

Interaction of Inoculum Levels of *Verticillium dahliae* and Cultivar Resistance

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Neil C. Gudmestad
Departments of Plant Pathology
North Dakota State University

Executive Summary

Verticillium wilt, caused by *Verticillium dahliae*, is the principle pathogen involved in the early dying syndrome. Early dying is arguably the most economically damaging disease of potato in the USA when considering direct and indirect losses due to the disease and the cost of control. Soil fumigation with metam sodium is the primary means by which irrigated potato producers manage this disease and a soil level of >8 *Verticillium* propagules per gram (vppg) of soil triggers fumigation with cultivars such as Russet Burbank. Approximately 34 million pounds of the active ingredient metam sodium are applied by the potato industry each year for the control of *Verticillium* wilt at cost of nearly \$170 million, not including the cost of application. Metam sodium has been recently been re-registered by the Environmental Protection Agency (EPA) but with considerable restrictions placed on its use. Potato cultivars that resist *V. dahliae* are economically and environmentally more favorable for the control *Verticillium* wilt and can potentially eliminate the need for soil fumigation. However, preliminary data suggests high levels of the *V. dahliae* may overcome genetic resistance to this pathogen. The research proposed here will investigate the interaction of soil inoculum levels of *V. dahliae* and cultivar resistance to determine if genetic resistance can succumb to high levels of this pathogen. The aim of this research is to establish the economic threshold of soil inoculum for potato cultivars moderately resistant and highly resistant to *Verticillium* wilt.

Introduction

Verticillium dahliae infects the water conducting tissues of many plant species, including the potato (*Solanum tuberosum* L.), causing a disease known as *Verticillium* wilt. This pathogen is also the principle component of the early dying complex. The fungus survives in the soil as microsclerotia which allow the pathogen to survive long periods of time in the absence of a suitable plant host. The application of metam sodium to the soil kills the microsclerotia and is the primary means by which the potato industry controls this disease. The economic threshold for densities of *V. dahliae* in soil for susceptible cultivars such as Russet Burbank is 8 vppg, which is not a very high level of the pathogen. However, we know from previous research performed in Minnesota that soil densities after multiple potato crops can easily exceed 200 vppg (Taylor et al., 2005). These levels of *V. dahliae* make soil fumigation less effective especially when you consider studies in which places metam sodium efficacy at approximately 72% (Taylor et al., 2005). High soil densities of *V. dahliae* may also affect disease expression in *Verticillium* resistant cultivars.

A number of potato cultivars have been described as possessing resistance to *V. dahliae*. These cultivars include Alturas (Novy et al. 2003), Defender (Novy et al. 2006), Goldrush (Johansen et al. 1994), Ranger Russet (Pavek et al. 1992), Reddale, Russet Nugget (Holm et al. 1992), Umatilla Russet (Mosley et al. 2000), and Western Russet (Love et al. 2006), among others. While Ranger Russet and Umatilla Russet have impacted the processing industry, most cultivars with purported resistance are not widely grown and/or are unsuitable for French fry

processing. Unfortunately, most cultivars reported as resistant to *Verticillium* wilt have been evaluated only in small plot trials for their ability to yield well in soils infested with *V. dahliae*. This method of evaluation fails to distinguish tolerance from resistance or moderate resistance, a flaw in methodology employed by many potato breeding programs. Cultivars tolerant to *V. dahliae* do not resist the pathogen but may not express symptoms in the field and, therefore, return as many propagules of the pathogen to the soil as a susceptible cultivar due to colonization of the stems. This can lead to a build up of inoculum in the soil which can lead to a breakdown of the tolerant reaction. A methodology has been proposed recently for evaluating potato clones for resistance to *V. dahliae* which involves a three-pronged approach, including determining the levels of the pathogen multiplying in the plant (Jansky, 2009). This methodology is very similar to the one used at the University of Minnesota in the 1970's (Hoya, et al. 1991, 1993).

More recently, studies conducted at NDSU have verified that a number of potato cultivars have moderate to high levels of resistance to *V. dahliae* (Pasche, Gudmestad & Thompson, unpublished data). These cultivars vary in the degree of wilt expressed during the growing season and in the quantity of *V. dahliae* present in the plant. Preliminary data from these trials also suggests that genetic resistance in these cultivars may 'break' under high inoculum pressure, reducing yield. Six of eight cultivars evaluated had lower yields under high inoculum density compared to low inoculum density (12 vppg).

The research proposed here will investigate the interaction of *V. dahliae* levels in soil and genetic resistance to *Verticillium* wilt in several potato cultivars. The ultimate goal will be to determine if there are economic thresholds at which the yield of *Verticillium* resistant cultivars will be significantly reduced. In these cultivars, soil fumigation may be warranted when extremely high soil levels of *V. dahliae* exist.

