Foliage and Tuber Symptoms Caused by Current Season Infection by Potato Virus Y Strains in Different Potato Cultivars

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Introduction

Potato Virus Y (PVY) continues to be a serious disease problem during potato production. Initially causing only yield reduction, new strains have been identified that also cause external and internal defects in tubers. These quality issues can be substantial. Researchers have seen a range of symptoms (both on foliage and in and on tubers) being produced by the different strains in different cultivars. However, documenting the symptom variation is very difficult in the field due to natural spread of the virus by aphids. Only growth chamber and greenhouse tests have successfully helped begin to document these differences. Still, greenhouse and growth chamber tests likely do not fully replicate environmental conditions potato plants experience when planted in soil in a field situation.

Field trials were attempted during the early 2000's to determine yield and quality losses due to these PVY strains. In these trials different cultivars were exposed to different PVY strains but because the different PVY strains were also spread naturally throughout the trial by local populations of aphids, mixed infections resulted. Attempts to control the aphids, by both chemical means and by planting trap crops around the plot were also unsuccessful and did not allow the collection of useful data. The building of a large screen house at the Hermiston Agricultural Research and Extension Center (HAREC) early in 2008 has allowed the study of these strains in different cultivars without virus cross contamination.

The objectives of this study were: 1) Determine the foliar and tuber symptoms produced and yield loss by cultivar when 8 cultivars are individually infected with 6 isolates of PVY (two each of PVY^{O}, PVY^{NTN}, and $PVY^{N:O}$) and 2) Determine the overall susceptibility of the 8 potato cultivars to infection by the different PVY strains.

Methods

The following PVY strains/isolates were used both years; PVY^{O} (CO35 & T1), PVY^{NTN} (T3V2 & OR0363), and $PVY^{N:O}$ (AL1 & OR2). Eight cultivars were planted; Alturas, Russet Burbank, Russet Norkotah, Premier Russet, Ranger Russet, Yukon Gem, Yukon Gold, and Blazer Russet. Yukon Gem and Premier Russet were selected due to their reported resistance to PVY^{O}. Alturas was included because of internal tuber symptoms seen previously were thought to be due to $PVY^{N:O}$. Data on symptoms, yield, and quality were obtained.

Seven blocks of potatoes were planted in the screen house during 2008 and 2009. In each block 10 nuclear seed pieces (free of virus) of each of the 8 potato cultivars were planted in 2 rows (5 seed pieces/row, 12 inches apart) in the spring of both years. When plants are approximately 8-10 inches in height, the 80 plants in each block (except the control block), were inoculated with one of the 6 PVY strains. Inoculation consisted of spraying each of the plants with a mixture of virus in a buffer solution containing Carborundum using a hand held paint applicator with 30 lbs psi. The virus inoculum was produced in tobacco plants. One week later the inoculation

procedure was repeated. The control or non-infected block was sprayed with water containing Carborundum.

Four weeks after the second inoculation all plants were tested by ELISA to confirm infection. Selected plants within each block were further tested by RT-PCR to confirm the presence of the correct virus strain. ELISA testing was done two additional times, at approximately 1 month intervals, from plants previously testing negative. Foliage symptoms were recorded at least three times and photos taken to document symptoms produced by each virus strain on each cultivar.

The exterior of each block was fenced to prevent touching of plants between blocks (this prevented mechanical spread of the virus between blocks) and each cultivar within each block was fenced to help keep plants erect and allow for easier recording of symptoms. Normal fertility and watering was done typical of potato production in the region. Weeding was by hand and insect control was aggressively maintained to ensure the enclosure was insect-free. Plants were killed down in late August/mid September each year. Individual hills of all plants were harvested, yield determined, and tubers were individually observed for symptoms. Yield for each variety was determined based on when and if plants were infected.

Results

Since data between each year was similar, only foliar symptoms from 2009 are provided. Table 1 describes foliar symptoms produced by each virus strain in each of the cultivars. The different strains produced different foliar symptoms and similar strains of each virus did not consistently cause the same foliar symptoms in the same cultivar (See Photo Plate 1).

Internal tuber symptoms were seen primarily in response to infection by $PVY^{N:O}$ in Alturas, Yukon Gold and Ranger (Table 2 &3, See Photo Plate 2). The two isolates of PVY^{NTN} produced few tuber symptoms in the cultivars tested. Similar to what resulted from foliage observations, isolates of the same PVY strain did not produce the same tuber symptoms in the same cultivar (Table 2). One isolate of PVY^{O} (T1) produced considerable symptoms in tubers while the other (C035) cause very little.

Overall infection by the different PVY isolates in the different cultivars appeared to be different over the two years of testing (Figure 1). While all potato cultivars were exposed to very high levels of virus by mechanical inoculation, Premier and Yukon Gem had less infection (they are reported to be highly resistant and resistant to PVY^{O}, respectively) as did most of the other cultivars compared to Russet Norkotah that had 100 and 95% infection in 2008 and 2009 respectively. Overall, yield was impacted by PVY infection in each cultivar except Russet Norkotah (Figure 2). Mixed yield results due to infection were seen in Premier and Blazer over the two years of the study. Virus strains and isolates appeared to differ in their ability to infect potatoes (Figure 3). Highest infection overall in cultivars occurred by isolate OR2 (an $^{N:O}$ strain) while CO35, T1, and T3V2 had the lowest overall infection percentage. The overall rate of infection was less in the PVY^{O} strains primarily due to the use of two potato cultivars that are reported to be resistant (Yukon Gem and Premier). When compared by virus, all isolates negatively impacted yield (Figure 4).

