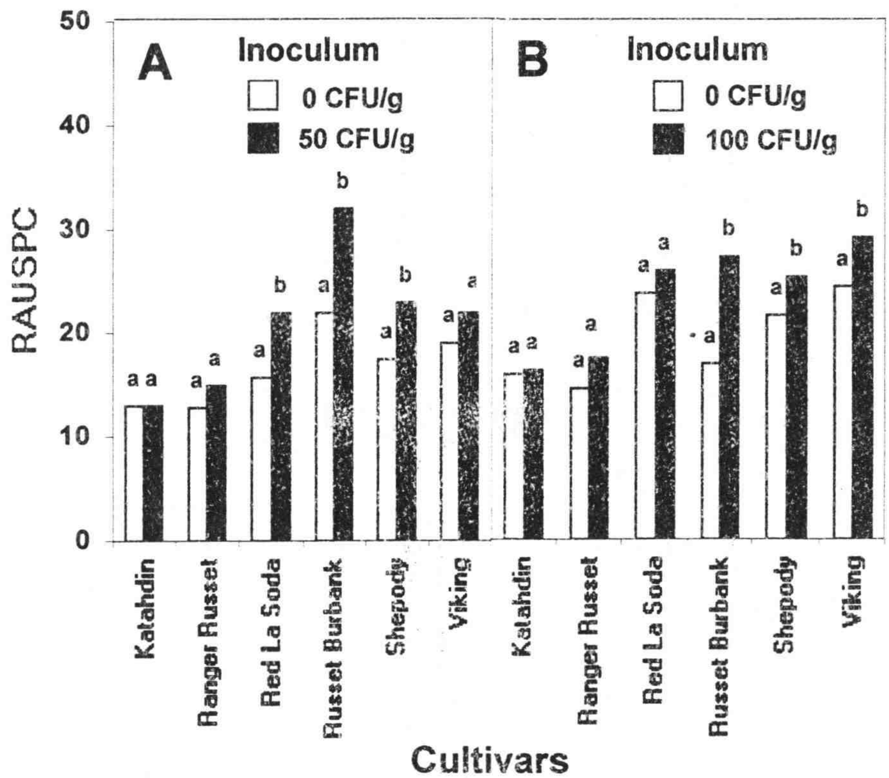


Fig. 4. Inoculum density of *Verticillium dahliae* x cultivar interactions on relative area under the senescence progress curve (RAUSPC) of potato in **A**, 1996 and **B**, 1997. Within cultivar, bars with the same letter did not differ significantly according to Fisher's protected least significant difference (LSD) test ($P \leq 0.05$). Inoculum density of *Verticillium dahliae* x cultivar interactions for **A**, $P$=0.0090 and **B**, $P$=0.0194.

**Aerial biomass.** With a decrease in amount of applied water, aerial biomass was significantly reduced in all cultivars in both years ($P$=0.0001 and $P$=0.0001, 1996 and

Table 2. Aerial biomass of six potato cultivars grown under three amounts of applied water across two inoculum densities of *Verticillium dahliae* in 1996 and 1997.

| | Cultivars | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Katahdin | | Ranger Russet | | Red La Soda | | Russet Burbank | | Shepody | | Viking | |
| | 1996 | 1997 | 1996 | 1997 | 1996 | 1997 | 1996 | 1997 | 1996 | 1997 | 1996 | 1997 |
| Irrigation treatment[a] | | | | | | | | | | | | |
| Low | 2.94[b]a[c] | 3.48a | 2.89a | 3.14a | 2.58a | 2.74a | 2.02a | 2.86a | 3.04 a | 2.96a | 2.59a | 3.10a |
| Medium | 3.36 ab | 3.95 b | 3.55 b | 3.45ab | 3.02ab | 3.30 b | 2.68 b | 3.54 b | 3.39 b | 3.37 b | 3.27 b | 3.46 b |
| High | 3.95 b | 4.11 b | 3.93 b | 3.72 b | 3.28 b | 3.81 c | 3.29 c | 3.95 c | 3.95 b | 3.91 c | 3.47 b | 3.93 c |

[a] Water was applied by a line source irrigation system. For the low, medium, and high amount of water treatments, a total of 27, 44, or 61 cm and 17, 31, or 41 cm of water was applied in 1996 and 1997, respectively.
[b] Values presented are ln aerial biomass (g) at growth stage V.
[c] Within year, values with the same letter did not differ significantly according to Fischer's protected least significant difference (LSD) test ($P \leq 0.05$)

1997, respectively) (Table 2). Aerial biomass was reduced by 36 and 62% (1996) and 33 and 58% (1997) when amount of applied water was decreased from 61 to 44 or to 27 cm, and from 44 to 33 or to 17 cm, in 1996 and 1997, respectively. Inoculum density of *V. dahliae* resulted in a significant ($P$=0.0262) decrease (11%) in aerial biomass in 1997, but had no effect in 1996.

**Apical stem assay.** *V. dahliae* was recovered from stem apices in all cultivars grown in infested soil. Cultivars differed, however, in population size recovered in 1996 ($P$=0.0001) and 1997 ($P$=0.0001) (Table 3). In 1996, cv Katahdin had a significantly lower population than all other cultivars. In 1997, amount of *V. dahliae* recovered from the stem apices was significantly lower in cvs Katahdin and Ranger Russet compared to the other cultivars.

Table 3. Population size (CFU/g) of *Verticillium dahliae* in stem apices of six potato cultivars grown in *Verticillium* infested soil across three amounts of applied water in 1996 and 1997.

| Cultivar | 1996[a] | 1997[a] |
|---|---|---|
| Katahdin | 2.5 a[b] | 3.8 a |
| Ranger Russet | 5.1 b | 3.8 a |
| Red La Soda | 5.5 bc | 6.4 c |
| Russet Burbank | 5.7 bc | 5.7 bc |
| Shepody | 6.8 c | 5.9 bc |
| Viking | 5.6 bc | 5.1 b |

[a] Values are ln CFU/g stem apices.
[b] Within year, values with the same letter did not differ significantly according to Fisher's protected least significant difference (LSD) test ($P\leq0.05$).

**Graded tuber yield.** Amount of applied water had a major impact on tuber yield components. There were significant interactions of cultivar x amount of applied water for size classes <113 g and 171-340 g in both 1996 and 1997 (Fig 5). Cultivar differences within these interactions, however, varied between years. The overall effect was that in the driest plots, yields of smaller tubers (<170 g) were higher than in wetter plots, and as the amount of applied water increased, yields of tubers greater than 170 g increased. Main effects of cultivar and amount of applied water were significant for marketable tubers (combined yield components of 113-170, 171-340, and >340 g tubers) (Table 4), but there were no interactions influencing this response variable. Inoculum density of *Verticillium* had no effect on marketable yield.

The water x cultivar interaction for non-marketable tubers (culls plus <113 g) was significant in both 1996 (*P*=0.0002) and 1997 (*P*=0.0165) (Fig. 6). With a decrease in amount of applied water yield of this class did not change for cvs Katahdin and Ranger Russet. Only in 1996 was there a significant (*P*=0.0004) decrease (29%) in non-marketable tubers in the *V. dahliae* infested plots.

Fig. 5. Amount of applied water x cultivar interactions on tuber yield components of potato in **A**, 1996, <113 g; **B**, 1996, 114-170 g; **C**, 1996, 171-340 g; **D**, 1996, >340 g; **E**, 1997, <113 g; **F**, 1997, 114-170 g; **G**, 1997, 171-340 g; and **H**, 1997, >340 g. Within cultivars, bars with the same letter did not differ significantly according the Fisher's protected least significant difference (LSD) test $P$=0.05. Amount of applied water x cultivar interaction for **A**, 1996 $P$=0.0025; **B**, 1996 $P$=0.0201; **C**, 1996 $P$=0.0052; **D**, 1996 $P$=0.0016; **E**, 1997 $P$=0.0011; **F**, 1997 $P$=0.2069; **G**, 1997 $P$=0.0016; and **H**, 1997 $P$=0.1356.

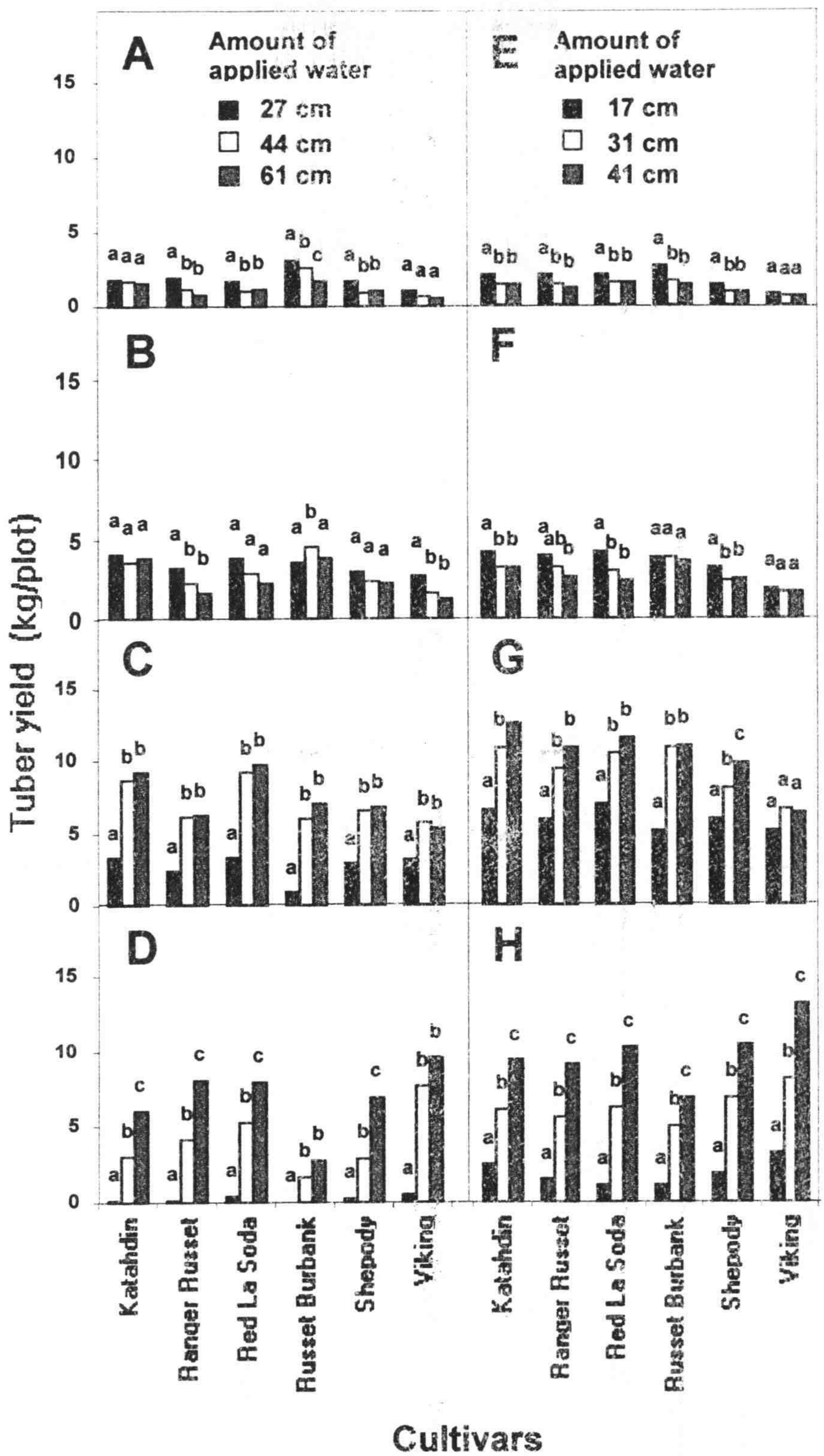
A
Amount of applied water
27 cm
44 cm
61 cm
E
Amount of applied water
17 cm
31 cm
41 cm
B
F
C
G
D
H
Tuber yield (kg/plot)
Katahdin
Ranger Russet
Red La Soda
Russet Burbank
Shepody
Viking
Cultivars

Table 4. Yield of marketable tubers of six potato cultivars grown under three amounts of applied water across two inoculum densities of *Verticillium dahliae* 1996 and 1997.

| | Cultivars | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Katahdin | | Ranger Russet | | Red La Soda | | Russet Burbank | | Shepody | | Viking | |
| | 1996 | 1997 | 1996 | 1997 | 1996 | 1997 | 1996 | 1997 | 1996 | 1997 | 1996 | 1997 |
| Irrigation treatment | | | | | | | | | | | | |
| Low[a] | 7.6[b]a[c] | 13.3a | 5.7a | 7.6a | 7.5a | 12.3a | 4.5a | 10.1a | 6.1a | 11.0a | 6.4a | 10.2a |
| Medium | 15.3 b | 20.2 b | 12.5 b | 15.3 b | 17.3 b | 19.7 b | 12.3 b | 19.6 b | 11.7 b | 17.5 b | 15.0 b | 16.6 b |
| High | 18.9 c | 25.3 c | 15.9 c | 18.9 c | 18.5 c | 24.2 c | 13.6 b | 21.4 b | 16.0 c | 22.7 c | 13.6 b | 21.3 c |

[a] Water was applied by a line source irrigation system. A total of 27, 44, or 61 cm and 17, 31, or 41 cm of water was applied in 1996 and 1997, respectively.
[b] Values presented are kg/plot.
[c] Within year, values with the same letter did not differ significantly according to Fischer's protected least significant difference (LSD) test ($P \leq 0.05$)

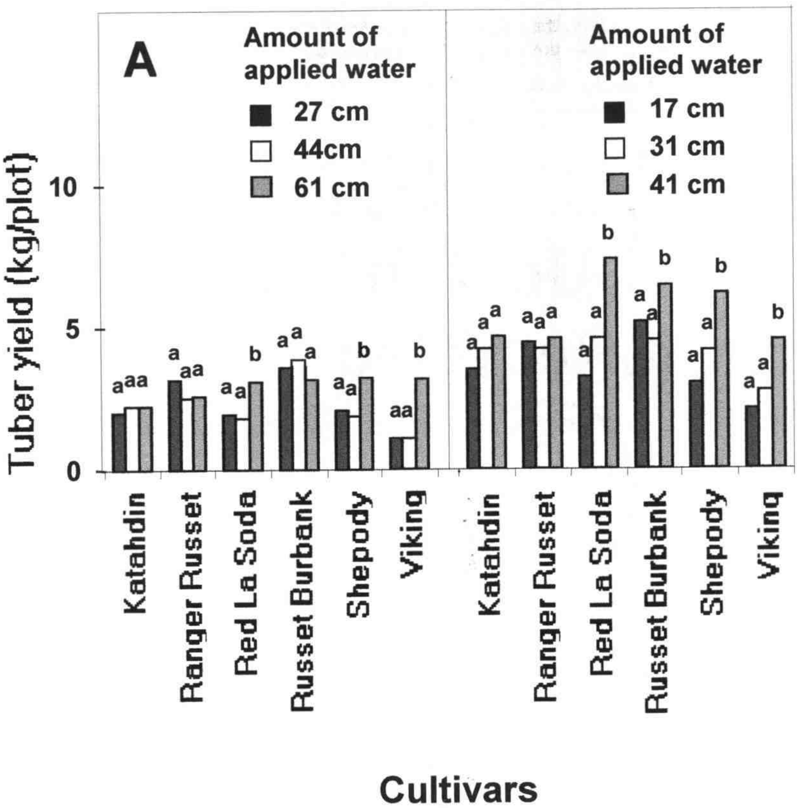


Fig. 6. Amount of applied water x cultivar interactions on nonmarketable tuber yield of potato in **A,** 1996 and **B**, 1997. Within cultivars, bars with the same letter did not differ significantly according the Fisher's protected least significant difference (LSD) test ($P \leq 0.05$). Amount of applied water x cultivar interaction for **A**, $P=0.0002$ and **B**, $P=0.016$

## Discussion

Severity of foliar senescence due to a moisture deficit stress paralleled that associated with *V. dahliae* in four of the six potato cultivars. Based on amount of foliar senescence, tolerance to a mild moisture deficit stress was associated with resistance to Verticillium wilt in cv Katahdin. Cv Ranger Russet was also resistant to Verticillium wilt, but more sensitive to moisture stress than cv Katahdin. In contrast, significant increases in foliar senescence developed in response to a mild moisture deficit stress and to inoculum of *V. dahliae* in cvs Russet Burbank and Shepody. Populations of *V. dahliae* recovered from the stem apices were small in cvs Ranger Russet and Katahdin and large in Shepody and Russet Burbank.