Research Objectives

- 1) Evaluate potato cultivars with varying levels of resistance for *Verticillium* wilt development under several levels of inoculum density
- 2) Determine economic thresholds of *V. dahliae* in potato cultivars that are moderately resistant and highly resistant to the pathogen and compare to susceptible cultivars

Research Plan

These research studies will be conducted initially under greenhouse conditions to rapidly determine soil levels of *V. dahliae* at which genetic resistance may be insufficient to prevent yield loss. Levels of *V. dahliae* will include 0, 10, 100, 300 and 1,000 vppg dry soil. Seed pieces of susceptible, moderately resistant and highly resistant potato cultivars such as Russet Nortkotah, Russet Burbank, Umatilla Russet, Ranger Russet, Classic Russet, Premier Russet, Dakota Trailblazer, and Alturas will be inoculated at each inoculum density. *V. dahliae* will be grown on sterilized wheat seed for approximately three months, air-dried, and ground into a powder so that it can be applied in furrow at planting to achieve varying levels of soil inoculum.

The study will be conducted as a completely random design with three replications and 5 potato plants at each cultivar X soil inoculum concentration. Data on the degree of wilting, colonization of the pathogen in each cultivar at each inoculum concentration and yield will be taken for each treatment combination.

Results

Under greenhouse conditions increasing levels of *V. dahliae* inoculum increased the level of wilt severity in the susceptible cultivar Russet Norkotah and to some degree in the moderately susceptible cultivar Russet Burbank (Figure 1, Table 1). Wilt severity, as measured by the relative area under the wilt progress curve (RAUWC) also increased slightly for the highly resistant cultivar Dakota Trailblazer. However, increasing levels of inoculum did not increase wilt severity in the moderately resistant cultivar Bannock Russet.

Verticillium wilt severity progressed as expected over the course of the growing season in all cultivars (Figure 2). Verticillium wilt progressed the most rapidly in the susceptible check cultivar Russet Norkotah and was significantly slower in moderately resistant and resistant cultivars Premier Russet and Dakota Trailblazer, respectively, resulting in significantly different relative areas under the wilt progress curve (RAUWPC) (Figure 3).

Unfortunately, *V. dahliae* inoculum levels introduced into the soil at planting did not appreciably increase wilt levels in any cultivar (Table 2). As a result, increasing levels of *V. dahliae* inoculum did not significantly affect yield (Table 3).

These results are difficult to interpret. Either the Verticillium-infested wheat we introduced was nonviable, or the inoculum levels left in the soil after fumigation of the Inkster plot land were sufficiently high to negate any soil inoculum effect. Soil inoculum levels determined during the growing season revealed *V. dahliae* levels up to 16 Verticillium propagules per gram of soil, approximately 2X the economic threshold for Russet Burbank. Although the Inkster plot land was fumigated in November, 2009, the land where the Verticillium wilt research was placed was the sandiest and highest ground in the approximately 20 acre plot area. We speculate that this area may have been too dry prior to fumigation and, therefore, we did not obtain sufficient kill of the resident *V. dahliae* microsclerotia. As a result, the additional inoculum infested into the soil had no effect on increasing wilt disease incidence and severity.

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Table 1. Wilt severity, area under the wilt progress curve (AUWPC) and relative area under the wilt progress curve (RAUWPC) among four Russet cultivars inoculated via soil infestation at planting with varying levels of *Verticillium dahliae* microsclerotia (ms) under greenhouse conditions. Mean separation based on Fisher's protected least significant difference (LSD) test ($P = 0.05$).

Cultivar	Reported Susceptibility	Inoculation Rate	Wilt Severity (%)				AUWPC	RAUWPC
			6/3	6/10	6/16	6/22		
Russet Norkotah	Susceptible check	Non-inoculated	6.9	13.8	19.7	50.4	383.5	0.202
Russet Norkotah	Susceptible check	10 ms/g	13.5	20.1	44.6	60.6	627.0	0.330
Russet Norkotah	Susceptible check	100 ms/g	7.2	15.2	44.8	77.2	624.2	0.329
Russet Norkotah	Susceptible check	1000 ms/g	20.5	49.8	79.8	90.4	1144.9	0.603
Russet Norkotah	Susceptible check	7500 ms/g	18.3	48.1	95.3	100.0	1247.9	0.657
Bannock Russet	Moderately Resistant	Non-inoculated	3.0	5.7	6.9	22.1	135.4	0.071
Bannock Russet	Moderately Resistant	10 ms/g	2.5	6.8	7.4	11.7	121.5	0.064
Bannock Russet	Moderately Resistant	100 ms/g	4.0	5.1	14.7	39.0	210.3	0.111
Bannock Russet	Moderately Resistant	1000 ms/g	3.1	4.1	5.2	18.3	123.3	0.065
Bannock Russet	Moderately Resistant	7500 ms/g	3.6	4.5	6.1	13.2	117.8	0.062
Russet Burbank	Moderately Susceptible- Moderately Resistant	Non-inoculated	5.0	7.2	11.5	17.7	186.2	0.098
Russet Burbank	Moderately Susceptible- Moderately Resistant	10 ms/g	1.9	9.1	12.3	19.4	148.6	0.078
Russet Burbank	Moderately Susceptible- Moderately Resistant	100 ms/g	8.1	11.5	20.6	33.1	217.5	0.115
Russet Burbank	Moderately Susceptible- Moderately Resistant	1000 ms/g	11.1	19.1	21.3	47.1	431.6	0.227
Russet Burbank	Moderately Susceptible- Moderately Resistant	7500 ms/g	12.3	16.1	38.3	63.3	567.7	0.299
Dakota TrailBlazer	Very Resistant	Non-inoculated	5.7	5.3	6.9	22.4	156.2	0.082
Dakota TrailBlazer	Very Resistant	10 ms/g	3.0	2.9	7.5	21.3	138.2	0.073
Dakota TrailBlazer	Very Resistant	100 ms/g	5.0	7.6	8.4	31.3	211.0	0.111
Dakota TrailBlazer	Very Resistant	1000 ms/g	11.7	10.4	11.5	30.8	270.0	0.142
Dakota TrailBlazer	Very Resistant	7500 ms/g	6.0	6.8	9.6	29.4	210.6	0.111
LSD $P = 0.05$			6.3	10.5	11.7	17.4	165.1	0.087
Russet Norkotah	Susceptible check		12.2	26.8	50.6	71.5	735.2	0.387
Bannock Russet	Moderately Resistant		3.2	5.3	7.7	20.6	140.6	0.074
Russet Burbank	Moderately Susceptible- Moderately Resistant		7.4	11.8	19.5	33.7	289.7	0.152
Dakota TrailBlazer	Very Resistant		6.2	6.4	8.5	26.3	190.4	0.100
LSD $P = 0.05$			2.7	4.5	5.0	7.4	71.1	0.037