Two cultivars (Russet Burbank and Yukon Gem) were selected in this report to show the kinds of infection and yield data obtained for each potato cultivar used during this trial. Russet Burbank infection neared 100% by all the PVY isolates used except T3V2 (Figure 5). Yield in Russet Burbank was nearly always substantially reduced, regardless of PVY isolate or strain

(Figure 6), oftentimes by 50% or more. Yukon Gem is reported to be resistant to PVY^{O}. Our data confirms that information but this same cultivar is readily infected by $PVY^{N:O}$ but not PVY^{NTN} strains, at least by the PVY strains tested during this work (Figure 7). There was no yield loss in Yukon Gem due to one isolate of PVY^{O} or PVY^{NTN} because none of the plants became infected (Figure 8). Compared to controls, yield loss was substantial in infected plants compared to healthy controls. Yukon Gem has significant tuber symptoms due to $PVY^{N:O}$ infections (Table 2).

Discussion

These trials provided a means to determine impacts of three PVY strains in 8 potato cultivars, in an environment that mimicked field conditions and provided a better understanding of the differences in symptoms produced by each PVY strain in each cultivar. From this work it was learned that PVY may or may not have caused similar foliar or tuber symptoms in each cultivar. In addition, each PVY strain did not always cause the same foliar or tuber symptom in the same cultivar. Therefore symptoms are not a reliable way to distinguish the strains (^{O}, $^{N:O}$,and ^{NTN}) or isolates of the same strain. Therefore the use of symptoms may not be readily used to identify PVY strain and that further testing using ELISA and/or PCR is necessary.

Data gathered during this trial also confirmed that PVY, regardless of strain, can impact yield. Some cultivars seem to be less impacted by specific PVY strains then others. Ability of some of the PVY strains used in this trial to infect plants also appeared to be different.

The risk of reduced yields by PVY^{O} has been clearly indentified in past studies, primarily from seedborne infection. Yield loss from current season infection is not as well understood. The result of current season infection was identified during this work, not only related to yield loss but the identification of foliar symptoms by strains other than PVY^{O}. Additional loss due to tuber symptoms caused by some strains of PVY was also identified. Tuber symptoms were not limited to PVY^{NTN} or $^{N:O}$ strains since one of the PVY^{O} isolates used in this study (T1) also produced tuber symptoms.

Table 1. Foliar symptoms (2009) in eight potato cultivars growing in a screen house following inoculation with 6 isolates and 3 strains (^{O},$^{N:O}$, and ^{NTN}) of PVY.

Virus Treatment	Cultivar Name	Foliar Symptoms
Control	Premier	NS = no symptoms[1]
T3V2 (NTN)	Premier	Mild Yellowing
C035 (O)	Premier	NS
AL1 (N:O)	Premier	Mild yellowing, mild vein clearing
OR0363 (NTN)	Premier	Mild mosaic, leaf pebbling, shiny leaves
T1 (O)	Premier	Mild yellowing to NS
OR2 (N:O)	Premier	Mild to pronounced mosaic, vein clearing, stunted leaves, leaf pebbling
Control	Alturas	NS
T3V2 (NTN)	Alturas	Wavy leaf margins, stunted leaves, mild mosaic, pebbling, vein burning
C035 (O)	Alturas	Mild Yellowing or NS
AL1 (N:O)	Alturas	Pronounced mosaic, leaf pebbling
OR0363 (NTN)	Alturas	Pronounced mosaic, sever leaf pebbling, leaf stunting
T1 (O)	Alturas	Mild yellowing
OR2 (N:O)	Alturas	NS
Control	Yukon Gem	NS
T3V2 (NTN)	Yukon Gem	NS
C035 (O)	Yukon Gem	NS
AL1 (N:O)	Yukon Gem	Mild yellowing, vein burning
OR0363 (NTN)	Yukon Gem	Leaf Yellowing
T1 (O)	Yukon Gem	Mild mosaic
OR2 (N:O)	Yukon Gem	Leaf yellowing, mild mosaic, mild pebbling
Control	Ranger	NS
T3V2 (NTN)	Ranger	Mild Yellowing
C035 (O)	Ranger	Vein Necrosis, leaf distortion, mild mosaic, mild vein clearing
AL1 (N:O)	Ranger	Pronounced mosaic, leaf pebbling, yellowing
OR0363 (NTN)	Ranger	Pronounced mosaic, leaf pebbling
T1 (O)	Ranger	Mild mosaic, yellowing, mild leaf distortion
OR2 (N:O)	Ranger	Mild mosaic, yellowing, mild vein clearing
Control	Burbank	NS
T3V2 (NTN)	Burbank	Mild Yellowing
C035 (O)	Burbank	Leaf pebbling, pronounced mosaic
AL1 (N:O)	Burbank	Leaf yellowing (spider mite damage)
OR0363 (NTN)	Burbank	Pronounced mosaic, wavy leaves, mild pebbling
T1 (O)	Burbank	Mild yellowing
OR2 (N:O)	Burbank	leaf yellowing, mild to pronounced mosaic, leaf pebbling

[1]NS= no symptoms seen in leaves due to virus infection

Table 1 Continued.