A 'mild moisture deficit stress' is distinguished from 'drought' in that the former is imposed by applying water in amounts that are detrimental to plant health and performance, but frequently enough that some soil moisture is maintained throughout the season (Kramer, 1983b). In contrast, 'drought' is an absence of irrigation or rainfall for a period of time long enough to result in soil water depletion to levels that severely restrict plant growth and health (Kramer, 1983c). Soils may then be watered to return soil moisture to normal agronomic levels. This cycle may be repeated a number of times, with each event termed a 'drought episode'. In our study, irrigation frequency and duration were the same for the three moisture treatments; however, each treatment received a different amount of water, depending upon the distance from the irrigation line. Therefore, a consistent, mild moisture deficit stress was created at the farthest distance from the irrigation line. In this treatment, the average percent volumetric soil water approximately 24 hr post irrigation was 4 and 6% in 1996 and 1997, respectively. These values are below the 10% volumetric soil water designated as the permanent wilting point for a sandy loam soil (Kramer, 1983a). The percent volumetric soil at 15 cm may be slightly lower than that which the potato root actually reaches, which could explain why in the driest plots, growth still occurred.

There was no cultivar x amount of applied water x inoculum density interaction for foliar senescence. Had there been, some cultivars would have had more severe disease than others when grown in wet soils in the presence of *Verticillium*. Likewise, some cultivars could have had more severe foliar senescence than others when grown in dry soils in the presence of *Verticillium*. As it were, a mild soil moisture deficit stress had no direct effect on severity of Verticillium wilt. This is in contrast to earlier studies by Cappaert et al. (1992, 1994) which showed that Verticillium wilt was favored by moist soils. This disparity may be attributed by differences in both methodology and environmental conditions. In her studies, irrigation frequency differed among treatments; i.e., the wettest treatments (150 or 200% ECU) were delivered two or four times as often as the moderate (100% ECU) and dry treatments (50% ECU), respectively. Each irrigation event, however, delivered the same amount of water. A second reason was the difference between irrigation treatments. Our wettest treatment was designed to equal 100% ECU of the plant whereas 100% ECU or 150 or 200% ECU, respectively, were the moderate and excessive treatments in the Cappaert studies. It is the excessive treatment that resulted in more disease. Had we applied water at these higher amounts, disease may have been proportionately higher than what occurred in the treatments we applied. Excess moisture may enhance germination of microsclerotia, and also wetter soils may promote shallow root growth, where *Verticillium* inoculum is more concentrated. These factors may explain, in part, why foliar senescence was less severe at the high compared to the low amount of applied water in our study.

Environmental conditions in Madras were not very favorable for severe disease expression. The minimum and maximum temperature range for August was 10.6-29.8 C and 11.7-29.7 C for 1996 and 1997, respectively (Table 5), slightly lower than the optimum maximum temperature (21-27 C) for Verticillium wilt (Schnathorst 1981). In addition, the degree-days after planting (DDAP) reached only 742 and 664 in 1996 and

1997, respectively. Disease severity is not accelerated until after 800 DDAP (Cappaert et al. 1994), an amount that was not reach in this study. The length of the growing season in Central Oregon is only 90-100 days. compared to 180 days in the Columbia Basin of Oregon and Washington, where Verticillium wilt can be a serious problem.

Table 5. Mean maximum and minimum daily and average monthly temperatures for Madras in 1996 and 1997.

| | 1996 | | | 1997 | | |
|---|---|---|---|---|---|---|
| | mean daily max | mean daily min | mean | mean daily max | mean daily min | mean |
| May | 17.8 | 5.3 | 11.6 | 22.2 | 7.7 | 15.0 |
| June | 24.2 | 6.6 | 15.4 | 22.3 | 7.2 | 14.8 |
| July | 31.2 | 11.3 | 21.2 | 28.5 | 9.8 | 19.1 |
| August | 29.8 | 10.6 | 20.2 | 29.7 | 11.7 | 20.7 |
| September | 23.7 | 7.2 | 15.4 | 28.8 | 12.3 | 20.4 |
| Seasonal average | 26.1 | 8.5 | 17.3 | 26.2 | 9.3 | 17.7 |

At all moisture levels, *V. dahliae* accelerated foliar senescence. Under the season long mild moisture deficit stress, however, it was difficult to visually separate the effect of treatment (*Verticillium* or moisture deficit) on vine death. Therefore, the apical stem assay was used to determine if senescence was due to *Verticillium* or moisture stress When *Verticillium* is the cause of premature senescence, populations of the fungus are high in the stem apices (Davis et al., 1983). Populations of *V. dahliae* recovered from stem apices of cv Katahdin were significantly lower than all other cultivars except cv Ranger Russet in 1997. Both cvs Shepody and Russet had large apical populations of *V. dahliae* in both years. In a study by Davis et al. (1994), populations of *V. dahliae* reached 525 CFU/g tissue in cv Russet Burbank before a correlation between disease incidence and populations were significant. In our study, populations of *V. dahliae* in Russet

Burbank reached 285 and 299 CFU/g in 1996 and 1997, respectively. Infection rate by *V. dahliae* may have been too low to cause a yield reduction. The low 'infection rate' may be due, in part, to the method of soil infestation. Inoculum was applied to the furrow at planting with a fertilizer belt. Inoculum was undoubtedly concentrated near the seed piece. As the roots grew beyond the furrow, the new root growth would not have come in contact with the inoculum. In other studies (Davis and Sorensen, 1986; Kotcon et al., 1984; Nnodu and Harrison, 1979), the soil was naturally infested with *V. dahliae*; therefore, microsclerotia were more evenly distributed throughout the soil profile. In microplot studies by Cappaert et al. (1992, 1994), soil infestation was achieved by mixing soil with the pathogen in a cement mixer, assuring even distribution of inoculum.

Aerial biomass at growth stage V was reduced by similar amounts in all cultivars when amount of applied water was reduced in both years. It has been shown that drought resistance of a cultivar and total dry matter production are not strongly related (Bodlander et al., 1986). A significant decrease in aerial biomass across cultivar and irrigation treatments in 1997 alone was associated with *V. dahliae* infestation. This is likely due to the two-fold higher inoculum density in 1997 compared to 1996.

Analysis of the yield components indicated that these cultivars did not respond differentially to either moisture deficit stress or *V. dahliae* inoculum. A decrease in amount of applied water resulted in an increase in yield of U.S. No. 1's <170 g and a decrease in U.S. No. 1's weighing >170 g. This is probably due to insufficient water during the tuber bulking phase. Although interactions of cultivar and amount of applied water were significant in some size classes in both years, the interactions were inconsistent from year to year. In 1997, *V. dahliae* was associated with a decrease in

U.S. No. 1's weighing >340g. This reduction in yield of large tubers has been previously reported in the presence of *V. dahliae* alone as well as the presence of both *V. dahliae* and the root lesion nematode *Pratylenchus penetrans* (Botseas and Rowe, 1994). In that same study, higher yields of small sized tubers occurred as well, suggesting that infected plants set more tubers than healthy plants, but most of these remained small and diverted phytosynthates from the larger tubers. In our study, there were no significant main effect interactions on marketable tuber yield. As with foliar senescence, temperatures in Madras were not high enough to allow the Verticillium to impact yield. Rowe et al, (1985) reported significant yield reductions due to Verticillium wilt only when the average July-August temperature was 24 C, and little effect on tuber yield when the average July-August temperature was 20 C. Therefore, temperatures were not warm enough to cause yield reductions in the presence of Verticillium wilt.

In general, potato plants are sensitive to moisture deficits due primarily to their relatively shallow root system. Physiological responses of potato to water deficits may include reduced rate of photosynthesis, reduced canopy expansion, premature senescence (Jeffries and Mackerron, 1993), decreased host water potential (Kirkham and Orion, 1990), reduced yield, reduced tuber dry matter accumulation, and diminished external quality of tubers (Levy, 1985; van Loon, 1981). With reduced plant canopy expansion, soil temperature increases, and evapo-transpiration rates may increase.

The physiological aspects of tolerance to moisture deficit stress in potato have been investigated (Coleman, 1986). Cultivars that are reportedly drought tolerant may have one to several features such as greater leaf water retention, more epicuticular wax, higher desiccation tolerance, greater root depth and extension, and greater stomatal number, size and resistance. The sum of the factors unique to a given cultivar, however, is likely the determinant of cultivar differences in reaction to water stress. For example, Epstien and Grant (1973) determined leaf diffusion resistance under conditions of water stress for cvs Russet Burbank and Katahdin. Stomatal diffusion resistance of cv Russet Burbank was two to three times greater than that of cv Katahdin, suggesting cv Russet Burbank was better able to maintain its water levels; the difference in relative water content of the two cultivars, however, was small. Necas (1974) showed that there are varietal differences in osmotic values of the cell sap at decreasing leaf water potentials. Mechanisms that contribute to cultivar responses to moisture stress may occur at the root level. Davies and Zhang (1991) showed that plants in unwatered soil exhibited low conductance when their shoot water potentials were high, suggesting that plants sense the availability of water in the soil. Chemicals such as abscisic acid conveyed from roots to shoots in response to small changes in turgor, volume, or pressure on membranes of only a few roots may regulate stomatal behaviour, affecting leaf gas exchange in some plants (Davies and Zhang, 1991). If the response of potato to available soil water is initiated at the root, as it is to *Verticillium,* the responses to both stresses may be similar. If a potato cultivar has mechanisms at the root to tolerate a mild moisture deficit stress, then some of these same mechanisms may be responsible for resisting infection to *V. dahliae.*

We established a link between tolerance to moisture deficit stress and resistance to Verticillium wilt in potato. Based on amount of foliar senescence and population size of *V. dahliae* in the stem apices, cv Katahdin was classified as both tolerant to moisture deficit stress and resistant to Verticillium wilt. Based on RAUSPC values, cv Ranger Russet was less tolerant to moisture deficit stress than cv Katahdin, but it was more tolerant than the other four cultivars in 1996, and was resistant to *V. dahliae* in both years. In contrast, sensitivity to a moisture deficit stress corresponded to susceptibility to Verticillium wilt in cvs Russet Burbank and Shepody. Cvs Viking and Red La Soda were sensitive to a moisture deficit stress, and susceptible to Verticillium wilt in terms of apical stem populations, and although foliar senescence for these two cultivars were not significantly increased both years, cv Viking is reportedly susceptible to Verticillium wilt. These results suggest that this relationship may eventually be useful as a germplasm-screening tool. Since traditional screening for resistance to *Verticillium* involves growing potential germplasm in infested soil, (Corsini, 1988) using moisture deficit stress as the screening technique, one could shorten the screening process and make it simpler by avoiding either having to infest a field or monitor one that is infested.

# CHAPTER 4.

## Summary

In conclusion, the results of this study indicate there is a relationship between a potato cultivar's response to moisture deficit stress and Verticillium wilt. Based on these findings, the possibility arises that this relationship may occur in other host-parasite interactions involving wilt pathogens. The possibility of exploiting this relationship may be in the future of modern agriculture, and the impact of reduced use of chemicals and water would benefit all.

The lack of a *Verticillium* associated yield reduction in this study suggests that other responses be measured as indicators of plant stress. Changes in physiological parameters such as stomatal conductance and transpiration rates could be measured as they are also indicators of stress.

If I were to pursue our hypothesis further, I would propose conducting the research in a location with a longer growing season, higher average temperatures, and on ground with history of Verticillium wilt. Moisture treatments would be of two types: 1) a season long moisture deficit stress, and 2) repeated drought episodes. Cultivars of each maturity class would be grouped into separate experiments to eliminate the need to adjust area under the senescence progress curves. Soil moisture would be monitored with the use of instrumentation that is placed in the plots for the entire season and recorded every hour. In addition to tuber yield, specific gravity measurements would be made to determine if the quality parameters would be influenced by water and disease. Perhaps

with these adjustments, variance within treatments may be reduced, and results may be more conclusive.