Table 1. (con't)

Cultivar	Reported Susceptibility	Inoculation Rate	Wilt Severity (%)				AUWPC	RAUWPC
			6/3	6/10	6/16	6/22		
Russet Norkotah	Susceptible check	Non-inoculated	6.9	13.8	19.7	50.4	383.5	0.202
Russet Norkotah	Susceptible check	10 ms/g	13.5	20.1	44.6	60.6	627.0	0.330
Russet Norkotah	Susceptible check	100 ms/g	7.2	15.2	44.8	77.2	624.2	0.329
Russet Norkotah	Susceptible check	1000 ms/g	20.5	49.8	79.8	90.4	1144.9	0.603
Russet Norkotah	Susceptible check	7500 ms/g	18.3	48.1	95.3	100.0	1247.9	0.657
LSD _{P = 0.05}			9.9	18.5	19.7	21.4	287.2	0.151
Bannock Russet	Moderately Resistant	Non-inoculated	3.0	5.7	6.9	22.1	135.4	0.071
Bannock Russet	Moderately Resistant	10 ms/g	2.5	6.8	7.4	11.7	121.5	0.064
Bannock Russet	Moderately Resistant	100 ms/g	4.0	5.1	14.7	39.0	210.3	0.111
Bannock Russet	Moderately Resistant	1000 ms/g	3.1	4.1	5.2	18.3	123.3	0.065
Bannock Russet	Moderately Resistant	7500 ms/g	3.6	4.5	6.1	13.2	117.8	0.062
LSD _{P = 0.05}			NS	NS	5.4	16.5	NS	NS
Russet Burbank	Moderately Susceptible- Moderately Resistant	Non-inoculated	5.0	7.2	11.5	17.7	186.2	0.098
Russet Burbank	Moderately Susceptible- Moderately Resistant	10 ms/g	1.9	9.1	12.3	19.4	148.6	0.078
Russet Burbank	Moderately Susceptible- Moderately Resistant	100 ms/g	8.1	11.5	20.6	33.1	217.5	0.115
Russet Burbank	Moderately Susceptible- Moderately Resistant	1000 ms/g	11.1	19.1	21.3	47.1	431.6	0.227
Russet Burbank	Moderately Susceptible- Moderately Resistant	7500 ms/g	12.3	16.1	38.3	63.3	567.7	0.299
LSD _{P = 0.05}			5.6	6.3	9.5	16.5	129.9	0.068
Dakota TrailBlazer	Very Resistant	Non-inoculated	5.7	5.3	6.9	22.4	156.2	0.082
Dakota TrailBlazer	Very Resistant	10 ms/g	3.0	2.9	7.5	21.3	138.2	0.073
Dakota TrailBlazer	Very Resistant	100 ms/g	5.0	7.6	8.4	31.3	211.0	0.111
Dakota TrailBlazer	Very Resistant	1000 ms/g	11.7	10.4	11.5	30.8	270.0	0.142
Dakota TrailBlazer	Very Resistant	7500 ms/g	6.0	6.8	9.6	29.4	210.6	0.111
LSD _{P = 0.05}			4.1	4.3	NS	NS	74.5	0.039

A significant interaction was observed between the main effects of cultivar and inoculation was observed in wilt severity on all dates as well as the AUWPC and RAUWPC ($P = 0.05$).