Control	Norkotah	NS[1]
T3V2 (NTN)	Norkotah	Mild Yellowing (symptoms masked by spider mite damage)
C035 (O)	Norkotah	Mild yellowing
AL1 (N:O)	Norkotah	Mild yellowing
OR0363 (NTN)	Norkotah	Mild mosaic, mild vein clearing
T1 (O)	Norkotah	Mild yellowing (major mite damage)
OR2 (N:O)	Norkotah	NS
Control	Yukon Gold	NS
T3V2 (NTN)	Yukon Gold	Mild Yellowing
C035 (O)	Yukon Gold	Mild leaf pebbling, mild yellowing
AL1 (N:O)	Yukon Gold	Mild Yellowing
OR0363 (NTN)	Yukon Gold	Mild mosaic, mild wavy leaves
T1 (O)	Yukon Gold	severe vein burning, vein necrosis, Mild yellowing (mite damage)
OR2 (N:O)	Yukon Gold	Pronounced mosaic, leaf cupping, yellowing
Control	Blazer	NS
T3V2 (NTN)	Blazer	Mild leaf pebbling, mild yellowing, mild vein clearing, leaf distortion
C035 (O)	Blazer	Mild yellowing, mild mosaic
AL1 (N:O)	Blazer	Mild Mosaic, vein clearing
OR0363 (NTN)	Blazer	Mild mosaic, mild vein clearing
T1 (O)	Blazer	Pronounced mosaic, sever leaf pebbling, wavy leaves
OR2 (N:O)	Blazer	Mild to pronounced mosaic, mild leaf pebbling

[1]NS= no symptoms seen in leaves due to virus infection

Table 2. Tuber symptoms (2009) in eight potato cultivars growing in a screen house following inoculation with 6 isolates and 3 strains (^{O}, $^{N:O}$, and ^{NTN}) of PVY.[1]

Virus Treatment	Cultivar Name	Tuber Symptoms (# tubers)	TOTAL TUBERS
Control	Premier	NS	62
Control	Alturas	NS	104
Control	Yukon Gem	NS	103
Control	Ranger	NS	102
Control	Burbank	NS	115
Control	Norkotah	NS	45
Control	Yukon Gold	NS	54
Control	Blazer	NS	53
T3V2 (NTN)	Premier	NS	57
T3V2 (NTN)	Alturas	RL (1), MSC (2), SN (1), A	134
T3V2 (NTN)	Yukon Gem	NS	110
T3V2 (NTN)	Ranger	MSC (2), A	95
T3V2 (NTN)	Burbank	MSC (1), A	102
T3V2 (NTN)	Norkotah	NS	44
T3V2 (NTN)	Yukon Gold	MRL (1), SN (2), A	38
T3V2 (NTN)	Blazer	NS	72
C035 (O)	Premier	NS	56
C035 (O)	Alturas	RL (2), MSC (3), A	84
C035 (O)	Yukon Gem	MSC (2)	129
C035 (O)	Ranger	RL (1), MSC (1), RLSE (3), A	89
C035 (O)	Burbank	MSC (4)	109
C035 (O)	Norkotah	NS	58
C035 (O)	Yukon Gold	NS	45
C035 (O)	Blazer	NS	58
AL1 (N:O)	Premier	NS	58
AL1 (N:O)	Alturas	RL (9), MSC (28), SSC (30), SN (27), SL (1), A, I	71
AL1 (N:O)	Yukon Gem	MRL (2), MSC (7), SN (7), A, I	96
AL1 (N:O)	Ranger	RL (8), MSC (59), SNSE (2), A	92
AL1 (N:O)	Burbank	NS	106
AL1 (N:O)	Norkotah	NS	62
AL1 (N:O)	Yukon Gold	RL (24), SN (39), SNSE (27), A, I	48
AL1 (N:O)	Blazer	NS	53

[1]RL = Raised lesions; MRL = mild raised lesions; RLSE = raised lesion stem end; MSC = Mild skin cracks; SSC = Severe skin cracking; SN = sunken necrotic lesion; SL = sunken lesion; SNSE = sunken necrotic stem end; A = internal symptoms associated. Numbers in parenthesis indicate the number of tubers with that symptom. Tubers could have more than one symptom.