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# APPENDICES

# APPENDIX 1

## Data Tables

Table 1.1 Aerial biomass for six potato cultivars grown under three amounts of applied water and two inoculum densities of *Verticillium dahliae* in 1996 and 1997.

| | 1996 | | | 1997 | | |
|---|---|---|---|---|---|---|
| **Katahdin**[a] | | | | | | |
| Irrigation treatment | - *V. dahliae*[b] | + *V. dahliae* | P | - *V. dahliae* | + *V. dahliae* | P[c] |
| 1[d] | 4.33[e] | 3.57 | 0.0256 | 4.22 | 4.00 | 0.3470 |
| 2 | 3.27 | 3.44 | 0.5982 | 3.96 | 3.95 | 0.9515 |
| 3 | 2.87 | 3.00 | 0.6953 | 3.25 | 3.72 | 0.0431 |
| P | 0.0001 | 0.2095 | | 0.0001 | 0.4267 | |
| **Ranger Russet** | | | | | | |
| Irrigation treatment | - *V. dahliae* | + *V. dahliae* | P | - *V. dahliae* | + *V. dahliae* | P |
| 1 | 4.00 | 3.86 | 0.6836 | 3.93 | 3.51 | 0.0729 |
| 2 | 3.61 | 3.49 | 0.7272 | 3.51 | 3.39 | 0.6267 |
| 3 | 3.14 | 2.64 | 0.1388 | 3.27 | 3.02 | 0.2822 |
| P | 0.0405 | 0.0013 | | 0.0172 | 0.0885 | |
| **Red La Soda** | | | | | | |
| Irrigation treatment | - *V. dahliae* | + *V. dahliae* | P | - *V. dahliae* | + *V. dahliae* | P |
| 1 | 3.57 | 2.99 | 0.0846 | 3.72 | 3.90 | 0.4193 |
| 2 | 3.18 | 2.86 | 0.3542 | 3.30 | 3.31 | 0.9431 |
| 3 | 2.61 | 2.56 | 0.8746 | 2.91 | 2.58 | 0.1608 |
| P | 0.0182 | 0.4249 | | 0.0027 | 0.0001 | |
| **Russet Burbank** | | | | | | |
| Irrigation treatment | - *V. dahliae* | + *V. dahliae* | P | - *V. dahliae* | + *V. dahliae* | P |
| 1 | 3.25 | 3.33 | 0.8186 | 4.23 | 3.68 | 0.0176 |
| 2 | 2.93 | 2.42 | 0.1323 | 3.68 | 3.39 | 0.2104 |
| 3 | 1.98 | 2.06 | 0.8248 | 2.95 | 2.76 | 0.4324 |
| P | 0.0007 | 0.0007 | | 0.0001 | 0.0004 | |
| **Shepody** | | | | | | |
| Irrigation treatment | - *V. dahliae* | + *V. dahliae* | P | - *V. dahliae* | + *V. dahliae* | P |
| 1 | 3.82 | 4.08 | 0.4432 | 3.77 | 4.05 | 0.2275 |
| 2 | 3.38 | 3.41 | 0.9254 | 3.52 | 3.23 | 0.2106 |
| 3 | 2.76 | 3.32 | 0.0961 | 3.01 | 2.91 | 0.6883 |
| P | 0.0075 | 0.0499 | | 0.0039 | 0.0001 | |
| **Viking** | | | | | | |
| Irrigation treatment | - *V. dahliae* | + *V. dahliae* | P | - *V. dahliae* | + *V. dahliae* | P |
| 1 | 3.54 | 3.39 | 0.6465 | 3.92 | 3.95 | 0.9091 |
| 2 | 3.42 | 3.10 | 0.3356 | 3.74 | 3.18 | 0.0170 |
| 3 | 2.37 | 2.80 | 0.2056 | 3.04 | 3.16 | 0.5952 |
| P | 0.0009 | 0.2235 | | 0.0004 | 0.0008 | |

[a]Each matrix reports results adding inoculum from left to right and decreasing amount of applied water from top to bottom for each cultivar.

[b]Population levels of *V. dahliae* after soil infestation: - = 0, + = ~50 (1996) or ~100 (1997) CFU/g soil.

[c]P denotes linear trend significance level, based on differences between means for the change in one variable while holding the other variable constant.

[d]Cumulative amount of applied water in 1996 and 1997 for treatments 1, 2, and 3 = 61, 44, or 27 cm, and 41, 31, or 17 cm, respectively.

[e]Each value represents the means of the ln aerial biomass.

Table 1.2. Aerial biomass for six potato cultivars grown under two inoculum densities of *Verticillium dahliae* across three amounts of applied water in 1996 and 1997.

| | 1996 | | | 1997 | | |
|---|---|---|---|---|---|---|
| Cultivar | - *V. dahliae* | + *V. dahliae* | P | - *V. dahliae* | + *V. dahliae* | P |
| Katahdin | 3.49 | 3.34 | 0.4429 | 3.81 | 3.89 | 0.5513 |
| Ranger Russet | 3.58 | 3.33 | 0.1965 | 3.57 | 3.31 | 0.0533 |
| Red La Soda | 3.12 | 2.80 | 0.1052 | 3.31 | 3.27 | 0.7611 |
| Russet Burbank | 2.72 | 2.61 | 0.5425 | 3.62 | 3.28 | 0.0112 |
| Shepody | 3.32 | 3.61 | 0.1451 | 3.43 | 3.40 | 0.7965 |
| Viking | 3.12 | 3.10 | 0.9291 | 3.57 | 3.43 | 0.3100 |

[a]Population levels of *V. dahliae* after soil infestation: - = 0, + = ~50 (1996) or ~100 (1997) CFU/g soil
[b]Each value represents the ln aerial biomass (g).

Table 1.3. Aerial biomass for six potato cultivars grown under three amounts of applied water across two inoculum densities of *Verticillium dahliae* in 1996 and 1997.

| | 1996 | | | | 1997 | | | |
|---|---|---|---|---|---|---|---|---|
| | Cumulative amount of applied water | | | | Cumulative amount of applied water | | | |
| Cultivar | 61 cm | 44 cm | 27 cm | P | 41 cm | 31 cm | 17 cm | P |
| Katahdin | 3.95 | 3.36 | 2.94 | 0.0002 | 4.11 | 3.95 | 3.48 | 0.0005 |
| Ranger Russet | 3.93 | 3.55 | 2.89 | 0.0001 | 3.72 | 3.45 | 3.14 | 0.0026 |
| Red La Soda | 3.28 | 3.02 | 2.58 | 0.0145 | 3.81 | 3.30 | 2.74 | 0.0001 |
| Russet Burbank | 3.29 | 2.68 | 2.02 | 0.0001 | 3.95 | 3.54 | 2.86 | 0.0001 |
| Shepody | 3.95 | 3.39 | 3.04 | 0.0008 | 3.91 | 3.37 | 2.96 | 0.0001 |
| Viking | 3.47 | 3.27 | 2.59 | 0.0008 | 3.93 | 3.46 | 3.10 | 0.0001 |

[a]Each value represents the ln aerial biomass (g).

Table 1.4. Relative area under the senescence progress curves for six potato cultivars grown under three amounts of applied water and two inoculum densities of *Verticillium dahliae* in 1996 and 1997.

| Katahdin[a] Irrigation treatment | 1996 - *V. dahliae*[b] | 1996 + *V. dahliae* | 1996 P | 1997 - *V. dahliae* | 1997 + *V. dahliae* | 1997 P[c] |
|---|---|---|---|---|---|---|
| 1[d] | 10.66[e] | 10.21 | 0.8963 | 16.20 | 16.66 | 0.8827 |
| 2 | 14.47 | 12.05 | 0.4910 | 14.39 | 12.87 | 0.6212 |
| 3 | 13.42 | 17.54 | 0.2432 | 16.65 | 18.77 | 0.4893 |
| P | 0.5355 | 0.0974 | | 0.7371 | 0.1522 | |

| Ranger Russet Irrigation treatment | - *V. dahliae* | + *V. dahliae* | P | - *V. dahliae* | + *V. dahliae* | P |
|---|---|---|---|---|---|---|
| 1 | 10.11 | 10.13 | 0.9970 | 10.97 | 14.84 | 0.2119 |
| 2 | 13.27 | 16.66 | 0.3366 | 13.53 | 15.40 | 0.5446 |
| 3 | 14.73 | 18.79 | 0.2493 | 18.77 | 21.21 | 0.4286 |
| P | 0.4075 | 0.0392 | | 0.0377 | 0.0740 | |

| Red La Soda Irrigation treatment | - *V. dahliae* | + *V. dahliae* | P | - *V. dahliae* | + *V. dahliae* | P |
|---|---|---|---|---|---|---|
| 1 | 8.57 | 16.75 | 0.0210 | 18.08 | 22.61 | 0.1415 |
| 2 | 17.29 | 23.64 | 0.0727 | 25.89 | 24.22 | 0.5864 |
| 3 | 20.79 | 26.01 | 0.1396 | 26.35 | 29.74 | 0.2708 |
| P | 0.0020 | 0.0254 | | 0.0114 | 0.0538 | |

| Russet Burbank Irrigation treatment | - *V. dahliae* | + *V. dahliae* | P | - *V. dahliae* | + *V. dahliae* | P |
|---|---|---|---|---|---|---|
| 1 | 10.48 | 21.11 | 0.0029 | 10.05 | 15.75 | 0.0646 |
| 2 | 22.65 | 33.78 | 0.0018 | 16.09 | 23.89 | 0.0119 |
| 3 | 33.13 | 40.74 | 0.0317 | 24.00 | 41.29 | 0.0001 |
| P | 0.0001 | 0.0001 | | 0.0001 | 0.0001 | |

| Shepody Irrigation treatment | - *V. dahliae* | + *V. dahliae* | P | - *V. dahliae* | + *V. dahliae* | P |
|---|---|---|---|---|---|---|
| 1 | 10.99 | 12.34 | 0.7021 | 19.02 | 17.69 | 0.6658 |
| 2 | 17.32 | 24.65 | 0.0389 | 20.29 | 24.85 | 0.2016 |
| 3 | 23.85 | 31.09 | 0.0409 | 23.94 | 33.39 | 0.0024 |
| P | 0.0016 | 0.0001 | | 0.2732 | 0.0001 | |

| Viking Irrigation treatment | - *V. dahliae* | + *V. dahliae* | P | - *V. dahliae* | + *V. dahliae* | P |
|---|---|---|---|---|---|---|
| 1 | 12.77 | 14.85 | 0.5543 | 18.82 | 24.38 | 0.0717 |
| 2 | 16.84 | 21.79 | 0.1605 | 20.64 | 25.41 | 0.1223 |
| 3 | 27.61 | 28.55 | 0.7888 | 32.86 | 36.14 | 0.2861 |
| P | 0.0001 | 0.0007 | | 0.0001 | 0.0002 | |

[a]Each matrix reports results adding inoculum from left to right and decreasing amount of applied water from top to bottom for each cultivar.
[b]Population levels of *V. dahliae* after soil infestation: - = 0, + = ~50 (1996) or ~100 (1997) CFU/g soil.
[c]P denotes linear trend significance level, based on differences between means for the change in one variable while holding the other variable constant
[d]Cumulative amount of applied water in 1996 and 1997 for treatments 1, 2, and 3 =61, 44, or 27 cm, and 41, 31, or 17 cm, respectively.

[c]Each value represents the means of the relative area under the senescence progress curves, adjusted for maturity class.

Table 1.5. Relative area under the senescence progress curves for six potato cultivars grown under two inoculum densities of *Verticillium dahliae* across three amounts of applied water in 1996 and 1997.

| | 1996 | | | 1997 | | |
|---|---|---|---|---|---|---|
| Cultivar | - *V. dahliae*[a] | + *V. dahliae* | P | - *V. dahliae* | + *V. dahliae* | P |
| Katahdin | 12.85[b] | 13.26[c] | 0.8399 | 15.75 | 16.09 | 0.8421 |
| Ranger Russet | 12.71 | 15.19 | 0.2219 | 14.43 | 17.15 | 0.1274 |
| Red La Soda | 15.55 | 22.13 | 0.0014 | 23.44 | 25.52 | 0.2413 |
| Russet Burbank | 22.09 | 31.88 | 0.0001 | 16.71 | 26.97 | 0.0001 |
| Shepody | 17.39 | 22.69 | 0.0098 | 21.28 | 25.31 | 0.0244 |
| Viking | 19.17 | 21.73 | 0.1918 | 24.11 | 28.64 | 0.0113 |

[a]Population levels of *V. dahliae* after soil infestation: - = 0, + = ~50 (1996) or ~100 (1997) CFU/g soil.
[b]Each value represents the means of the relative area under the senescence progress curves, adjusted for maturity class.
$P$=0.0194 and $P$=0.0033 for *V. dahliae* x cultivar interaction in 1996 and 1997, respectively.

Table 1.6. Relative area under the senescence progress curves for six potato cultivars grown under three amounts of applied water across two inoculum densities of *Verticillium dahliae* in 1996 and 1997.

| | 1996 | | | | 1997 | | | |
|---|---|---|---|---|---|---|---|---|
| | Cumulative amount of applied water | | | | Cumulative amount of applied water | | | |
| Cultivar | 52 cm | 36 cm | 21 cm | P | 38 cm | 28 cm | 15 cm | P |
| Katahdin | 10.43 | 13.26 | 15.48 | 0.1287 | 16.42 | 13.36 | 17.71 | 0.1565 |
| Ranger Russet | 10.12 | 14.96 | 16.76 | 0.0238 | 12.92 | 14.46 | 19.99 | 0.0001 |
| Red La Soda | 12.66 | 20.47 | 23.40 | 0.0001 | 20.34 | 25.05 | 28.04 | 0.0021 |
| Russet Burbank | 15.79 | 28.21 | 36.94 | 0.0001 | 12.90 | 19.99 | 32.64 | 0.0034 |
| Shepody | 11.66 | 20.99 | 27.47 | 0.0001 | 18.36 | 22.88 | 28.66 | 0.0001 |
| Viking | 13.81 | 19.31 | 28.08 | 0.0001 | 21.60 | 23.02 | 34.50 | 0.0001 |

[a]Each value represents the means of the relative area under the senescence progress curves, adjusted for maturity class.
$P$=0.0009 and $P$=0.0194 for amount of applied water x cultivar interaction in 1996 and 1997, respectively.

Table 1.7. Yield (kg/plot) of tubers weighing <113 g for six potato cultivars grown under three amounts of applied water and two inoculum densities of *Verticillium dahliae* in 1996 and 1997.

| | 1996 | | | 1997 | | |
|---|---|---|---|---|---|---|
| **Katahdin**[a] | | | | | | |
| Irrigation treatment | - *V. dahliae*[b] | + *V. dahliae* | P[c] | - *V. dahliae* | + *V. dahliae* | P |
| 1[d] | 1.61 | 1.37 | 0.4166 | 1.52 | 1.29 | 0.3558 |
| 2 | 1.17 | 2.07 | 0.0031 | 1.32 | 1.50 | 0.4599 |
| 3 | 1.95 | 1.68 | 0.3754 | 2.26 | 1.89 | 0.1410 |
| P | 0.0342 | 0.0694 | | 0.0006 | 0.0571 | |
| **Ranger Russet** | | | | | | |
| Irrigation treatment | - *V. dahliae* | + *V. dahliae* | P | - *V. dahliae* | + *V. dahliae* | P |
| 1 | 0.76 | 0.74 | 0.9442 | 1.04 | 1.25 | 0.4080 |
| 2 | 0.98 | 1.26 | 0.3524 | 1.55 | 1.34 | 0.4139 |
| 3 | 2.00 | 1.77 | 0.4420 | 1.79 | 2.47 | 0.0075 |
| P | 0.0001 | 0.0031 | | 0.0111 | 0.0001 | |
| **Red La Soda** | | | | | | |
| Irrigation treatment | - *V. dahliae* | + *V. dahliae* | P | - *V. dahliae* | + *V. dahliae* | P |
| 1 | 1.13 | 1.20 | 0.8117 | 1.65 | 1.47 | 0.4726 |
| 2 | 1.18 | 0.92 | 0.3801 | 1.62 | 1.57 | 0.8390 |
| 3 | 1.77 | 1.61 | 0.6000 | 2.30 | 1.86 | 0.0847 |
| P | 0.0633 | 0.0700 | | 0.0109 | 0.2692 | |
| **Russet Burbank** | | | | | | |
| Irrigation treatment | - *V. dahliae* | + *V. dahliae* | P | - *V. dahliae* | + *V. dahliae* | P |
| 1 | 1.84 | 1.47 | 0.2219 | 1.33 | 1.58 | 0.3180 |
| 2 | 2.77 | 2.42 | 0.2423 | 1.98 | 1.40 | 0.0208 |
| 3 | 3.53 | 2.64 | 0.0035 | 2.54 | 2.92 | 0.1329 |
| P | 0.0001 | 0.0003 | | 0.0001 | 0.0001 | |
| **Shepody** | | | | | | |
| Irrigation treatment | - *V. dahliae* | + *V. dahliae* | P | - *V. dahliae* | + *V. dahliae* | P |
| 1 | 1.05 | 0.90 | 0.6245 | 1.14 | 0.74 | 0.1123 |
| 2 | 0.96 | 0.90 | 0.8372 | 0.86 | 1.00 | 0.5792 |
| 3 | 1.56 | 1.70 | 0.6494 | 1.35 | 1.45 | 0.6884 |
| P | 0.0001 | 0.0001 | | 0.1519 | 0.0182 | |
| **Viking** | | | | | | |
| Irrigation treatment | - *V. dahliae* | + *V. dahliae* | P | - *V. dahliae* | + *V. dahliae* | P |
| 1 | 0.44 | 0.65 | 0.4818 | 0.65 | 0.77 | 0.6300 |
| 2 | 0.52 | 0.68 | 0.6030 | 0.57 | 0.66 | 0.7291 |
| 3 | 1.11 | 0.90 | 0.4928 | 0.72 | 0.79 | 0.7885 |
| P | 0.0994 | 0.0101 | | 0.8341 | 0.8554 | |

[a]Each matrix reports results adding inoculum from left to right and decreasing amount of applied water from top to bottom for each cultivar.