Table 2. Wilt incidence, area under the wilt progress curve (AUWPC) and relative area under the wilt progress curve (RAUWPC) among five Russet cultivars inoculated in-furrow with varying levels of *Verticillium dahliae*. Mean separation based on Fisher's protected least significant difference (LSD) test ($P = 0.05$).

Cultivar	Reported Susceptibility	Inoculation Rate	Vigor (6/29)	Wilt Incidence (%)					AUWPC	RAUWPC
				7/26	8/5	8/18	8/30	9/8		
Russet Norkotah	Susceptible check	-	3.0	5.5	18.9	22.4	84.4	90.5	1852.1	0.421
Russet Norkotah	Susceptible check	1X	3.0	4.7	22.1	21.5	89.5	94.0	1942.5	0.441
Russet Norkotah	Susceptible check	2X	3.0	9.2	19.6	26.7	85.7	85.4	1922.0	0.437
Russet Norkotah	Susceptible check	4X	2.8	6.9	14.6	38.5	93.4	95.7	2134.9	0.485
Premier Russet	Moderately Resistant	-	2.0	1.1	11.4	11.9	25.1	42.6	747.3	0.170
Premier Russet	Moderately Resistant	1X	2.0	1.0	4.2	4.7	25.1	45.5	591.5	0.134
Premier Russet	Moderately Resistant	2X	2.0	1.3	4.2	6.0	26.4	44.6	619.3	0.141
Premier Russet	Moderately Resistant	4X	2.0	2.0	4.8	5.6	24.1	45.4	601.3	0.137
Russet Burbank	Moderately Susceptible- Moderately Resistant	-	4.0	1.4	12.0	21.0	45.9	66.7	1206.6	0.274
Russet Burbank	Moderately Susceptible- Moderately Resistant	1X	4.0	0.7	5.6	16.7	48.6	67.1	1110.2	0.252
Russet Burbank	Moderately Susceptible- Moderately Resistant	2X	4.0	2.1	4.7	14.8	48.3	67.2	1081.4	0.246
Russet Burbank	Moderately Susceptible- Moderately Resistant	4X	4.0	0.3	3.4	13.4	42.0	65.6	963.6	0.219
Ranger Russet	Resistant Check	-	3.8	6.4	12.2	8.8	31.5	45.8	829.3	0.188
Ranger Russet	Resistant Check	1X	3.8	9.0	7.4	5.9	34.5	50.3	805.0	0.183
Ranger Russet	Resistant Check	2X	3.5	9.1	6.6	6.7	38.3	47.9	839.1	0.191
Ranger Russet	Resistant Check	4X	3.5	9.8	7.2	9.1	41.9	46.7	913.4	0.208
Dakota Trailblazer	Very Resistant	-	2.5	0.6	11.6	15.9	24.8	38.0	773.7	0.176
Dakota Trailblazer	Very Resistant	1X	2.8	0.6	4.9	7.6	22.2	37.4	563.8	0.128
Dakota Trailblazer	Very Resistant	2X	2.8	0.6	5.2	9.5	28.7	46.1	701.7	0.159
Dakota Trailblazer	Very Resistant	4X	2.5	1.5	5.2	9.2	29.9	50.1	733.8	0.167
LSD _{P = 0.06}			0.5	3.5	4.6	6.7	14.7	14.3	275.2	0.063
Russet Norkotah	Susceptible check		2.9	6.6	18.8	27.3	88.3	91.4	1962.9	0.446
Premier Russet	Moderately Resistant		2.0	1.4	6.1	7.1	25.2	44.5	639.9	0.145
Russet Burbank	Moderately Susceptible- Moderately Resistant		4.0	1.1	6.4	16.5	46.2	66.6	1090.5	0.248
Ranger Russet	Resistant Check		3.6	8.6	8.3	7.6	36.6	47.7	846.7	0.192
Dakota Trailblazer	Very Resistant		2.6	0.8	6.7	10.5	26.4	42.9	693.3	0.158
LSD _{P = 0.06}			0.2	1.7	2.3	3.3	7.4	7.1	137.6	0.031
		-	3.1	3.0	13.2	16.0	42.3	56.7	1081.8	0.246
		1X	3.1	3.2	8.8	11.3	44.0	58.9	1002.6	0.228
		2X	3.1	4.5	8.1	12.7	45.5	58.2	1032.7	0.235
		4X	3.0	4.1	7.0	15.2	46.3	60.7	1069.4	0.243
LSD _{P = 0.06}			NS	NS	2.1	3.0	NS	NS	NS	NS

Table 2. (cont)