Table 2. Continued

OR0363 (NTN)	Premier	NS	54
OR0363 (NTN)	Alturas	SN (1), A	113
OR0363 (NTN)	Yukon Gem	SNSE (4), A	102
OR0363 (NTN)	Ranger	RL (1), MSC (1), SN (1), A	84
OR0363 (NTN)	Burbank	NS	129
OR0363 (NTN)	Norkotah	NS	67
OR0363 (NTN)	Yukon Gold	RL (45),	47
OR0363 (NTN)	Blazer	NS	60
T1 (O)	Premier	NS	49
T1 (O)	Alturas	RL (28), MSC (4), SN (1), A, I	68
T1 (O)	Yukon Gem	RL (1), A	103
T1 (O)	Ranger	RL (43), MSC (21), A	82
T1 (O)	Burbank	NS	117
T1 (O)	Norkotah	NS	65
T1 (O)	Yukon Gold	RL (23), MSC (1), SSC (3), SN (12), A	50
T1 (O)	Blazer	NS	53
OR2 (N:O)	Premier	NS	57
OR2 (N:O)	Alturas	SSC (37), I	38
OR2 (N:O)	Yukon Gem	RL (9), MSC (4), SSC (22), SN (46), I	70
OR2 (N:O)	Ranger	RL (104), MSC (62), SSC (19), SN (93), A, I	128
OR2 (N:O)	Burbank	MSC (3), SN (2)	107
OR2 (N:O)	Norkotah	MSC (6), SN (2), A	45
OR2 (N:O)	Yukon Gold	RL (40), SN (42), A, I	42
OR2 (N:O)	Blazer	MSC (2), A	85

[1]RL = Raised lesions; MRL = mild raised lesions; RLSE = raised lesion stem end; MSC = Mild skin cracks; SSC = Severe skin cracking; SN = sunken necrotic lesion; SL = sunken lesion; SNSE = sunken necrotic stem end; A = internal symptoms associated. Numbers in parenthesis indicate the number of tubers with that symptom. Tubers could have more than one symptom.

Table 3. Summary of tubers with symptoms from each cultivar when infected with PVY strains, 2009.[1]

Virus	Cultivar							
	Premier Russet	Alturas	Yukon Gem	Ranger Russet	Russet Burbank	Russet Norkotah	Yukon Gold	Blazer Russet
Control	0	0	0	0	0	0	0	0
T3V2 (NTN)	0	1	0	1	1	0	1	0
OR0363 NTN)	0	1	1	1	0	0	96	0
CO35 (O)	0	1	1	1	1	0	0	0
T1 (O)	0	41	1	50	0	0	46	0
OR2 (N:O)	0	99	66	81	3	13	100	2
AL1 (N:O)	0	42	7	64	0	0	81	0

[1]Percent tubers infected

Figure 1. Overall infection in potato cultivars when inoculated individually with 3 strains and two isolates each of PVY^{O},$^{N:O}$, and ^{NTN}.

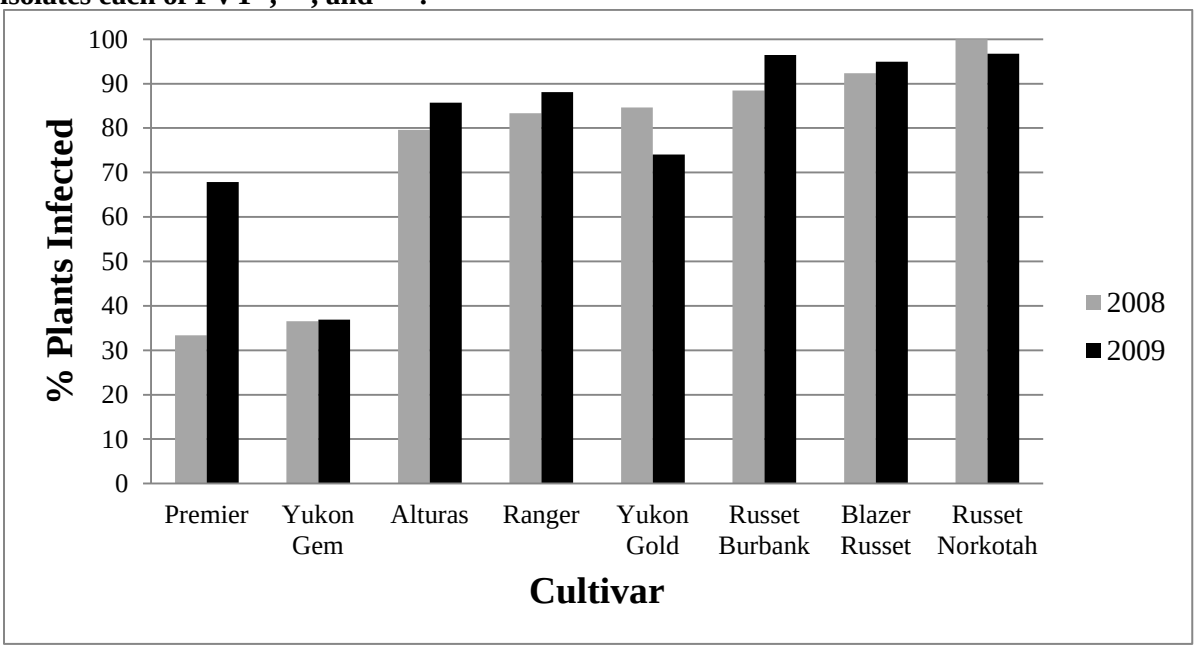

Figure 2. Overall yield of infected plants (+) by cultivar compare to healthy controls (-) inoculated with 3 strains and two isolates each of PVY^{O},$^{N:O}$, and ^{NTN}.