[b]Population levels of *V. dahliae* after soil infestation: - = 0, + = ~50 (1996) or ~100 (1997) CFU/g soil.

[c]P denotes linear trend significance level, based on differences between means for the change in one variable while holding the other variable constant

[d]Cumulative amount of applied water in 1996 and 1997 for treatments 1, 2, and 3 =61, 44, or 27 cm, and 41, 31, or 17 cm, respectively.

[e]Each value represents the means of tuber yield.

1997 $P$=0.0297 for cultivar x *V. dahliae* x amount of applied water interaction

Table 1.8. Yield (kg/plot) of tubers weighing <113 g for six potato cultivars grown under two inoculum densities of *Verticillium dahliae* across three amounts of applied water in 1996 and 1997.

| | 1996 | | | 1997 | | |
|---|---|---|---|---|---|---|
| Cultivar | - *V. dahliae* | + *V. dahliae*[a] | P | - *V. dahliae* | + *V. dahliae* | P |
| Katahdin | 1.58[b] | 1.71 | 0.4546 | 1.70 | 1.56 | 0.3380 |
| Ranger Russet | 1.25 | 1.26 | 0.9577 | 1.46 | 1.69 | 0.1188 |
| Red La Soda | 1.36 | 1.24 | 0.5014 | 1.85 | 1.63 | 0.1268 |
| Russet Burbank | 2.71 | 2.18 | 0.0023 | 1.95 | 1.97 | 0.9186 |
| Shepody | 1.19 | 1.16 | 0.8896 | 1.12 | 1.07 | 0.7126 |
| Viking | 0.69 | 0.74 | 0.7562 | 0.65 | 0.74 | 0.5269 |

[a]Population levels of *V. dahliae* after soil infestation: - = 0, + = ~50 (1996) or ~100 (1997) CFU/g soil.
[b]Each value represents the means of tuber yield.

Table 1.9. Yield (kg/plot) of tubers weighing <113 g of six potato cultivars grown under three amounts of applied water across two inoculum densities of *Verticillium dahliae* in 1996 and 1997.

| | 1996 | | | | 1997 | | | |
|---|---|---|---|---|---|---|---|---|
| | Cumulative amount of applied water | | | | Cumulative amount of applied water | | | |
| Cultivar | 61 cm | 44 cm | 27 cm | P | 38 cm | 28 cm | 15 cm | P |
| Katahdin | 1.49[a] | 1.62 | 1.82 | 0.3022 | 1.41 | 1.41 | 2.08 | 0.0001 |
| Ranger Russet | 0.75 | 1.12 | 1.89 | 0.0001 | 1.14 | 1.44 | 2.13 | 0.0001 |
| Red La Soda | 1.16 | 1.05 | 1.69 | 0.0066 | 1.56 | 1.60 | 2.08 | 0.0055 |
| Russet Burbank | 1.65 | 2.60 | 3.08 | 0.0001 | 1.45 | 1.69 | 2.73 | 0.0001 |
| Shepody | 0.97 | 0.93 | 1.63 | 0.0001 | 0.94 | 0.93 | 1.40 | 0.0117 |
| Viking | 0.54 | 0.60 | 1.01 | 0.0014 | 0.71 | 0.62 | 0.76 | 0.7221 |

$P$=0.0026 (1996) and $P$=0.0011 (1997) for cultivar by amount of applied water interaction.
[a]Each value represents the means of tuber yield.

Table 1.10. Yield (kg/plot) of tubers weighing 113-170g for six potato cultivars grown under three amounts of applied water and two inoculum densities of *Verticillium dahliae* in 1996 and 1997.

| | 1996 | | | 1997 | | |
|---|---|---|---|---|---|---|
| **Katahdin**[a] | | | | | | |
| Irrigation treatment | - V. dahliae[b] | + V. dahliae | P[c] | - V. dahliae | + V. dahliae | P |
| 1[d] | 3.59 | 3.87 | 0.6549 | 3.09 | 3.36 | 0.6442 |
| 2 | 3.07 | 3.93 | 0.1590 | 3.06 | 3.35 | 0.6140 |
| 3 | 4.58 | 3.33 | 0.0506 | 4.45 | 3.88 | 0.3328 |
| P | 0.0556 | 0.5609 | | 0.0006 | 0.0571 | |
| **Ranger Russet** | | | | | | |
| Irrigation treatment | - V. dahliae | + V. dahliae | P | - V. dahliae | + V. dahliae | P |
| 1 | 1.38 | 1.71 | 0.6028 | 2.09 | 3.18 | 0.0630 |
| 2 | 1.80 | 2.44 | 0.3132 | 2.74 | 3.64 | 0.1218 |
| 3 | 2.58 | 3.66 | 0.0887 | 4.01 | 3.88 | 0.8226 |
| P | 0.1619 | 0.0090 | | 0.011 | 0.0001 | |
| **Red La Soda** | | | | | | |
| Irrigation treatment | - V. dahliae | + V. dahliae | P | - V. dahliae | + V. dahliae | P |
| 1 | 2.20 | 2.26 | 0.9266 | 2.34 | 2.42 | 0.8876 |
| 2 | 2.94 | 2.73 | 0.7343 | 2.94 | 3.08 | 0.8104 |
| 3 | 3.99 | 3.45 | 0.3931 | 4.14 | 4.38 | 0.6882 |
| P | 0.0199 | 0.1724 | | 0.0109 | 0.2692 | |
| **Russet Burbank** | | | | | | |
| Irrigation treatment | - V. dahliae | + V. dahliae | P | - V. dahliae | + V. dahliae | P |
| 1 | 3.53 | 3.88 | 0.5778 | 2.92 | 4.18 | 0.032 |
| 2 | 4.43 | 4.64 | 0.7343 | 3.80 | 3.80 | 0.9991 |
| 3 | 3.68 | 3.41 | 0.6654 | 3.82 | 3.93 | 0.8515 |
| P | 0.3164 | 0.1472 | | 0.0001 | 0.0001 | |
| **Shepody** | | | | | | |
| Irrigation treatment | - *V. dahliae* | + *V. dahliae* | P | - *V. dahliae* | + *V. dahliae* | P |
| 1 | 4.48 | 6.806 | 0.1498 | 1.76 | 2.67 | 0.9063 |
| 2 | 5.25 | 6.35 | 0.4948 | 2.06 | 2.50 | 0.2500 |
| 3 | 6.29 | 8.645 | 0.1449 | 2.47 | 3.40 | 0.5790 |
| P | 0.5295 | 0.3218 | | 0.1519 | 0.0182 | |
| **Viking** | | | | | | |
| Irrigation treatment | - *V. dahliae* | + *V. dahliae* | P | - *V. dahliae* | + *V. dahliae* | P |
| 1 | 1.13 | 1.37 | 0.7072 | 2.08 | 1.21 | 0.1404 |
| 2 | 1.38 | 1.66 | 0.6474 | 1.70 | 1.64 | 0.9205 |
| 3 | 2.50 | 2.94 | 0.4948 | 2.02 | 1.72 | 0.6156 |
| P | 0.0711 | 0.0333 | | 0.8341 | 0.8554 | |

[a]Each matrix reports results adding inoculum from left to right and decreasing amount of applied water from top to bottom for each cultivar.
[b]Population levels of *V. dahliae* after soil infestation: - = 0, + = ~50 (1996) or ~100 (1997) CFU/g soil.
[c]P denotes linear trend significance level, based on differences between means for the change in one variable while holding the other variable constant
[d]Cumulative amount of applied water in 1996 and 1997 for treatments 1, 2, and 3 = 61, 44, or 27 cm, and 41, 31, or 17 cm, respectively
[e]Each value represents the means of tuber yield.

Table 1.11. Yield (kg/plot) of tubers weighing 113-170 g for six potato cultivars grown under two inoculum densities of *Verticillium dahliae* across three amounts of applied water in 1996 and 1997.

| | 1996 | | | 1997 | | |
|---|---|---|---|---|---|---|
| Cultivar | - *V. dahliae* | + *V. dahliae*[a] | P | - *V. dahliae* | + *V. dahliae* | P |
| Katahdin | 3.75[b] | 3.72 | 0.9509 | 3.53 | 3.53 | 0.9985 |
| Ranger Russet | 1.92 | 2.60 | 0.0627 | 2.95 | 3.57 | 0.0662 |
| Red La Soda | 3.04 | 2.81 | 0.5248 | 3.14 | 3.29 | 0.6515 |
| Russet Burbank | 3.88 | 3.98 | 0.7889 | 3.51 | 3.97 | 0.1783 |
| Shepody | 2.10 | 2.85 | 0.0394 | 2.64 | 2.73 | 0.7817 |
| Viking | 1.67 | 1.99 | 0.3819 | 1.93 | 1.52 | 0.2306 |

[a]Population levels of *V. dahliae* after soil infestation: - = 0, + = ~50 (1996) or ~100 (1997) CFU/g soil.
[b]Each value represents the means of tuber yield.

Table 1.12. Yield (kg/plot) of tubers weighing 113-170 g for six potato cultivars grown under three amounts of applied water across two inoculum densities of *Verticillium dahliae* in 1996 and 1997.

| | 1996 | | | | 1997 | | | |
|---|---|---|---|---|---|---|---|---|
| | Cumulative amount of applied water | | | | Cumulative amount of applied water | | | |
| Cultivar | 61 cm | 44 cm | 27 cm | P | 41 cm | 31 cm | 17 cm | P |
| Katahdin | 3.73[b] | 3.52 | 3.95 | 0.6185 | 3.22 | 3.20 | 4.17 | 0.0306 |
| Ranger Russet | 1.54 | 2.12 | 3.12 | 0.0022 | 2.64 | 3.19 | 3.95 | 0.0071 |
| Red La Soda | 2.23 | 2.83 | 3.71 | 0.0046 | 2.37 | 3.01 | 4.26 | 0.0001 |
| Russet Burbank | 3.70 | 4.54 | 3.54 | 0.0621 | 3.55 | 3.80 | 3.87 | 0.7156 |
| Shepody | 2.22 | 2.28 | 2.93 | 0.2088 | 2.46 | 2.38 | 3.21 | 0.0860 |
| Viking | 1.25 | 1.52 | 2.72 | 0.0027 | 1.64 | 1.67 | 1.87 | 0.8391 |

$P$=0.0201 (1996) and $P$=0.2069 (1997) for cultivar x amount of applied water interaction.
[a]Each value represents the means of tuber yield.

Table 1.13. Yield (kg/plot) of tubers weighing 171-340 g for six potato cultivars grown under three amounts of applied water and two inoculum densities of *Verticillium dahliae* in 1996 and 1997.

Katahdin[a]

| Irrigation treatment | 1996 - *V. dahliae*[b] | 1996 + *V. dahliae* | 1996 P[c] | 1997 - *V. dahliae* | 1997 + *V. dahliae* | 1997 P |
|---|---|---|---|---|---|---|
| 1[d] | 9.27 | 9.12 | 0.8888 | 12.19 | 12.71 | 0.6406 |
| 2 | 8.53 | 8.85 | 0.7669 | 9.43 | 12.05 | 0.0202 |
| 3 | 3.44 | 3.32 | 0.9136 | 5.79 | 7.27 | 0.1867 |
| P | 0.0001 | 0.0001 | | 0.0001 | 0.0001 | |

Ranger Russet

| Irrigation treatment | 1996 - *V. dahliae* | 1996 + *V. dahliae* | 1996 P | 1997 - *V. dahliae* | 1997 + *V. dahliae* | 1997 P |
|---|---|---|---|---|---|---|
| 1 | 6.35 | 6.27 | 0.9395 | 11.05 | 10.52 | 0.6343 |
| 2 | 5.86 | 6.57 | 0.5140 | 9.46 | 9.21 | 0.8183 |
| 3 | 2.53 | 2.36 | 0.8789 | 5.09 | 5.09 | 0.1454 |
| P | 0.0009 | 0.0001 | | 0.0007 | 0.0001 | |

Red La Soda

| Irrigation treatment | 1996 - *V. dahliae* | 1996 + *V. dahliae* | 1996 P | 1997 - *V. dahliae* | 1997 + *V. dahliae* | 1997 P |
|---|---|---|---|---|---|---|
| 1 | 10.55 | 8.87 | 0.1243 | 11.39 | 11.51 | 0.9120 |
| 2 | 10.19 | 8.22 | 0.0708 | 11.02 | 9.68 | 0.2334 |
| 3 | 3.46 | 3.29 | 0.8717 | 6.51 | 7.40 | 0.4271 |
| P | 0.0001 | 0.0001 | | 0.0001 | 0.0015 | |

Russet Burbank

| Irrigation treatment | 1996 - *V. dahliae* | 1996 + *V. dahliae* | 1996 P | 1997 - *V. dahliae* | 1997 + *V. dahliae* | 1997 P |
|---|---|---|---|---|---|---|
| 1 | 7.10 | 7.09 | 0.9962 | 11.47 | 10.27 | 0.2825 |
| 2 | 6.19 | 5.98 | 0.8500 | 10.43 | 11.07 | 0.5646 |
| 3 | 1.14 | 0.69 | 0.6795 | 4.49 | 5.85 | 0.2267 |
| P | 0.0001 | 0.0001 | | 0.0001 | 0.0001 | |

Shepody

| Irrigation treatment | 1996 - *V. dahliae* | 1996 + *V. dahliae* | 1996 P | 1997 - *V. dahliae* | 1997 + *V. dahliae* | 1997 P |
|---|---|---|---|---|---|---|
| 1 | 7.29 | 6.27 | 0.3498 | 9.71 | 9.73 | 0.9865 |
| 2 | 7.10 | 5.94 | 0.2849 | 8.41 | 7.64 | 0.4940 |
| 3 | 3.39 | 2.53 | 0.4318 | 6.73 | 5.00 | 0.1228 |
| P | 0.0004 | 0.0010 | | 0.0305 | 0.0002 | |

Viking

| Irrigation treatment | 1996 - *V. dahliae* | 1996 + *V. dahliae* | 1996 P | 1997 - *V. dahliae* | 1997 + *V. dahliae* | 1997 P |
|---|---|---|---|---|---|---|
| 1 | 4.64 | 6.11 | 0.1768 | 6.37 | 6.34 | 0.9734 |
| 2 | 4.95 | 6.53 | 0.1471 | 6.81 | 6.37 | 0.6877 |
| 3 | 2.74 | 3.73 | 0.3636 | 5.18 | 4.99 | 0.8604 |
| P | 0.0912 | 0.0226 | | 0.3225 | 0.3725 | |

[a]Each matrix reports results adding inoculum from left to right and decreasing amount of applied water from top to bottom for each cultivar.