Cultivar	Reported Susceptibility	Inoculation Rate	Vigor (6/29)	Wilt Incidence (%)					AUWPC	RAUWPC
				7/26	8/5	8/18	8/30	9/8		
Russet Norkotah	Susceptible check	-	3.0	5.5	18.9	22.4	84.4	90.5	1852.1	0.421
Russet Norkotah	Susceptible check	1X	3.0	4.7	22.1	21.5	89.5	94.0	1942.5	0.441
Russet Norkotah	Susceptible check	2X	3.0	9.2	19.6	26.7	85.7	85.4	1922.0	0.437
Russet Norkotah	Susceptible check	4X	2.8	6.9	14.6	38.5	93.4	95.7	2134.9	0.485
LSD _{P = 0.06}			NS	NS	NS	10.2	NS	NS	NS	NS
Premier Russet	Moderately Resistant	-	2.0	1.1	11.4	11.9	25.1	42.6	747.3	0.170
Premier Russet	Moderately Resistant	1X	2.0	1.0	4.2	4.7	25.1	45.5	591.5	0.134
Premier Russet	Moderately Resistant	2X	2.0	1.3	4.2	6.0	26.4	44.6	619.3	0.141
Premier Russet	Moderately Resistant	4X	2.0	2.0	4.8	5.6	24.1	45.4	601.3	0.137
LSD _{P = 0.06}			.	NS	4.4	4.7	NS	NS	NS	NS
Russet Burbank	Moderately Susceptible-Moderately Resistant	-	4.0	1.4	12.0	21.0	45.9	66.7	1206.6	0.274
Russet Burbank	Moderately Susceptible-Moderately Resistant	1X	4.0	0.7	5.6	16.7	48.6	67.1	1110.2	0.252
Russet Burbank	Moderately Susceptible-Moderately Resistant	2X	4.0	2.1	4.7	14.8	48.3	67.2	1081.4	0.246
Russet Burbank	Moderately Susceptible-Moderately Resistant	4X	4.0	0.3	3.4	13.4	42.0	65.6	963.6	0.219
LSD _{P = 0.06}			.	NS	3.1	NS	NS	NS	NS	NS
Ranger Russet	Resistant Check	-	3.8	6.4	12.2	8.8	31.5	45.8	829.3	0.188
Ranger Russet	Resistant Check	1X	3.8	9.0	7.4	5.9	34.5	50.3	805.0	0.183
Ranger Russet	Resistant Check	2X	3.5	9.1	6.6	6.7	38.3	47.9	839.1	0.191
Ranger Russet	Resistant Check	4X	3.5	9.8	7.2	9.1	41.9	46.7	913.4	0.208
LSD _{P = 0.06}			NS	NS	4.1	NS	NS	NS	NS	NS
Dakota Trailblazer	Very Resistant	-	2.5	0.6	11.6	15.9	24.8	38.0	773.7	0.176
Dakota Trailblazer	Very Resistant	1X	2.8	0.6	4.9	7.6	22.2	37.4	563.8	0.128
Dakota Trailblazer	Very Resistant	2X	2.8	0.6	5.2	9.5	28.7	46.1	701.7	0.159
Dakota Trailblazer	Very Resistant	4X	2.5	1.5	5.2	9.2	29.9	50.1	733.8	0.167
LSD _{P = 0.06}			NS	NS	NS	3.9	NS	8.9	106.4	0.024

A significant interaction was observed between the main effects of cultivar and inoculation in percent wilted stems on 8/18 ($P = 0.05$).

Table 3. Wilt severity, area under the wilt progress curve (AUWPC), relative area under the wilt progress curve (RAUWPC) and total yield among five Russet cultivars inoculated in-furrow with varying levels of *Verticillium dahliae*. Mean separation based on Fisher's protected least significant difference (LSD) test ($P = 0.05$).