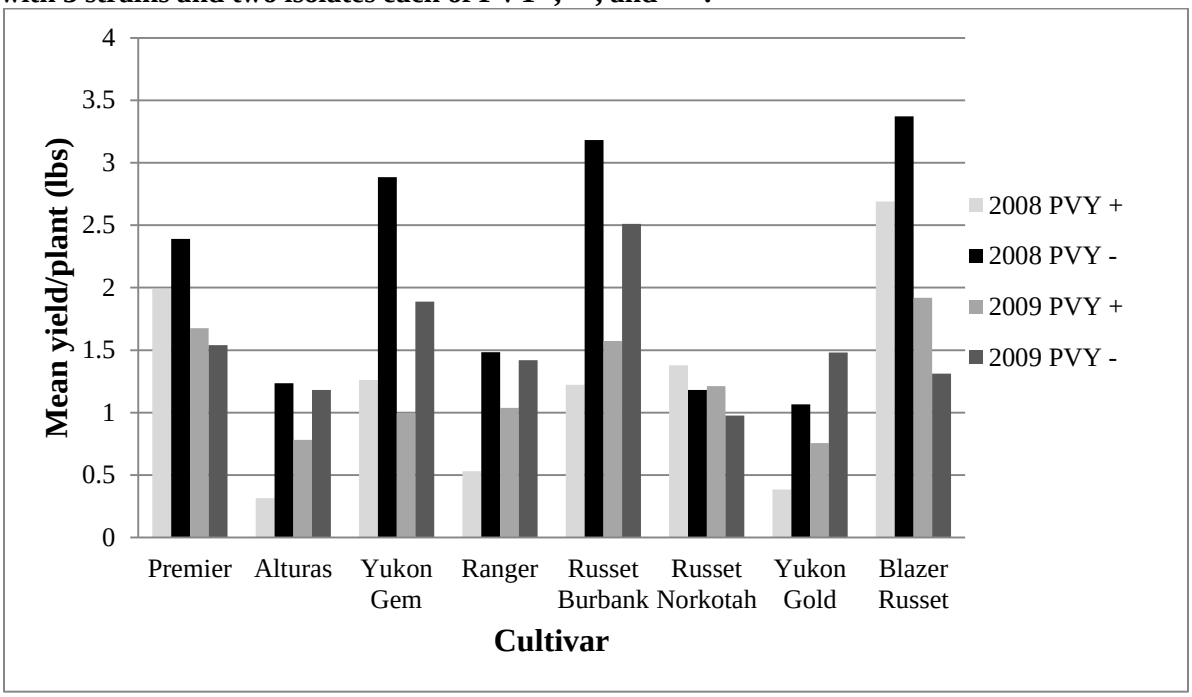

Figure 3. Overall "current season" infection by PVY strains and isolates in 8 cultivars of potato.

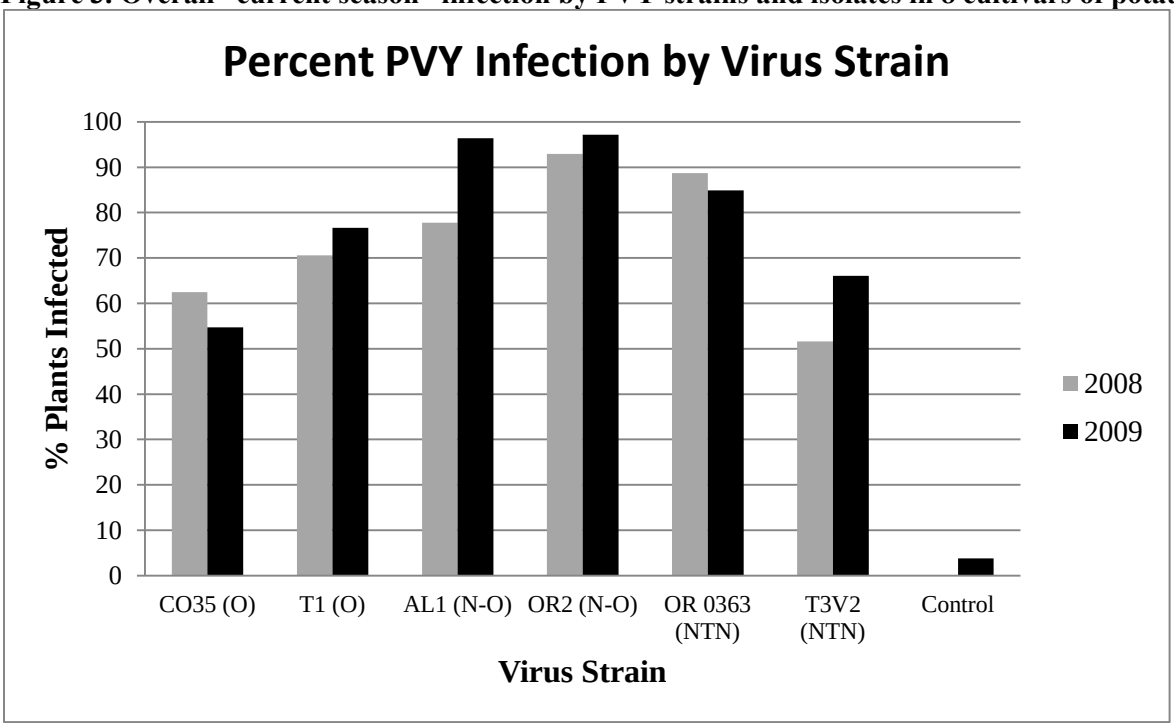

Figure 4. Overall yield from plants infected by six isolates of PVY (two each PVY^{O}, $^{N:O}$, and ^{NTN} compared to healthy plants (controls)