[b]Population levels of *V. dahliae* after soil infestation: - = 0, + = ~50 (1996) or ~100 (1997) CFU/g soil.

[c]P denotes linear trend significance level, based on differences between means for the change in one variable while holding the other variable constant

[d]Cumulative amount of applied water in 1996 and 1997 for treatments 1, 2, and 3 = 61, 44, or 27 cm, and 41, 31, or 17 cm, respectively.

[e]Each value represents the means of marketable tuber yield.

Table 1.14. Yield (kg/plot) of tubers weighing 171-340 g for six potato cultivars grown under two inoculum densities of *Verticillium dahliae* across three amounts of applied water in 1996 and 1997.

| | 1996 | | | 1997 | | |
|---|---|---|---|---|---|---|
| Cultivar | - *V. dahliae* | + *V. dahliae*[a] | P | - *V. dahliae* | + *V. dahliae* | P |
| Katahdin | 7.08[b] | 7.10 | 0.9778 | 9.13 | 10.68 | 0.0180 |
| Ranger Russet | 4.91 | 5.07 | 0.8063 | 9.08 | 8.27 | 0.2122 |
| Red La Soda | 8.07 | 6.79 | 0.0434 | 9.64 | 9.53 | 0.8676 |
| Russet Burbank | 4.81 | 4.59 | 0.7259 | 8.80 | 9.06 | 0.6814 |
| Shepody | 4.91 | 4.91 | 0.1081 | 8.28 | 7.46 | 0.2018 |
| Viking | 5.93 | 5.45 | 0.0330 | 6.12 | 5.90 | 0.7242 |

[a]Population levels of *V. dahliae* after soil infestation: - = 0, + = ~50 (1996) or ~100 (1997) CFU/g soil.
[b]Each value represents the means of tuber yield.

Table 1.15. Yield (kg/plot) of tubers weighing 171-340 g for six potato cultivars grown under three amounts of applied water across two inoculum densities of *Verticillium dahliae* in 1996 and 1997.

| | 1996 | | | | 1997 | | | |
|---|---|---|---|---|---|---|---|---|
| | Cumulative amount of applied water | | | | Cumulative amount of applied water | | | |
| Cultivar | 61 cm | 44 cm | 27 cm | P | 41 cm | 31 cm | 17 cm | P |
| Katahdin | 9.20[a] | 8.69 | 3.38 | 0.0001 | 12.45 | 10.74 | 6.53 | 0.0001 |
| Ranger Russet | 6.31 | 6.21 | 2.44 | 0.0001 | 10.79 | 9.33 | 5.91 | 0.0001 |
| Red La Soda | 9.71 | 9.20 | 3.38 | 0.0001 | 11.45 | 10.35 | 6.96 | 0.0001 |
| Russet Burbank | 7.09 | 6.08 | 0.92 | 0.0001 | 10.87 | 10.75 | 5.17 | 0.0001 |
| Shepody | 6.78 | 6.52 | 2.96 | 0.0001 | 9.72 | 8.03 | 5.86 | 0.0001 |
| Viking | 5.37 | 5.73 | 3.23 | 0.0025 | 6.36 | 6.59 | 5.09 | 0.1259 |

$P$=0.0052 (1996) and $P$=0.0016 (1997) for cultivar x amount of applied water interaction.
[a]Each value represents the means of tuber yield.

Table 1.16. Yield (kg/plot) of tubers weighing >340 g for six potato cultivars grown under three amounts of applied water and two inoculum densities of *Verticillium dahliae* in 1996 and 1997.

| | 1996 | | | 1997 | | |
|---|---|---|---|---|---|---|
| **Katahdin**[a] | | | | | | |
| Irrigation treatment | - *V. dahliae*[b] | + *V. dahliae* | P[c] | - *V. dahliae* | + *V. dahliae* | P |
| 1[d] | 6.33 | 5.66 | 0.5613 | 9.86 | 9.33 | 0.6802 |
| 2 | 3.90 | 2.15 | 0.1212 | 7.22 | 5.18 | 0.1122 |
| 3 | 0.23 | 0.15 | 0.9479 | 1.63 | 3.53 | 0.1414 |
| P | 0.0001 | 0.0001 | | 0.0001 | 0.0001 | |
| **Ranger Russet** | | | | | | |
| Irrigation treatment | - *V. dahliae* | + *V. dahliae* | P | - *V. dahliae* | + *V. dahliae* | P |
| 1 | 8.93 | 7.13 | 0.1109 | 9.24 | 9.41 | 0.8933 |
| 2 | 4.82 | 3.47 | 0.2303 | 7.21 | 4.24 | 0.0217 |
| 3 | 0.08 | 0.29 | 0.8546 | 1.91 | 1.67 | 0.7611 |
| P | 0.0001 | 0.0001 | | 0.0001 | 0.0001 | |
| **Red La Soda** | | | | | | |
| Irrigation treatment | - *V. dahliae* | + *V. dahliae* | P | - *V. dahliae* | + *V. dahliae* | P |
| 1 | 7.65 | 8.20 | 0.6224 | 9.50 | 11.23 | 0.1782 |
| 2 | 5.14 | 5.40 | 0.8163 | 5.90 | 6.78 | 0.4932 |
| 3 | 0.41 | 0.41 | 0.9991 | 1.45 | 0.82 | 0.9297 |
| P | 0.0001 | 0.0001 | | 0.0001 | 0.0001 | |
| **Russet Burbank** | | | | | | |
| Irrigation treatment | - *V. dahliae* | + *V. dahliae* | P | - *V. dahliae* | + *V. dahliae* | P |
| 1 | 2.61 | 2.92 | 0.7861 | 8.40 | 5.60 | 0.0299 |
| 2 | 1.88 | 1.38 | 0.6579 | 5.96 | 4.11 | 0.1521 |
| 3 | 0.00 | 0.09 | 0.9312 | 1.02 | 1.14 | 0.9297 |
| P | 0.0585 | 0.0445 | | 0.0001 | 0.0024 | |
| **Shepody** | | | | | | |
| Irrigation treatment | - *V. dahliae* | + *V. dahliae* | P | - *V. dahliae* | + *V. dahliae* | P |
| 1 | 6.90 | 7.03 | 0.9034 | 9.91 | 11.07 | 0.3666 |
| 2 | 2.66 | 3.18 | 0.6382 | 7.74 | 6.32 | 0.2700 |
| 3 | 0.34 | 0.13 | 0.8500 | 1.84 | 1.91 | 0.9508 |
| P | 0.0001 | 0.0001 | | 0.0001 | 0.0001 | |
| **Viking** | | | | | | |
| Irrigation treatment | - *V. dahliae* | + *V. dahliae* | P | - *V. dahliae* | + *V. dahliae* | P |
| 1 | 8.88 | 10.28 | 0.2153 | 14.43 | 12.23 | 0.0888 |
| 2 | 8.32 | 7.11 | 0.2906 | 9.09 | 7.51 | 0.2173 |
| 3 | 0.51 | 0.42 | 0.9349 | 4.18 | 2.33 | 0.1512 |
| P | 0.0001 | 0.0001 | | 0.0001 | 0.0001 | |

[a]Each matrix reports results adding inoculum from left to right and decreasing amount of applied water from top to bottom for each cultivar.
[b]Population levels of *V. dahliae* after soil infestation: - = 0, + = ~50 (1996) or ~100 (1997) CFU/g soil.
[c]P denotes linear trend significance level, based on differences between means for the change in one variable while holding the other variable constant
[d]Cumulative amount of applied water in 1996 and 1997 for treatments 1, 2, and 3 =61, 44, or 27 cm, and 41, 31, or 17 cm, respectively.
[e]Each value represents the means of tuber yield.

Table 1.17. Yield (kg/plot) of tubers weighing >340 g for six potato cultivars grown under two inoculum densities of *Verticillium dahliae* across three amounts of applied water in 1996 and 1997.

| | 1996 | | | 1997 | | |
|---|---|---|---|---|---|---|
| Cultivar | - *V. dahliae* | + *V. dahliae*[a] | P | - *V. dahliae* | + *V. dahliae* | P |
| Katahdin | 3.48[b] | 2.66 | 0.2047 | 6.24 | 6.01 | 0.7592 |
| Ranger Russet | 4.61 | 3.63 | 0.1318 | 6.04 | 4.98 | 0.1529 |
| Red La Soda | 4.40 | 4.67 | 0.6762 | 5.61 | 6.28 | 0.3727 |
| Russet Burbank | 1.49 | 1.46 | 0.9608 | 5.13 | 3.62 | 0.0425 |
| Shepody | 3.30 | 3.45 | 0.8162 | 6.49 | 6.43 | 0.9359 |
| Viking | 5.90 | 5.94 | 0.9532 | 9.24 | 7.36 | 0.0121 |

[a]Population levels of *V. dahliae* after soil infestation: - = 0, + = ~50 (1996) or ~100 (1997) CFU/g soil.
[b]Each value represents the means of tuber yield.

Table 1.18. Yield (kg/plot) of tubers weighing >340 g for six potato cultivars grown under three amounts of applied water across two inoculum densities of *Verticillium dahliae* in 1996 and 1997.

| | 1996 | | | | 1997 | | | |
|---|---|---|---|---|---|---|---|---|
| | Cumulative amount of applied water | | | | Cumulative amount of applied water | | | |
| Cultivar | 61 cm | 44 cm | 27 cm | P | 41 cm | 31 cm | 17 cm | P |
| Katahdin | 6.00[a] | 3.02 | 0.19 | 0.0001 | 9.60 | 6.20 | 2.58 | 0.0001 |
| Ranger Russet | 8.03 | 4.15 | 0.18 | 0.0001 | 9.33 | 5.73 | 1.47 | 0.0001 |
| Red La Soda | 7.93 | 5.27 | 0.41 | 0.0001 | 10.37 | 6.34 | 1.13 | 0.0001 |
| Russet Burbank | 2.76 | 1.63 | 0.05 | 0.0033 | 7.00 | 5.03 | 1.08 | 0.0001 |
| Shepody | 6.96 | 2.92 | 0.23 | 0.0001 | 10.49 | 7.03 | 1.87 | 0.0001 |
| Viking | 9.58 | 7.73 | 0.46 | 0.0001 | 13.33 | 8.30 | 3.26 | 0.0001 |

$P$=0.0016 (1996) and $P$=0.1356 (1997) for cultivar x amount of applied water interaction.
[a]Each value represents the means of tuber yield.

Table 1.19. Marketable tuber yield (kg/plot) for six potato cultivars grown under three amounts of applied water and two inoculum densities of *Verticillium dahliae* in 1996 and 1997.

| | 1996 | | | 1997 | | |
|---|---|---|---|---|---|---|
| **Katahdin**[a] | | | | | | |
| Irrigation treatment | - *V. dahliae*[b] | + *V. dahliae* | P[c] | - *V. dahliae* | + *V. dahliae* | P |
| 1[d] | 22.14 | 21.54 | 0.7674 | 25.40 | 25.14 | 0.8708 |
| 2 | 17.88 | 17.27 | 0.7642 | 20.59 | 19.72 | 0.5910 |
| 3 | 9.52 | 7.86 | 0.4164 | 14.69 | 11.88 | 0.0845 |
| P | 0.0001 | 0.0001 | | 0.0001 | 0.0001 | |
| **Ranger Russet** | | | | | | |
| Irrigation treatment | - *V. dahliae* | + *V. dahliae* | P | - *V. dahliae* | + *V. dahliae* | P |
| 1 | 19.23 | 17.43 | 0.3800 | 23.12 | 22.39 | 0.6516 |
| 2 | 14.40 | 14.40 | 0.9995 | 17.10 | 19.42 | 0.1537 |
| 3 | 5.99 | 7.28 | 0.5250 | 10.26 | 12.42 | 0.1846 |
| P | 0.0001 | 0.0001 | | 0.0001 | 0.0001 | |
| **Red La Soda** | | | | | | |
| Irrigation treatment | - *V. dahliae* | + *V. dahliae* | P | - *V. dahliae* | + *V. dahliae* | P |
| 1 | 21.97 | 23.89 | 0.3467 | 25.17 | 23.23 | 0.2337 |
| 2 | 21.10 | 18.87 | 0.2749 | 19.55 | 19.87 | 0.8442 |
| 3 | 9.07 | 8.25 | 0.6837 | 12.60 | 12.11 | 0.7606 |
| P | 0.0001 | 0.0001 | | 0.0001 | 0.0001 | |
| **Russet Burbank** | | | | | | |
| Irrigation treatment | - *V. dahliae* | + *V. dahliae* | P | - *V. dahliae* | + *V. dahliae* | P |
| 1 | 15.28 | 16.03 | 0.7118 | 20.04 | 22.80 | 0.0906 |
| 2 | 14.42 | 13.86 | 0.7822 | 18.99 | 20.19 | 0.4603 |
| 3 | 4.85 | 5.57 | 0.7226 | 10.92 | 9.34 | 0.3302 |
| P | 0.0001 | 0.0001 | | 0.0001 | 0.0001 | |
| **Shepody** | | | | | | |
| Irrigation treatment | - *V. dahliae* | + *V. dahliae* | P | - *V. dahliae* | + *V. dahliae* | P |
| 1 | 18.40 | 18.44 | 0.9848 | 23.23 | 22.12 | 0.4942 |
| 2 | 13.64 | 13.41 | 0.9077 | 16.68 | 18.19 | 0.3524 |
| 3 | 7.16 | 6.99 | 0.9359 | 9.97 | 11.95 | 0.2232 |
| P | 0.0001 | 0.0001 | | 0.0001 | 0.0001 | |
| **Viking** | | | | | | |
| Irrigation treatment | - *V. dahliae* | + *V. dahliae* | P | - *V. dahliae* | + *V. dahliae* | P |
| 1 | 16.91 | 20.49 | 0.0798 | 19.79 | 22.88 | 0.0580 |
| 2 | 16.90 | 17.69 | 0.6989 | 15.52 | 17.61 | 0.1979 |
| 3 | 6.63 | 8.17 | 0.4511 | 9.05 | 11.39 | 0.1507 |
| | 0.0001 | 0.0001 | | 0.0001 | 0.0001 | |

[a]Each matrix reports results adding inoculum from left to right and decreasing amount of applied water from top to bottom for each cultivar.

[b]Population levels of *V. dahliae* after soil infestation: - = 0, + = ~50 (1996) or ~100 (1997) CFU/g soil.

[c]P denotes linear trend significance level, based on differences between means for the change in one variable while holding the other variable constant

[d]Cumulative amount of applied water in 1996 and 1997 for treatments 1, 2, and 3 = 61, 44, or 27 cm, and 41, 31, or 17 cm, respectively.

[e]Each value represents the means of marketable tuber yield.