Cultivar	Reported Susceptibility	Inoculation Rate	Wilt Severity (%)					AUWPC	RAUWPC	Total Yield (cwt/a)
			7/26	8/5	8/18	8/30	9/8			
Russet Norkotah	Susceptible check	-	6.7	7.0	19.8	92.4	99.2	1800.4	0.409	473.0
Russet Norkotah	Susceptible check	1X	3.6	9.3	23.7	93.7	99.4	1880.2	0.427	482.5
Russet Norkotah	Susceptible check	2X	5.1	10.4	33.1	95.2	99.3	2072.6	0.471	447.6
Russet Norkotah	Susceptible check	4X	6.6	12.3	28.9	94.8	99.7	1994.0	0.453	476.6
Premier Russet	Moderately Resistant	-	0.6	2.1	2.6	3.6	9.5	131.5	0.030	429.0
Premier Russet	Moderately Resistant	1X	0.7	1.4	1.8	2.9	11.8	121.6	0.028	434.3
Premier Russet	Moderately Resistant	2X	0.7	1.4	1.5	5.5	19.0	171.1	0.039	460.1
Premier Russet	Moderately Resistant	4X	1.1	1.5	2.0	5.8	16.9	169.3	0.038	437.8
Russet Burbank	Moderately Susceptible-Moderately Resistant	-	1.5	3.2	5.9	63.3	88.5	1072.6	0.244	490.1
Russet Burbank	Moderately Susceptible-Moderately Resistant	1X	0.7	2.8	11.0	70.2	87.4	1279.0	0.291	498.8
Russet Burbank	Moderately Susceptible-Moderately Resistant	2X	1.1	2.1	6.9	61.7	87.7	1085.6	0.247	527.7
Russet Burbank	Moderately Susceptible-Moderately Resistant	4X	0.2	2.2	5.4	60.6	90.1	1053.1	0.239	547.1
Ranger Russet	Resistant Check	-	2.9	2.9	2.5	15.3	37.1	426.5	0.097	480.3
Ranger Russet	Resistant Check	1X	3.1	1.9	2.3	16.4	48.3	445.7	0.101	482.7
Ranger Russet	Resistant Check	2X	3.3	1.9	2.4	11.1	43.9	392.6	0.089	520.3
Ranger Russet	Resistant Check	4X	2.8	2.2	2.5	15.9	44.6	434.1	0.099	506.4
Dakota Trailblazer	Very Resistant	-	0.3	1.7	1.5	2.8	5.2	90.4	0.021	471.3
Dakota Trailblazer	Very Resistant	1X	0.5	1.5	1.5	3.3	7.4	107.0	0.024	479.4
Dakota Trailblazer	Very Resistant	2X	0.3	1.4	4.0	5.8	10.3	151.3	0.034	447.2
Dakota Trailblazer	Very Resistant	4X	0.6	1.6	1.7	5.2	5.9	129.9	0.030	481.6
LSD _{P = 0.06}			3.5	6.0	9.4	5.6	4.4	164.5	0.037	50.8
Russet Norkotah	Susceptible check		5.6	9.6	27.0	94.0	99.4	1936.8	0.440	469.9
Premier Russet	Moderately Resistant		0.8	1.7	2.1	4.5	14.4	148.4	0.034	440.3
Russet Burbank	Moderately Susceptible-Moderately Resistant		0.9	2.8	7.3	64.0	88.4	1122.6	0.255	515.9
Ranger Russet	Resistant Check		3.0	2.3	2.4	14.6	43.5	424.7	0.097	497.4
Dakota Trailblazer	Very Resistant		0.4	1.6	2.1	4.3	7.3	119.6	0.027	469.9
LSD _{P = 0.06}			1.7	2.8	4.5	2.8	2.2	82.3	0.019	25.4
		-	3.4	4.0	8.8	59.3	66.4	704.3	0.160	468.7
		1X	2.5	5.8	13.6	61.6	68.1	766.7	0.174	475.5
		2X	3.3	6.3	17.5	57.2	66.5	774.7	0.176	480.6
		4X	3.4	6.3	16.8	58.5	68.7	756.1	0.172	489.9
LSD _{P = 0.06}			NS	NS	NS	NS	1.8	NS	NS	NS

Table 3. (cont)

Cultivar	Reported Susceptibility	Inoculation Rate	Wilt Severity (%)					AUWPC	RAUWPC	Total Yield (cwt/a)
			7/26	8/5	8/18	8/30	9/8			
Russet Norkotah	Susceptible check	-	6.7	7.0	19.8	92.4	99.2	1800.4	0.409	473.0
Russet Norkotah	Susceptible check	1X	3.6	9.3	23.7	93.7	99.4	1880.2	0.427	482.5
Russet Norkotah	Susceptible check	2X	5.1	10.4	33.1	95.2	99.3	2072.6	0.471	447.6
Russet Norkotah	Susceptible check	4X	6.6	12.3	28.9	94.8	99.7	1994.0	0.453	476.6
LSD _{P = 0.06}			NS	NS	7.7	NS	NS	172.7	0.039	NS
Premier Russet	Moderately Resistant	-	0.6	2.1	2.6	3.6	9.5	131.5	0.030	429.0
Premier Russet	Moderately Resistant	1X	0.7	1.4	1.8	2.9	11.8	121.6	0.028	434.3
Premier Russet	Moderately Resistant	2X	0.7	1.4	1.5	5.5	19.0	171.1	0.039	460.1
Premier Russet	Moderately Resistant	4X	1.1	1.5	2.0	5.8	16.9	169.3	0.038	437.8
LSD _{P = 0.06}			NS	0.6	0.8	NS	5.0	NS	NS	NS
Russet Burbank	Moderately Susceptible-Moderately Resistant	-	1.5	3.2	5.9	63.3	88.5	1072.6	0.244	490.1
Russet Burbank	Moderately Susceptible-Moderately Resistant	1X	0.7	2.8	11.0	70.2	87.4	1279.0	0.291	498.8
Russet Burbank	Moderately Susceptible-Moderately Resistant	2X	1.1	2.1	6.9	61.7	87.7	1085.6	0.247	527.7
Russet Burbank	Moderately Susceptible-Moderately Resistant	4X	0.2	2.2	5.4	60.6	90.1	1053.1	0.239	547.1
LSD _{P = 0.06}			NS	NS	3.6	6.5	NS	NS	NS	NS
Ranger Russet	Resistant Check	-	2.9	2.9	2.5	15.3	37.1	426.5	0.097	480.3
Ranger Russet	Resistant Check	1X	3.1	1.9	2.3	16.4	48.3	445.7	0.101	482.7
Ranger Russet	Resistant Check	2X	3.3	1.9	2.4	11.1	43.9	392.6	0.089	520.3
Ranger Russet	Resistant Check	4X	2.8	2.2	2.5	15.9	44.6	434.1	0.099	506.4
LSD _{P = 0.06}			NS	0.5	NS	NS	7.0	NS	NS	NS
Dakota Trailblazer	Very Resistant	-	0.3	1.7	1.5	2.8	5.2	90.4	0.021	471.3
Dakota Trailblazer	Very Resistant	1X	0.5	1.5	1.5	3.3	7.4	107.0	0.024	479.4
Dakota Trailblazer	Very Resistant	2X	0.3	1.4	4.0	5.8	10.3	151.3	0.034	447.2
Dakota Trailblazer	Very Resistant	4X	0.6	1.6	1.7	5.2	5.9	129.9	0.030	481.6
LSD _{P = 0.06}			NS	NS	NS	NS	3.4	NS	NS	NS