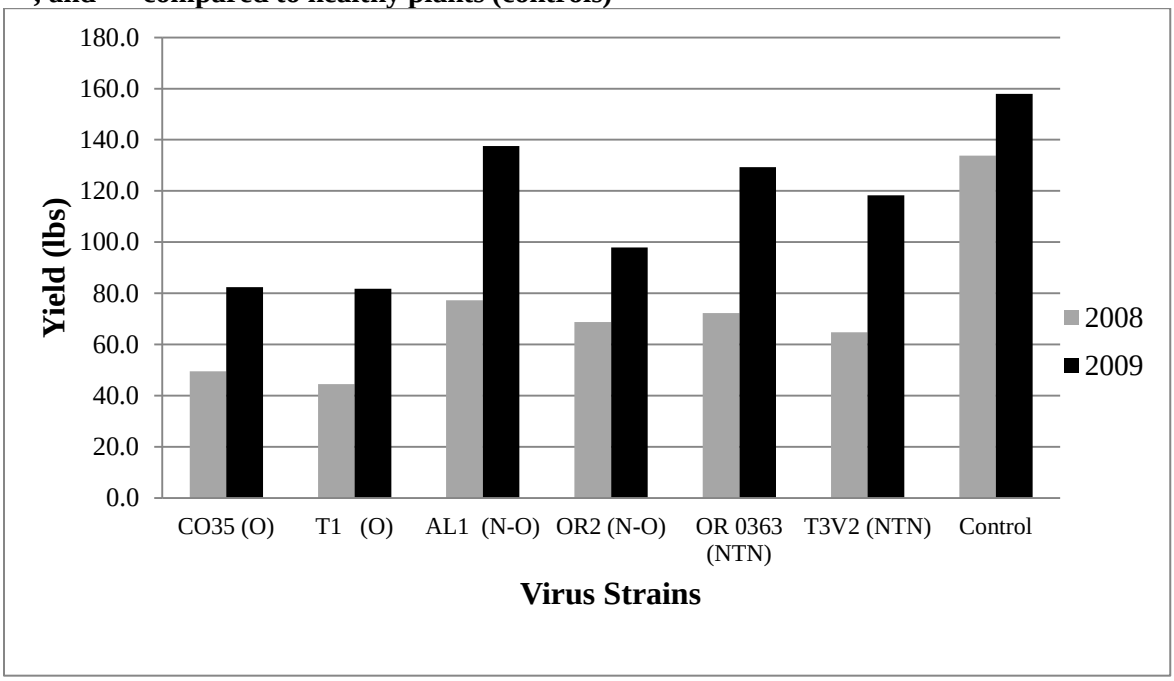

Figure 5.Infection by 6 PVY isolates and three strains in Russet Burbank.