Table 1.20. Marketable tuber yield (kg/plot) for six potato cultivars grown under two inoculum densities of *Verticillium dahliae* across three amounts of applied water in 1996 and 1997.

| | 1996 | | | 1997 | | |
|---|---|---|---|---|---|---|
| Cultivar | - *V. dahliae* | + *V. dahliae*[a] | P | - *V. dahliae* | + *V. dahliae* | P |
| Katahdin | 14.31[b] | 13.48 | 0.4806 | 18.91 | 20.22 | 0.1613 |
| Ranger Russet | 11.44 | 11.30 | 0.9035 | 18.07 | 16.82 | 0.1835 |
| Red La Soda | 14.62 | 14.28 | 0.7734 | 18.40 | 19.11 | 0.4528 |
| Russet Burbank | 10.19 | 10.03 | 0.8956 | 17.45 | 16.65 | 0.3987 |
| Shepody | 11.33 | 11.22 | 0.9290 | 17.42 | 16.63 | 0.3972 |
| Viking | 9.95 | 13.39 | 0.0038 | 17.30 | 14.78 | 0.0081 |

[a]Population levels of *V. dahliae* after soil infestation: - = 0, + = ~50 (1996) or ~100 (1997) CFU/g soil.
[b]Each value represents the means of tuber yield.

Table 1.21. Marketable tuber yield (kg/plot) for six potato cultivars grown under three amounts of applied water across two inoculum densities of *Verticillium dahliae* in 1996 and 1997.

| | 1996 | | | | 1997 | | | |
|---|---|---|---|---|---|---|---|---|
| | Cumulative amount of applied water | | | | Cumulative amount of applied water | | | |
| Cultivar | 61 cm | 44 cm | 27 cm | P | 41 cm | 31 cm | 17 cm | P |
| Katahdin | 18.93[a] | 15.23 | 7.53 | 0.0001 | 25.27 | 20.15 | 13.28 | 0.0001 |
| Ranger Russet | 15.89 | 12.48 | 5.75 | 0.0001 | 22.76 | 18.25 | 11.34 | 0.0001 |
| Red La Soda | 18.52 | 17.32 | 7.50 | 0.0001 | 24.20 | 19.71 | 12.36 | 0.0001 |
| Russet Burbank | 13.57 | 12.25 | 4.51 | 0.0001 | 21.42 | 19.59 | 10.13 | 0.0001 |
| Shepody | 15.96 | 11.72 | 6.13 | 0.0001 | 22.68 | 17.44 | 10.96 | 0.0001 |
| Viking | 13.60 | 14.99 | 6.41 | 0.0001 | 21.34 | 16.57 | 10.21 | 0.0001 |

[a]Each value represents the means of tuber yield.

Table 1.22. Yield (kg/plot) of culled tubers for six potato cultivars grown under three amounts of applied water and two inoculum densities of *Verticillium dahliae* in 1996 and 1997.

| | 1996 | | | 1997 | | |
|---|---|---|---|---|---|---|
| **Katahdin**[a] | | | | | | |
| Irrigation treatment | - *V. dahliae*[b] | + *V. dahliae* | P[c] | - *V. dahliae* | + *V. dahliae* | P |
| 1[d] | 0.64 | 0.79 | 0.7557 | 3.08 | 3.02 | 0.9513 |
| 2 | 0.39 | 0.79 | 0.3868 | 3.02 | 2.27 | 0.4509 |
| 3 | 0.15 | 0.12 | 0.6926 | 1.14 | 1.37 | 0.8189 |
| P | 0.7541 | 0.2590 | | 0.0885 | 0.2541 | |
| **Ranger Russet** | | | | | | |
| Irrigation treatment | - *V. dahliae* | + *V. dahliae* | P | - *V. dahliae* | + *V. dahliae* | P |
| 1 | 2.20 | 1.43 | 0.0972 | 3.82 | 2.59 | 0.2155 |
| 2 | 2.16 | 0.64 | 0.0014 | 2.57 | 2.57 | 0.9958 |
| 3 | 2.00 | 0.48 | 0.0014 | 2.37 | 1.79 | 0.5630 |
| P | 0.8980 | 0.0983 | | 0.2893 | 0.6633 | |
| **Red La Soda** | | | | | | |
| Irrigation treatment | - *V. dahliae* | + *V. dahliae* | P | - *V. dahliae* | + *V. dahliae* | P |
| 1 | 1.84 | 1.32 | 0.2653 | 5.97 | 5.01 | 0.3355 |
| 2 | 1.12 | 0.34 | 0.0939 | 2.19 | 3.43 | 0.2160 |
| 3 | 0.22 | 0.19 | 0.9575 | 1.38 | 0.59 | 0.4262 |
| P | 0.0029 | 0.0343 | | 0.0001 | 0.0001 | |
| **Russet Burbank** | | | | | | |
| Irrigation treatment | - *V. dahliae* | + *V. dahliae* | P | - *V. dahliae* | + *V. dahliae* | P |
| 1 | 1.71 | 1.27 | 0.3439 | 4.82 | 4.57 | 0.7960 |
| 2 | 1.77 | 0.74 | 0.0288 | 2.31 | 2.86 | 0.5822 |
| 3 | 0.68 | 0.30 | 0.4102 | 2.45 | 1.93 | 0.6030 |
| P | 0.0350 | 0.1194 | | 0.0200 | 0.0298 | |
| **Shepody** | | | | | | |
| Irrigation treatment | - *V. dahliae* | + *V. dahliae* | P | - *V. dahliae* | + *V. dahliae* | P |
| 1 | 2.14 | 1.63 | 0.2800 | 6.06 | 3.80 | 0.0248 |
| 2 | 0.95 | 0.91 | 0.9318 | 3.00 | 3.12 | 0.8992 |
| 3 | 0.48 | 0.31 | 0.6159 | 1.38 | 1.57 | 0.8537 |
| P | 0.0026 | 0.0225 | | 0.0001 | 0.0747 | |
| **Viking** | | | | | | |
| Irrigation treatment | - *V. dahliae* | + *V. dahliae* | P | - *V. dahliae* | + *V. dahliae* | P |
| 1 | 1.53 | 1.89 | 0.4461 | 2.49 | 4.69 | 0.0291 |
| 2 | 0.66 | 0.31 | 0.4604 | 1.60 | 2.38 | 0.4346 |
| 3 | 0.07 | 0.04 | 0.9575 | 1.08 | 1.32 | 0.8138 |
| P | 0.0080 | 0.0002 | | 0.3612 | 0.0031 | |

[a]Each matrix reports results adding inoculum from left to right and decreasing amount of applied water from top to bottom for each cultivar.
[b]Population levels of *V. dahliae* after soil infestation: - = 0, + = ~50 (1996) or ~100 (1997) CFU/g soil.
[c]P denotes linear trend significance level, based on differences between means for the change in one variable while holding the other variable constant
[d]Cumulative amount of applied water in 1996 and 1997 for treatments 1, 2, and 3 = 61, 44, or 27 cm, and 41, 31, or17 cm, respectively.
[e]Each value represents the means of tuber yield.

Table 1.23. Yield (kg/plot) of culled tubers for six potato cultivars grown under two inoculum densities of *Verticillium dahliae* across three amounts of applied water in 1996 and 1997.

| | 1996 | | | 1997 | | |
|---|---|---|---|---|---|---|
| Cultivar | - *V. dahliae* | + *V. dahliae*[a] | P | - *V. dahliae* | + *V. dahliae* | P |
| Katahdin | 0.44[b] | 0.57 | 0.6516 | 2.41 | 2.22 | 0.7349 |
| Ranger Russet | 2.12 | 0.85 | 0.0001 | 2.92 | 2.31 | 0.2928 |
| Red La Soda | 1.06 | 0.62 | 0.1011 | 3.18 | 3.01 | 0.7636 |
| Russet Burbank | 1.39 | 3.30 | 0.0228 | 3.20 | 3.12 | 0.8951 |
| Shepody | 1.21 | 0.95 | 0.3357 | 3.48 | 2.83 | 0.2608 |
| Viking | 0.75 | 0.75 | 0.9864 | 1.73 | 2.79 | 0.0648 |

*P*=0.0054 (1996) and *P*=0.3244 (1997) for cultivar x *V. dahliae* interaction

[a]Population levels of *V. dahliae* after soil infestation: - = 0, + = ~50 (1996) or ~100 (1997) CFU/g soil.

[b]Each value represents the means of tuber yield.

Table 1.24. Yield (kg/plot) of culled tubers of six potato cultivars grown under three amounts of applied water across two inoculum densities of *Verticillium dahliae* in 1996 and 1997.

| | 1996 | | | | 1997 | | | |
|---|---|---|---|---|---|---|---|---|
| | Cumulative amount of applied water | | | | Cumulative amount of applied water | | | |
| Cultivar | 61 cm | 44 cm | 27 cm | P | 41 cm | 31 cm | 17 cm | P |
| Katahdin | 0.72[a] | 0.59 | 0.21 | 0.2910 | 3.05 | 2.64 | 1.25 | 0.0299 |
| Ranger Russet | 1.82 | 1.40 | 1.24 | 0.1993 | 3.21 | 2.57 | 2.08 | 0.2815 |
| Red La Soda | 1.58 | 0.73 | 0.20 | 0.0002 | 5.49 | 2.81 | 0.99 | 0.0001 |
| Russet Burbank | 1.49 | 1.26 | 0.49 | 0.0079 | 4.69 | 2.59 | 2.19 | 0.0009 |
| Shepody | 1.88 | 0.92 | 0.45 | 0.0001 | 4.93 | 3.06 | 1.47 | 0.0001 |
| Viking | 1.71 | 0.48 | 0.06 | 0.0001 | 3.59 | 1.99 | 1.20 | 0.0031 |

[a]Each value represents the means of tuber yield.

Table 1.25. Yield (kg/plot) of nonmarketable tubers (culls plus <113g) for six potato cultivars grown under three amounts of applied water and two inoculum densities of *Verticillium dahliae* in 1996 and 1997.

Katahdin[a]

| Irrigation treatment | 1996 - *V. dahliae*[b] | 1996 + *V. dahliae* | 1996 P[c] | 1997 - *V. dahliae* | 1997 + *V. dahliae* | 1997 P |
|---|---|---|---|---|---|---|
| 1[d] | 2.26 | 2.16 | 0.9261 | 4.61 | 4.32 | 0.7694 |
| 2 | 1.55 | 2.86 | 0.2196 | 4.34 | 3.77 | 0.5720 |
| 3 | 2.26 | 1.81 | 0.6705 | 3.40 | 3.26 | 0.8850 |
| P | 0.7448 | 0.6011 | | 0.4500 | 0.5725 | |

Ranger Russet

| Irrigation treatment | 1996 - *V. dahliae* | 1996 + *V. dahliae* | 1996 P | 1997 - *V. dahliae* | 1997 + *V. dahliae* | 1997 P |
|---|---|---|---|---|---|---|
| 1 | 2.97 | 2.17 | 0.4508 | 4.87 | 3.84 | 0.3041 |
| 2 | 3.14 | 1.90 | 0.2453 | 4.12 | 3.91 | 0.8326 |
| 3 | 4.00 | 2.26 | 0.1000 | 4.16 | 4.26 | 0.9187 |
| P | 0.5752 | 0.9422 | | 0.7038 | 0.9009 | |

Red La Soda

| Irrigation treatment | 1996 - *V. dahliae* | 1996 + *V. dahliae* | 1996 P | 1997 - *V. dahliae* | 1997 + *V. dahliae* | 1997 P |
|---|---|---|---|---|---|---|
| 1 | 5.42 | 2.52 | 0.0068 | 7.62 | 6.48 | 0.2541 |
| 2 | 2.31 | 1.26 | 0.3224 | 3.81 | 5.00 | 0.2364 |
| 3 | 1.99 | 1.81 | 0.8635 | 3.68 | 2.45 | 0.2199 |
| P | 0.0021 | 0.4895 | | 0.0001 | 0.0004 | |

Russet Burbank

| Irrigation treatment | 1996 - *V. dahliae* | 1996 + *V. dahliae* | 1996 P | 1997 - *V. dahliae* | 1997 + *V. dahliae* | 1997 P |
|---|---|---|---|---|---|---|
| 1 | 3.55 | 2.74 | 0.4449 | 6.15 | 6.15 | 0.9963 |
| 2 | 4.55 | 3.17 | 0.1936 | 4.30 | 4.26 | 0.9697 |
| 3 | 4.21 | 2.94 | 0.2306 | 5.00 | 4.85 | 0.8871 |
| P | 0.6307 | 0.9211 | | 0.1755 | 0.1576 | |

Shepody

| Irrigation treatment | 1996 - *V. dahliae* | 1996 + *V. dahliae* | 1996 P | 1997 - *V. dahliae* | 1997 + *V. dahliae* | 1997 P |
|---|---|---|---|---|---|---|
| 1 | 3.18 | 3.18 | 0.9980 | 7.20 | 4.54 | 0.0085 |
| 2 | 1.91 | 1.81 | 0.9236 | 3.86 | 4.13 | 0.7900 |
| 3 | 2.13 | 2.03 | 0.9261 | 2.74 | 3.02 | 0.7764 |
| P | 0.4389 | 0.3787 | | 0.0001 | 0.2935 | |

Viking

| Irrigation treatment | 1996 - *V. dahliae* | 1996 + *V. dahliae* | 1996 P | 1997 - *V. dahliae* | 1997 + *V. dahliae* | 1997 P |
|---|---|---|---|---|---|---|
| 1 | 7.55 | 2.53 | 0.0001 | 3.14 | 5.45 | 0.0218 |
| 2 | 1.18 | 0.99 | 0.8581 | 2.17 | 3.04 | 0.3868 |
| 3 | 1.18 | 0.95 | 0.9261 | 1.81 | 2.11 | 0.3868 |
| P | 0.0001 | 0.2346 | | 0.3883 | 0.0031 | |

[a]Each matrix reports results adding inoculum from left to right and decreasing amount of applied water from top to bottom for each cultivar.

[b]Population levels of *V. dahliae* after soil infestation: - = 0, + = ~50 (1996) or ~100 (1997) CFU/g soil.

[c]P denotes linear trend significance level, based on differences between means for the change in one variable while holding the other variable constant

[d]Cumulative amount of applied water in 1996 and 1997 for treatments 1, 2, and 3= 61, 44, or 27 cm, and 41, 31, or 17 cm, respectively.

[e]Each value represents the means tuber yield.

Table 1.26. Yield (kg/plot) of nonmarketable tubers (culls plus <113 g) for six potato cultivars grown under two inoculum densities of *Verticillium dahliae* across three amounts of applied water in 1996 and 1997.

| | 1996 | | | 1997 | | |
|---|---|---|---|---|---|---|
| Cultivar | - *V. dahliae* | + *V. dahliae*[a] | P | - *V. dahliae* | + *V. dahliae* | P |
| Katahdin | 2.02[b] | 2.27 | 0.6811 | 4.11 | 3.78 | 0.1613 |
| Ranger Russet | 3.37 | 2.11 | 0.0405 | 4.38 | 4.00 | 0.1835 |
| Red La Soda | 3.24 | 1.86 | 0.0254 | 5.04 | 4.64 | 0.4528 |
| Russet Burbank | 4.10 | 2.95 | 0.0605 | 5.15 | 5.09 | 0.3987 |
| Shepody | 2.41 | 2.34 | 0.9144 | 4.60 | 3.89 | 0.3972 |
| Viking | 3.30 | 1.49 | 0.0034 | 2.37 | 3.53 | 0.0081 |

[a]Population levels of *V. dahliae* after soil infestation: - = 0, + = ~50 (1996) or ~100 (1997) CFU/g soil.
[b]Each value represents the means of tuber yield.