A significant interaction was observed between the main effects of cultivar and inoculation in percent wilted stems on 8/30 and 9/8 ($P = 0.05$).

No significant interaction was observed between the main effects of cultivar and inoculation in AUWPC, RAUWPC or yield ($P = 0.05$).

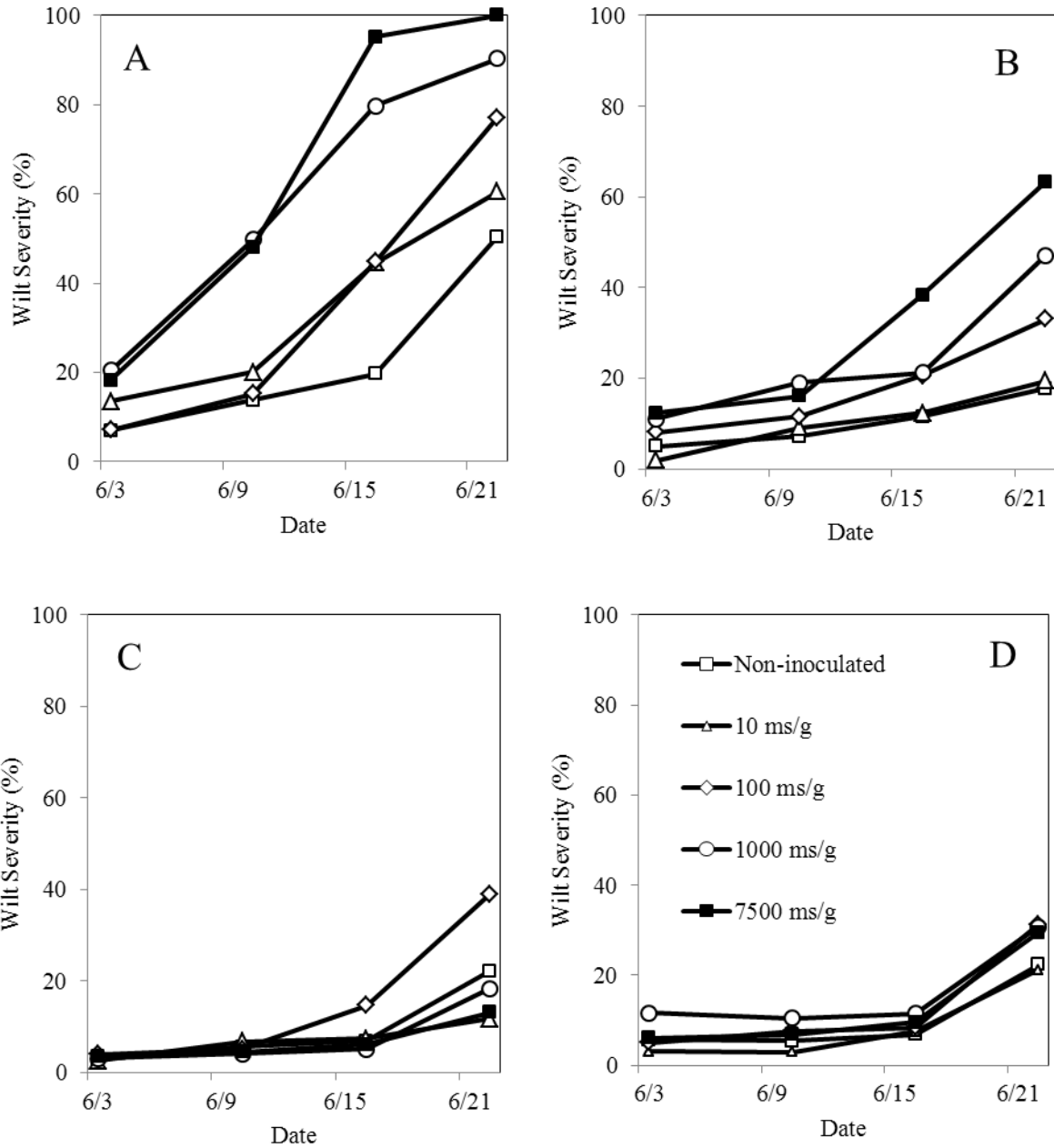


Figure 1. Verticillium wilt severity at five inoculation levels as measured under greenhouse conditions for four russet cultivars [Russet Norkotah (A), Russet Burbank (B), Bannock Russet (C) and Dakota Trailblazer (D)] with varying levels of resistance to Verticillium wilt caused by *Verticillium dahliae*.