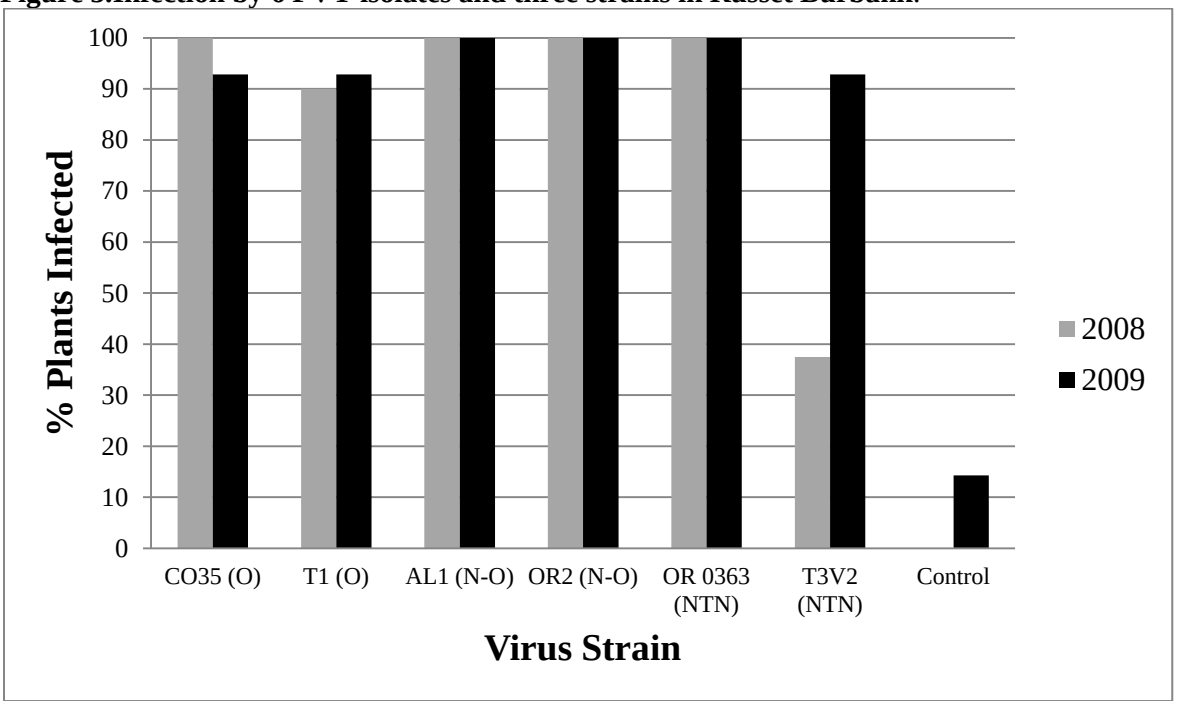

Figure 6. Yield of Russet Burbank following infection by 6 isolates (and 3 strains) of PVY.

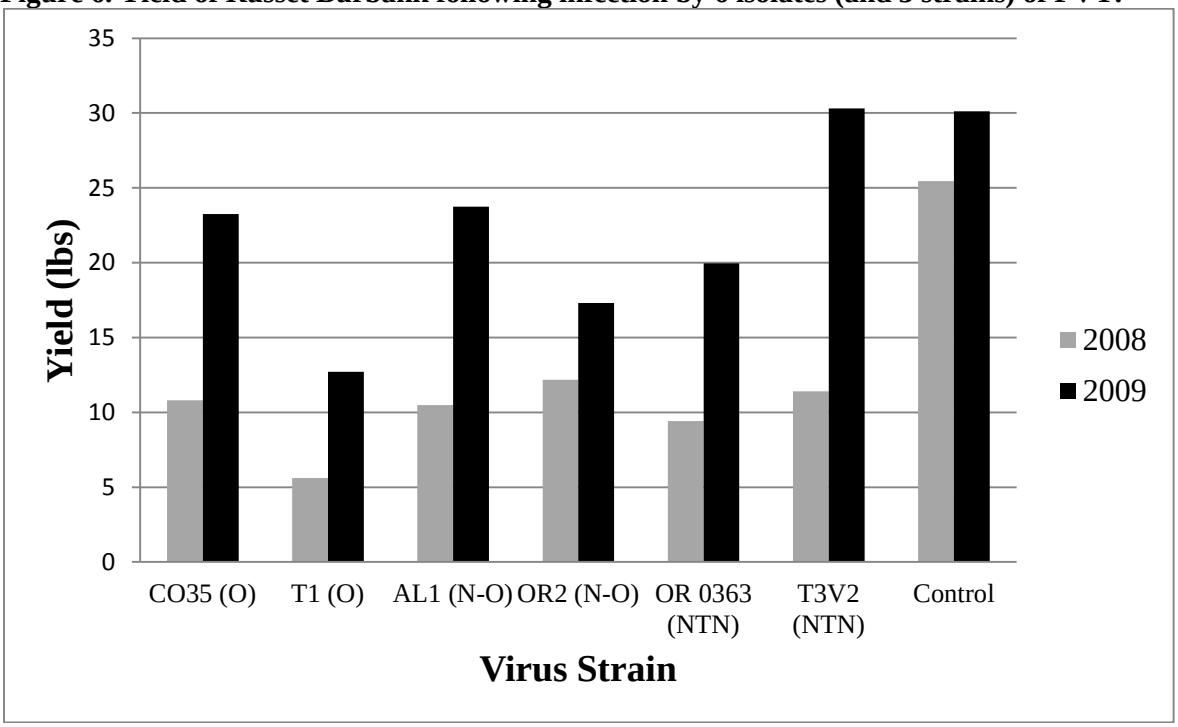

Figure 7. Infection by 6 isolates and 3 stains of PVY in Yukon Gem. No infection occurred in isolate CO35 or T3V2 either year.