Table 1.27. Yield (kg/plot) of nonmarketable (culls plus <113 g) tubers for six potato cultivars grown under three amounts of applied water across two inoculum densities of *Verticillium dahliae* in 1996 and 1997.

| | 1996 | | | | 1997 | | | |
|---|---|---|---|---|---|---|---|---|
| | Cumulative amount of applied water | | | | Cumulative amount of applied water | | | |
| Cultivar | 61 cm | 44 cm | 27 cm | P | 41 cm | 31 cm | 17 cm | P |
| Katahdin | 2.20[a] | 2.20 | 2.03 | 0.9646 | 4.46 | 4.06 | 3.33 | 0.2709 |
| Ranger Russet | 2.57 | 2.52 | 3.13 | 0.6628 | 5.87 | 4.02 | 4.21 | 0.8922 |
| Red La Soda | 3.97 | 1.78 | 1.90 | 0.0052 | 7.05 | 4.41 | 3.07 | 0.0001 |
| Russet Burbank | 3.14 | 3.86 | 3.58 | 0.6306 | 4.35 | 4.28 | 4.92 | 0.0289 |
| Shepody | 3.18 | 1.86 | 2.08 | 0.1683 | 6.15 | 3.99 | 2.88 | 0.0002 |
| Viking | 5.04 | 1.08 | 1.06 | 0.0001 | 4.30 | 2.61 | 1.96 | 0.0035 |

*P*=0.0002 (1996) and *P*=0.0165 (1997) for cultivar x amount of applied water interaction
[a]Each value represents the means of tuber yield.

Table 1.28. Total yield (kg/plot) of all tuber classes (nonmarketable plus marketable) for six potato cultivars grown under three amounts of applied water and two inoculum densities of *Verticillium dahliae* in 1996 and 1997.

| | 1996 | | | 1997 | | |
|---|---|---|---|---|---|---|
| **Katahdin**[a] | | | | | | |
| Irrigation treatment | - *V. dahliae*[b] | + *V. dahliae* | P[c] | - *V. dahliae* | + *V. dahliae* | P |
| 1[d] | 21.45 | 20.83 | 0.7184 | 29.75 | 29.72 | 0.9840 |
| 2 | 17.05 | 17.82 | 0.6526 | 24.05 | 24.36 | 0.8346 |
| 3 | 10.50 | 8.62 | 0.2731 | 15.28 | 17.94 | 0.0706 |
| P | 0.0001 | 0.0001 | | 0.0001 | 0.0001 | |
| **Ranger Russet** | | | | | | |
| Irrigation treatment | - *V. dahliae* | + *V. dahliae* | P | - *V. dahliae* | + *V. dahliae* | P |
| 1 | 19.63 | 17.28 | 0.1729 | 27.26 | 26.96 | 0.8395 |
| 2 | 15.62 | 14.38 | 0.4734 | 23.54 | 21.01 | 0.0857 |
| 3 | 9.19 | 8.56 | 0.7153 | 16.58 | 14.52 | 0.1625 |
| P | 0.0001 | 0.0001 | | 0.0001 | 0.0001 | |
| **Red La Soda** | | | | | | |
| Irrigation treatment | - *V. dahliae* | + *V. dahliae* | P | - *V. dahliae* | + *V. dahliae* | P |
| 1 | 23.12 | 21.86 | 0.4613 | 30.85 | 31.65 | 0.5892 |
| 2 | 20.59 | 17.61 | 0.0845 | 23.68 | 24.55 | 0.5543 |
| 3 | 9.85 | 8.95 | 0.6005 | 15.79 | 15.06 | 0.6162 |
| P | 0.0001 | 0.0001 | | 0.0001 | 0.0001 | |
| **Russet Burbank** | | | | | | |
| Irrigation treatment | - *V. dahliae* | + *V. dahliae* | P | - *V. dahliae* | + *V. dahliae* | P |
| 1 | 16.79 | 16.63 | 0.9268 | 28.96 | 26.19 | 0.0612 |
| 2 | 17.04 | 15.17 | 0.2778 | 24.49 | 23.25 | 0.3998 |
| 3 | 9.04 | 7.14 | 0.2701 | 14.33 | 15.78 | 0.3272 |
| P | 0.0001 | 0.0001 | | 0.0001 | 0.0001 | |
| **Shepody** | | | | | | |
| Irrigation treatment | - *V. dahliae* | + *V. dahliac* | P | - *V. dahliae* | + *V. dahliae* | P |
| 1 | 19.13 | 19.16 | 0.9836 | 29.32 | 27.77 | 0.2920 |
| 2 | 13.73 | 13.42 | 0.8587 | 22.06 | 20.81 | 0.3971 |
| 3 | 8.33 | 8.09 | 0.8887 | 14.68 | 12.98 | 0.2486 |
| P | 0.0001 | 0.0001 | | 0.0001 | 0.0001 | |
| **Viking** | | | | | | |
| Irrigation treatment | - *V. dahliae* | + *V. dahliae* | P | - *V. dahliae* | + *V. dahliae* | P |
| 1 | 16.99 | 20.29 | 0.0566 | 26.03 | 25.25 | 0.5953 |
| 2 | 15.82 | 16.32 | 0.7741 | 19.78 | 18.56 | 0.4036 |
| 3 | 6.92 | 8.03 | 0.5226 | 13.19 | 11.16 | 0.1662 |
| P | 0.0001 | 0.0001 | | 0.0001 | 0.0001 | |

[a]Each matrix reports results adding inoculum from left to right and decreasing amount of applied water from top to bottom for each cultivar.

[b]Population levels of *V. dahliae* after soil infestation: - = 0, + = ~50 (1996) or ~ 100 (1997) CFU/g soil.

[c]P denotes linear trend significance level, based on differences between means for the change in one variable while holding the other variable constant

[d] Cumulative amount of applied water in 1996 and 1997 for treatments 1, 2, and 3 = 61, 44, or 27 cm, and 41, 31, or 17 cm, respectively.

[e]Each value represents the means of tuber yield.

Table 1.29. Total yield (kg/plot) of all tuber classes (marketable plus nonmarketable) for six potato cultivars grown under two inoculum densities of *Verticillium dahliae* across three amounts of applied water in 1996 and 1997.

| | 1996 | | | 1997 | | |
|---|---|---|---|---|---|---|
| Cultivar | - *V. dahliae* | + *V. dahliae*[a] | P | - *V. dahliae* | + *V. dahliae* | P |
| Katahdin | 16.33[b] | 15.76 | 0.5606 | 23.03 | 24.00 | 0.2478 |
| Ranger Russet | 14.81 | 13.41 | 0.1586 | 22.59 | 21.74 | 0.0559 |
| Red La Soda | 17.85 | 16.14 | 0.0853 | 23.44 | 23.75 | 0.7159 |
| Russet Burbank | 14.29 | 12.98 | 0.1884 | 22.46 | 20.83 | 0.3148 |
| Shepody | 13.73 | 13.56 | 0.8637 | 22.02 | 20.52 | 0.0787 |
| Viking | 13.25 | 14.88 | 0.1020 | 19.67 | 18.32 | 0.1129 |

[a]Population levels of *V. dahliae* after soil infestation: - = 0, + = ~50 (1996) or ~100 (1997) CFU/g soil.
[b]Each value represents the means of tuber yield.

Table 1.30. Total yield (kg/plot) of all tuber classes (marketable plus nonmarketable) for six potato cultivars grown under three amounts of applied water across two inoculum densities of *Verticillium dahliae* in 1996 and 1997.

| | 1996 | | | | 1997 | | | |
|---|---|---|---|---|---|---|---|---|
| | Cumulative amount of applied water | | | | Cumulative amount of applied water | | | |
| Cultivar | 61 cm | 44 cm | 27 cm | P | 41 cm | 31 cm | 17 cm | P |
| Katahdin | 21.14[a] | 17.43 | 9.56 | 0.0728 | 29.73 | 24.20 | 16.61 | 0.0001 |
| Ranger Russet | 18.46 | 15.00 | 8.87 | 0.1627 | 27.11 | 22.27 | 15.55 | 0.0001 |
| Red La Soda | 22.49 | 19.10 | 9.40 | 0.2166 | 31.25 | 24.11 | 15.42 | 0.0001 |
| Russet Burbank | 16.71 | 16.11 | 8.09 | 0.0001 | 27.58 | 23.87 | 15.05 | 0.0001 |
| Shepody | 19.14 | 13.58 | 8.21 | 0.1627 | 28.54 | 21.43 | 13.83 | 0.0001 |
| Viking | 18.64 | 16.07 | 7.47 | 0.5000 | 25.64 | 19.17 | 12.18 | 0.0001 |

[a]Each value represents the means of tuber yield.

# APPENDIX 2

## General Linear Model Summaries

Table 2.1. General linear model summary of ln aerial biomass, 1996.

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| BLOCK | 5 | 10.1697703 | 2.0339541 | 5.96 | 0.0001 |
| IRR | 2 | 33.9632047 | 16.9816023 | 49.77 | 0.0001 |
| BLOCK*IRR | 10 | 3.3317758 | 0.3331776 | 0.98 | 0.4659 |
| CULTIVAR | 5 | 19.1007869 | 3.8201574 | 11.20 | 0.0001 |
| VERT | 1 | 0.4884646 | 0.4884646 | 1.43 | 0.2332 |
| IRR*CULTIVAR | 10 | 1.8257944 | 0.1825794 | 0.54 | 0.8635 |
| CULTIVAR*VERT | 5 | 2.0542709 | 0.4108542 | 1.20 | 0.3095 |
| IRR*VERT | 2 | 1.1249871 | 0.5624935 | 1.65 | 0.1955 |
| IRR*CULTIVAR*VERT | 10 | 3.3130706 | 0.3313071 | 0.97 | 0.4707 |

Table 2.2. General linear model summary of ln aerial biomass, 1997.

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| BLOCK | 5 | 6.5149110 | 1.3029822 | 8.14 | 0.0001 |
| IRR | 2 | 26.6971090 | 13.3485545 | 83.36 | 0.0001 |
| BLOCK*IRR | 10 | 4.2588032 | 0.4258803 | 2.66 | 0.0049 |
| CULTIVAR | 5 | 6.5080111 | 1.3016022 | 8.13 | 0.0001 |
| VERT | 1 | 0.8059634 | 0.8059634 | 5.03 | 0.0262 |
| IRR*CULTIVAR | 10 | 1.7936777 | 0.1793678 | 1.12 | 0.3500 |
| CULTIVAR*VERT | 5 | 1.1029609 | 0.2205922 | 1.38 | 0.2353 |
| IRR*VERT | 2 | 0.2469646 | 0.1234823 | 0.77 | 0.4642 |
| IRR*CULTIVAR*VERT | 10 | 2.5876434 | 0.2587643 | 1.62 | 0.1060 |

Table 2.3. General linear model summary of RAUSPC, 1996.

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| BLOCK | 5 | 84.03498 | 16.80700 | 0.45 | 0.8095 |
| IRR | 2 | 5470.76030 | 2735.38015 | 73.99 | 0.0001 |
| BLOCK*IRR | 10 | 986.52627 | 98.65263 | 2.67 | 0.0048 |
| CULTIVAR | 5 | 4591.45568 | 918.29114 | 24.84 | 0.0001 |
| VERT | 1 | 1110.98434 | 1110.98434 | 30.05 | 0.0001 |
| IRR*CULTIVAR | 10 | 1174.47054 | 117.44705 | 3.18 | 0.0009 |
| CULTIVAR*VERT | 5 | 513.71246 | 102.74249 | 2.78 | 0.0194 |
| IRR*VERT | 2 | 22.64209 | 11.32104 | 0.31 | 0.7366 |
| IRR*CULTIVAR*VERT | 10 | 204.14264 | 20.41426 | 0.55 | 0.8506 |

Table 2.4. General linear model summary of RAUSPC, 1997.

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| BLOCK | 5 | 776.33946 | 155.26789 | 5.50 | 0.0001 |
| IRR | 2 | 3707.26732 | 1853.63366 | 65.71 | 0.0001 |
| BLOCK*IRR | 10 | 755.00562 | 75.50056 | 2.68 | 0.0046 |
| CULTIVAR | 5 | 3580.13705 | 716.02741 | 25.38 | 0.0001 |
| VERT | 1 | 861.52178 | 861.52178 | 30.54 | 0.0001 |
| IRR*CULTIVAR | 10 | 1332.44791 | 133.24479 | 4.72 | 0.0001 |
| CULTIVAR*VERT | 5 | 523.20846 | 104.64169 | 3.71 | 0.0033 |
| IRR*VERT | 2 | 150.21934 | 75.10967 | 2.66 | 0.0728 |
| IRR*CULTIVAR*VERT | 10 | 352.02804 | 35.20280 | 1.25 | 0.2644 |

Table 2.5. General linear model summary of ln CFU/g stem apex 1996.

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| BLOCK | 5 | 63.726547 | 12.745309 | 2.40 | 0.0446 |
| IRR | 2 | 17.623021 | 8.811510 | 1.66 | 0.1968 |
| CULTIVAR | 5 | 186.870890 | 37.374178 | 7.05 | 0.0001 |
| BLOCK*IRR | 10 | 64.286846 | 6.428685 | 1.21 | 0.2973 |
| IRR*CULTIVAR | 10 | 48.164972 | 4.816497 | 0.91 | 0.5303 |

Table 2.6. General linear model summary of ln CFU/g stem apex 1997.

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| BLOCK | 5 | 33.348578 | 6.669716 | 2.06 | 0.0801 |
| IRR | 2 | 34.348764 | 17.174382 | 5.30 | 0.0070 |
| CULTIVAR | 5 | 110.313669 | 22.062734 | 6.81 | 0.0001 |
| BLOCK*IRR | 10 | 61.567867 | 6.156787 | 1.90 | 0.0582 |
| IRR*CULTIVAR | 10 | 29.609524 | 2.960952 | 0.91 | 0.5252 |

Table 2.7. General linear model summary of tuber yield <113 g, 1996.

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| BLOCK | 5 | 49.372450 | 9.874490 | 5.68 | 0.0001 |
| IRR | 2 | 140.840019 | 70.420010 | 40.51 | 0.0001 |
| CULTIVAR | 5 | 395.981383 | 79.196277 | 45.55 | 0.0001 |
| VERT | 1 | 2.265252 | 2.265252 | 1.30 | 0.2553 |
| BLOCK*IRR | 10 | 53.957281 | 5.395728 | 3.10 | 0.0012 |
| IRR*CULTIVAR | 10 | 49.662547 | 4.966255 | 2.86 | 0.0026 |
| CULTIVAR*VERT | 5 | 16.380909 | 3.276182 | 1.88 | 0.0997 |
| IRR*VERT | 2 | 8.319223 | 4.159612 | 2.39 | 0.0946 |
| IRR*CULTIVAR*VERT | 10 | 18.999299 | 1.899930 | 1.09 | 0.3705 |

Table 2.8. General linear model summary of tuber yield <113 g, 1997.