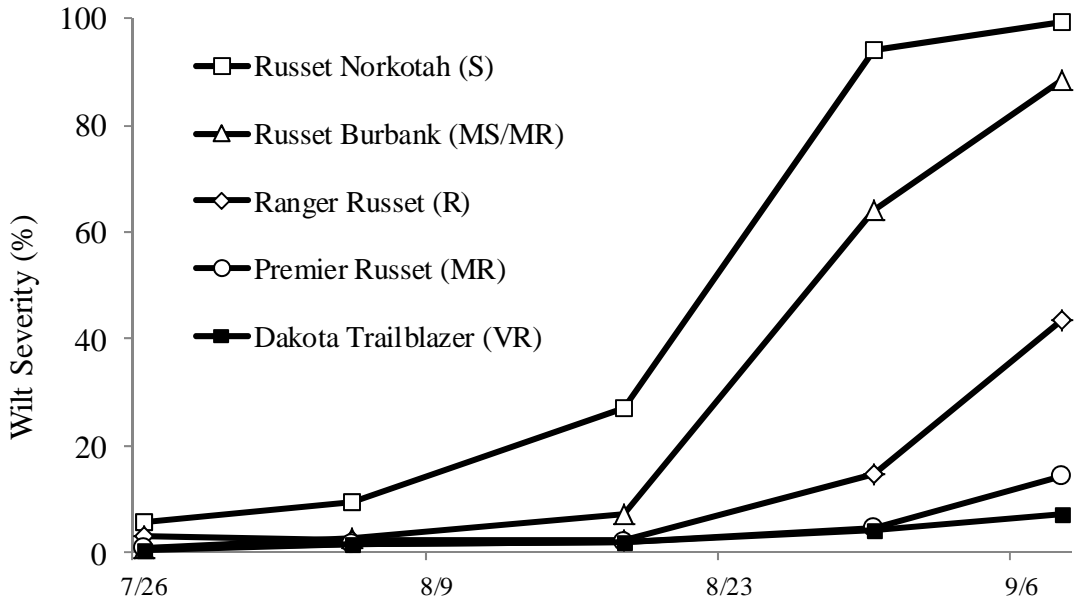


Figure 2. Verticillium wilt severity as measured across the growing season for five russet cultivars with varying levels of resistance to Verticillium wilt caused by *Verticillium dahliae*.

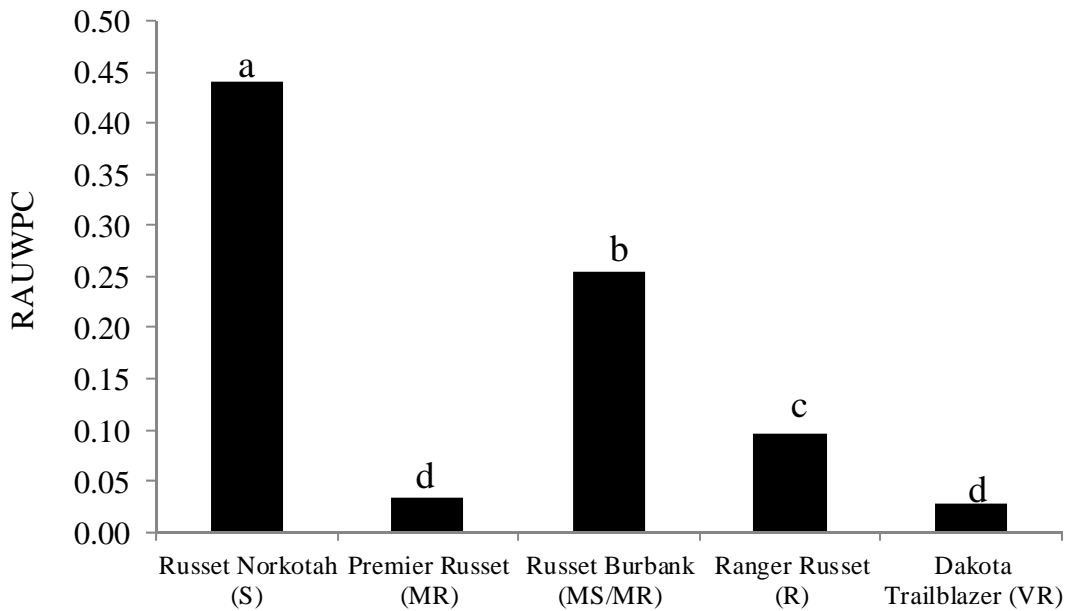


Figure 3. Verticillium wilt severity as measured by relative area under the wilt progress curve (RAUWPC) for five russet cultivars with varying levels of resistance to Verticillium wilt caused by *Verticillium dahliae*.