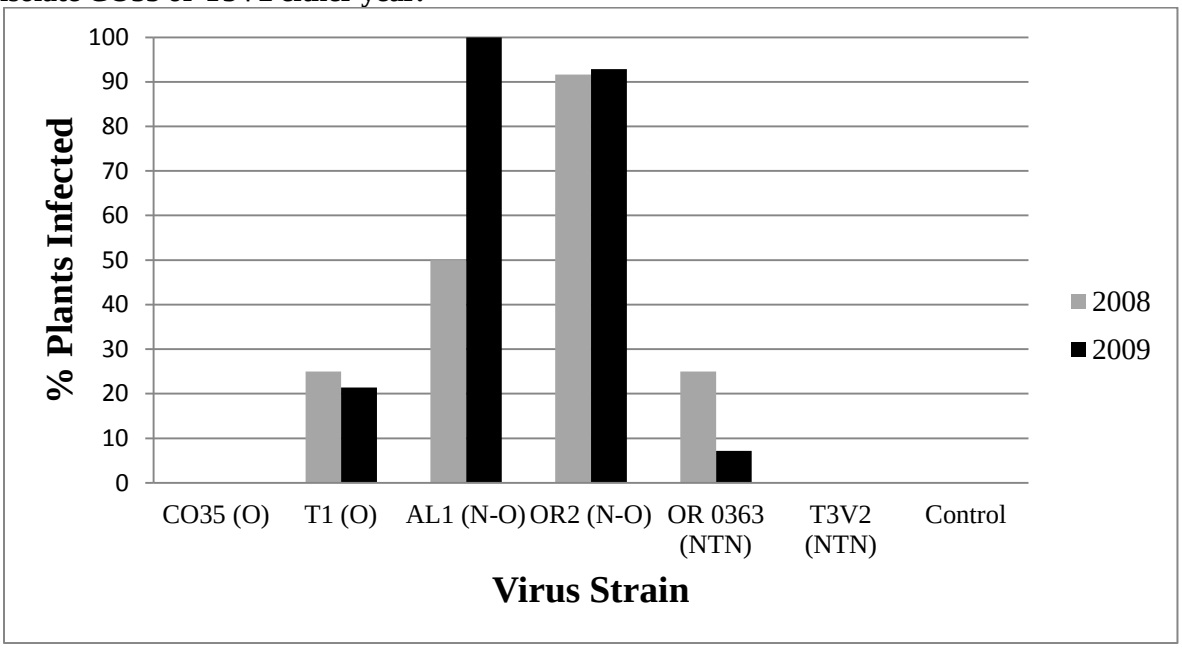

Figure 8. Yield of Yukon Gem following infection by 6 isolates (and 3 strains) of PVY compared to healthy controls. No infection occurred in isolate CO35 or T3V2 either year so no yield loss was seen.

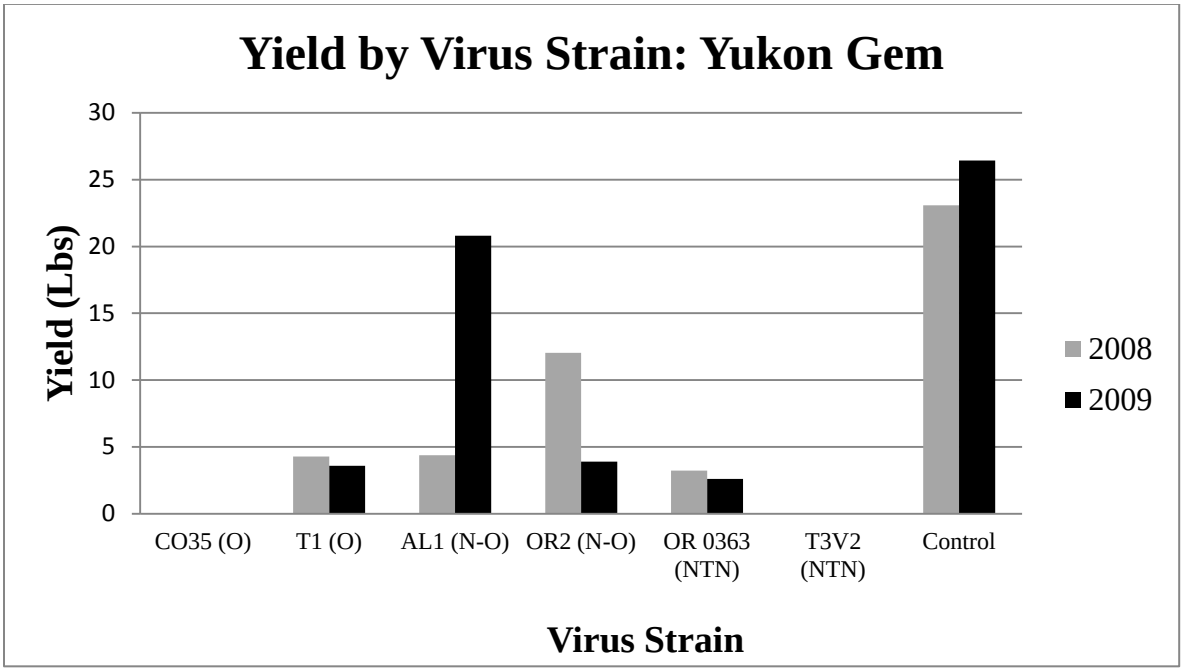

Photo Plate 1. Potato Virus Y^O (resulting from inoculations with the isolate T1) symptoms on four selected cultivars from screen house testing 2009. Photos taken on Aug 5, 2009. Notice the different symptoms produced by the same PVY^O isolate in the different cultivars. From top left clock wise: Yukon Gold (mosaic symptoms), Russet Norkotah (severe mosaic), Yukon Gem (Vein Burning), and Blazer Russet (Mosaic and "wavy leaf").

Photo Plate 2. Potato Virus $Y^{N:O}$ (resulting from inoculations with the isolate OR2) symptoms on four selected cultivars from screen house testing 2009. Notice the symptoms produced by this isolate in the different cultivars. From top left clockwise: Yukon Gold, Russet Ranger, Yukon Gem, and Alturas.