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| BLOCK | 5 | 15.857944 | 3.171589 | 2.59 | 0.0277 |
| IRR | 2 | 120.976975 | 60.488487 | 49.39 | 0.0001 |
| CULTIVAR | 5 | 254.850200 | 50.970040 | 41.62 | 0.0001 |
| VERT | 1 | 0.064067 | 0.064067 | 0.05 | 0.8194 |
| BLOCK*IRR | 10 | 24.796631 | 2.479663 | 2.02 | 0.0338 |
| IRR*CULTIVAR | 10 | 38.192075 | 3.819208 | 3.12 | 0.0011 |
| CULTIVAR*VERT | 5 | 7.633089 | 1.526618 | 1.25 | 0.2897 |
| IRR*VERT | 2 | 1.282136 | 0.641068 | 0.52 | 0.5934 |
| IRR*CULTIVAR*VERT | 10 | 25.334192 | 2.533419 | 2.07 | 0.0297 |

Table 2.9. General linear model summary of tuber yield 113-170 g, 1996.

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| BLOCK | 5 | 236.312169 | 47.262434 | 6.09 | 0.0001 |
| IRR | 2 | 184.908281 | 92.454141 | 11.92 | 0.0001 |
| CULTIVAR | 5 | 810.316669 | 162.063334 | 20.90 | 0.0001 |
| VERT | 1 | 24.976400 | 24.976400 | 3.22 | 0.0746 |
| BLOCK*IRR | 10 | 229.163774 | 22.916377 | 2.95 | 0.0019 |
| IRR*CULTIVAR | 10 | 170.595891 | 17.059589 | 2.20 | 0.0201 |
| CULTIVAR*VERT | 5 | 45.381613 | 9.076323 | 1.17 | 0.3260 |
| IRR*VERT | 2 | 7.274781 | 3.637391 | 0.47 | 0.6265 |
| IRR*CULTIVAR*VERT | 10 | 56.598780 | 5.659878 | 0.73 | 0.6957 |

Table 2.10. General linear model summary of tuber yield 113-170 g, 1997.

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| BLOCK | 5 | 190.624404 | 38.124881 | 5.77 | 0.0001 |
| IRR | 2 | 207.711545 | 103.855773 | 15.72 | 0.0001 |
| CULTIVAR | 5 | 619.008343 | 123.801669 | 18.74 | 0.0001 |
| VERT | 1 | 8.182230 | 8.182230 | 1.24 | 0.2674 |
| BLOCK*IRR | 10 | 181.917744 | 18.191774 | 2.75 | 0.0037 |
| IRR*CULTIVAR | 10 | 89.361655 | 8.936165 | 1.35 | 0.2069 |
| CULTIVAR*VERT | 5 | 37.918498 | 7.583700 | 1.15 | 0.3374 |
| IRR*VERT | 2 | 17.389240 | 8.694620 | 1.32 | 0.2710 |
| IRR*CULTIVAR*VERT | 10 | 45.002449 | 4.500245 | 0.68 | 0.7410 |

Table 2.11. General linear model summary of tuber yield 171-340 g, 1996.

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| BLOCK | 5 | 306.68417 | 61.33683 | 2.63 | 0.0234 |
| IRR | 2 | 6386.26603 | 3193.13302 | 139.50 | 0.0001 |
| CULTIVAR | 5 | 1713.85801 | 342.77160 | 14.98 | 0.0001 |
| VERT | 1 | 9.50461 | 9.50461 | 0.42 | 0.5202 |
| BLOCK*IRR | 10 | 1127.53569 | 112.75357 | 4.93 | 0.0001 |
| IRR*CULTIVAR | 10 | 604.36878 | 60.43688 | 2.64 | 0.0052 |
| CULTIVAR*VERT | 5 | 255.08728 | 51.01746 | 2.23 | 0.0538 |
| IRR*VERT | 2 | 1.08812 | 0.54406 | 0.02 | 0.9765 |
| IRR*CULTIVAR*VERT | 10 | 53.52783 | 5.35278 | 0.23 | 0.9925 |

Table 2.12. General linear model summary of tuber yield 171-340 g, 1997.

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| BLOCK | 5 | 1542.36763 | 308.47353 | 12.68 | 0.0001 |
| IRR | 2 | 4865.63289 | 2432.81644 | 100.04 | 0.0001 |
| CULTIVAR | 5 | 2324.10219 | 464.82044 | 19.11 | 0.0001 |
| VERT | 1 | 0.25972 | 0.25972 | 0.01 | 0.9178 |
| BLOCK*IRR | 10 | 660.18099 | 66.01810 | 2.71 | 0.0041 |
| IRR*CULTIVAR | 10 | 733.06317 | 73.30632 | 3.01 | 0.0016 |
| CULTIVAR*VERT | 5 | 224.59062 | 44.91812 | 1.85 | 0.1064 |
| IRR*VERT | 2 | 4.49933 | 2.24967 | 0.09 | 0.9117 |
| IRR*CULTIVAR*VERT | 10 | 208.80174 | 20.88017 | 0.86 | 0.5732 |

Table 2.13. General linear model summary of tuber yield >340 g, 1996.

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| BLOCK | 5 | 827.7559 | 165.5512 | 6.79 | 0.0001 |
| IRR | 2 | 10321.1810 | 5160.5905 | 211.57 | 0.0001 |
| CULTIVAR | 5 | 2619.4709 | 523.8942 | 21.48 | 0.0001 |
| VERT | 1 | 18.3925 | 18.3925 | 0.75 | 0.3865 |
| BLOCK*IRR | 10 | 736.6938 | 73.6694 | 3.02 | 0.0016 |
| IRR*CULTIVAR | 10 | 1325.0606 | 132.5061 | 5.43 | 0.0001 |
| CULTIVAR*VERT | 5 | 82.8380 | 16.5676 | 0.68 | 0.6398 |
| IRR*VERT | 2 | 33.2171 | 16.6086 | 0.68 | 0.5076 |
| IRR*CULTIVAR*VERT | 10 | 117.9604 | 11.7960 | 0.48 | 0.8990 |

Table 2.14. General linear model summary of tuber yield >340 g, 1997.

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| BLOCK | 5 | 2238.5056 | 447.7011 | 14.03 | 0.0001 |
| IRR | 2 | 15434.5872 | 7717.2936 | 241.79 | 0.0001 |
| CULTIVAR | 5 | 1938.2119 | 387.6424 | 12.14 | 0.0001 |
| VERT | 1 | 161.4955 | 161.4955 | 5.06 | 0.0258 |
| BLOCK*IRR | 10 | 1472.3767 | 147.2377 | 4.61 | 0.0001 |
| IRR*CULTIVAR | 10 | 485.6990 | 48.5699 | 1.52 | 0.1356 |
| CULTIVAR*VERT | 5 | 271.6678 | 54.3336 | 1.70 | 0.1368 |
| IRR*VERT | 2 | 121.6633 | 60.8316 | 1.91 | 0.1520 |
| IRR*CULTIVAR*VERT | 10 | 351.3379 | 35.1338 | 1.10 | 0.3645 |

Table 2.15. General linear model summary of yield of culled tubers 1996.

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| BLOCK | 5 | 49.437149 | 9.887430 | 2.34 | 0.0440 |
| IRR | 2 | 278.607019 | 139.303510 | 32.96 | 0.0001 |
| CULTIVAR | 5 | 133.313426 | 26.662685 | 6.31 | 0.0001 |
| VERT | 1 | 59.503504 | 59.503504 | 14.08 | 0.0002 |
| BLOCK*IRR | 10 | 38.054319 | 3.805432 | 0.90 | 0.5343 |
| IRR*CULTIVAR | 10 | 59.383375 | 5.938338 | 1.40 | 0.1820 |
| CULTIVAR*VERT | 5 | 73.016671 | 14.603334 | 3.45 | 0.0054 |
| IRR*VERT | 2 | 3.994886 | 1.997443 | 0.47 | 0.6242 |
| IRR*CULTIVAR*VERT | 10 | 24.075464 | 2.407546 | 0.57 | 0.8371 |

Table 2.16. General linear model summary of yield of culled tubers, 1997.

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| BLOCK | 5 | 197.47044 | 39.49409 | 2.05 | 0.0748 |
| IRR | 2 | 1627.82962 | 813.91481 | 42.17 | 0.0001 |
| CULTIVAR | 5 | 208.46689 | 41.69338 | 2.16 | 0.0609 |
| VERT | 1 | 3.86939 | 3.86939 | 0.20 | 0.6549 |
| BLOCK*IRR | 10 | 386.71429 | 38.67143 | 2.00 | 0.0359 |
| IRR*CULTIVAR | 10 | 333.65529 | 33.36553 | 1.73 | 0.0781 |
| CULTIVAR*VERT | 5 | 113.22721 | 22.64544 | 1.17 | 0.3244 |
| IRR*VERT | 2 | 34.91776 | 17.45888 | 0.90 | 0.4067 |
| IRR*CULTIVAR*VERT | 10 | 175.34033 | 17.53403 | 0.91 | 0.5267 |

Table 2.17. General linear model summary of yield of marketable tubers, 1996.

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| BLOCK | 5 | 2025.6415 | 405.1283 | 5.06 | 0.0002 |
| IRR | 2 | 24703.1744 | 12351.5872 | 154.19 | 0.0001 |
| CULTIVAR | 5 | 3287.7905 | 657.5581 | 8.21 | 0.0001 |
| VERT | 1 | 34.1294 | 34.1294 | 0.43 | 0.5148 |
| BLOCK*IRR | 10 | 2374.4668 | 237.4467 | 2.96 | 0.0019 |
| IRR*CULTIVAR | 10 | 1156.2671 | 115.6267 | 1.44 | 0.1654 |
| CULTIVAR*VERT | 5 | 706.4035 | 141.2807 | 1.76 | 0.1230 |
| IRR*VERT | 2 | 223.5885 | 111.7943 | 1.40 | 0.2506 |
| IRR*CULTIVAR*VERT | 10 | 699.9901 | 69.9990 | 0.87 | 0.5589 |

Table 2.18. General linear model summary of yield of marketable tubers, 1997.

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| BLOCK | 5 | 6813.9070 | 1362.7814 | 26.72 | 0.0001 |
| IRR | 2 | 31826.9354 | 15913.4677 | 312.00 | 0.0001 |
| CULTIVAR | 5 | 1930.3591 | 386.0718 | 7.57 | 0.0001 |
| VERT | 1 | 107.3151 | 107.3151 | 2.10 | 0.1488 |
| BLOCK*IRR | 10 | 1877.8156 | 187.7816 | 3.68 | 0.0002 |
| IRR*CULTIVAR | 10 | 389.3237 | 38.9324 | 0.76 | 0.6639 |
| CULTIVAR*VERT | 5 | 553.7040 | 110.7408 | 2.17 | 0.0597 |
| IRR*VERT | 2 | 51.3712 | 25.6856 | 0.50 | 0.6053 |
| IRR*CULTIVAR*VERT | 10 | 489.0860 | 48.9086 | 0.96 | 0.4813 |

Table 2.19. General linear model summary of yield of nonmarketable tubers, 1996.

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| BLOCK | 5 | 182.421293 | 36.484259 | 1.68 | 0.1420 |
| IRR | 2 | 374.242893 | 187.121446 | 8.62 | 0.0003 |
| CULTIVAR | 5 | 273.608654 | 54.721731 | 2.52 | 0.0315 |
| VERT | 1 | 285.200185 | 285.200185 | 13.14 | 0.0004 |
| BLOCK*IRR | 10 | 229.268574 | 22.926857 | 1.06 | 0.3993 |
| IRR*CULTIVAR | 10 | 795.932780 | 79.593278 | 3.67 | 0.0002 |
| CULTIVAR*VERT | 5 | 191.017870 | 38.203574 | 1.76 | 0.1239 |
| IRR*VERT | 2 | 88.758359 | 44.379180 | 2.04 | 0.1328 |
| IRR*CULTIVAR*VERT | 10 | 331.780802 | 33.178080 | 1.53 | 0.1333 |

Table 2.20. General linear model summary of yield of nonmarketable tubers, 1997.

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| BLOCK | 5 | 237.529225 | 47.505845 | 2.45 | 0.0359 |
| IRR | 2 | 977.476604 | 488.738302 | 25.19 | 0.0001 |
| CULTIVAR | 5 | 668.777147 | 133.755429 | 6.89 | 0.0001 |
| VERT | 1 | 4.953445 | 4.953445 | 0.26 | 0.6140 |
| BLOCK*IRR | 10 | 369.178896 | 36.917890 | 1.90 | 0.0480 |
| IRR*CULTIVAR | 10 | 439.580124 | 43.958012 | 2.27 | 0.0165 |
| CULTIVAR*VERT | 5 | 126.626591 | 25.325318 | 1.31 | 0.2641 |
| IRR*VERT | 2 | 30.333359 | 15.166680 | 0.78 | 0.4593 |
| IRR*CULTIVAR*VERT | 10 | 211.428180 | 21.142818 | 1.09 | 0.3728 |

Table 2.21. General linear model summary of total yield of tubers, 1996.

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| BLOCK | 5 | 2032.3388 | 406.4678 | 7.11 | 0.0001 |
| IRR | 2 | 28831.1688 | 14415.5844 | 252.20 | 0.0001 |
| CULTIVAR | 5 | 2349.2934 | 469.8587 | 8.22 | 0.0001 |
| VERT | 1 | 122.0105 | 122.0105 | 2.13 | 0.1459 |
| BLOCK*IRR | 10 | 2338.4775 | 233.8478 | 4.09 | 0.0001 |
| IRR*CULTIVAR | 10 | 987.4653 | 98.7465 | 1.73 | 0.0784 |
| CULTIVAR*VERT | 5 | 439.3817 | 87.8763 | 1.54 | 0.1809 |
| IRR*VERT | 2 | 30.6143 | 15.3072 | 0.27 | 0.7654 |
| IRR*CULTIVAR*VERT | 10 | 239.7271 | 23.9727 | 0.42 | 0.9358 |

Table 2.22. General linear model summary of total yield of tubers, 1997.

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| BLOCK | 5 | 5690.2777 | 1138.0555 | 27.27 | 0.0001 |
| IRR | 2 | 42978.8594 | 21489.4297 | 514.89 | 0.0001 |
| CULTIVAR | 5 | 3367.5957 | 673.5191 | 16.14 | 0.0001 |
| VERT | 1 | 158.3806 | 158.3806 | 3.79 | 0.0531 |
| BLOCK*IRR | 10 | 1691.7702 | 169.1770 | 4.05 | 0.0001 |
| IRR*CULTIVAR | 10 | 641.8683 | 64.1868 | 1.54 | 0.1300 |
| CULTIVAR*VERT | 5 | 337.0450 | 67.4090 | 1.62 | 0.1587 |
| IRR*VERT | 2 | 13.0300 | 6.5150 | 0.16 | 0.8556 |
| IRR*CULTIVAR*VERT | 10 | 350.4195 | 35.0420 | 0.84 | 0.5912 |