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BRIEF COMMUNICATION

Effect of Potato Virus Y on Yield of a Clonal Selection of Russet Norkotah

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Abstract Successful selections of Russet Norkotah lines have produced larger, more vigorous vines and higher yields than the standard Russet Norkotah (RN). Potato Virus Y (PVY), while producing mild or "latent" symptoms in this cultivar, has been shown to significantly reduce yields. To determine PVY's effect on yield of a RN selection, PVY infected RN and Russet Norkotah selection 3 (RN3) yields were compared after planting in Hermiston, Oregon in 2001, 2003, and 2006. After emergence, individual plants were ELISA tested for PVY multiple times during the growing season to confirm infection. Plants were categorized when infected; 1) current season, 2) seed borne or 3) "no PVY". At harvest, total and marketable yield data were collected. RN3 produced higher total yields than RN, regardless of infection categories. Highest yield reductions of RN and RN3 due to PVY were in the following order; seed borne PVY >>current season PVY >>no PVY.

Resumen Las selecciones exitosas de líneas de Russet NorKotah han producido follajes más grandes y vigorosos, y mayores rendimientos, que la Russet NorKotah (RN) convencional. El virus Y de la papa (PVY), mientras produce síntomas ligeros o "latentes" en esta variedad, se ha demostrado que reduce significativamente los rendimientos. A fin de determinar el efecto del PVY sobre el rendimiento de una selección de RN, se compararon los rendimientos entre RN infectada y una selección 3 de NorKotah (RN3), después de plantar en Hermiston, Oregon, en 2001, 2003 y 2006. Después de la emergencia se hicieron pruebas de ELISA para PVY muchas veces a plantas individuales durante el período de crecimiento para confirmar la infección. Cuando se infectaron, las plantas se categorizaron: 1) durante el crecimiento, 2) de la semilla, o 3) "no PVY". A la cosecha se tomaron datos de rendimiento total y comercial. RN3 produjo mayor rendimiento total que RN, independientemente de las categorías de infección. Las más altas reducciones en el rendimiento de RN y RN3 debido a PVY fueron en el siguiente orden; PVY proveniente de semilla >>PVY por infección de campo >>no PVY.

Keywords Clonal line selection · Current season virus · Seed borne virus · PVY

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Introduction

Potato virus Y (PVY) is the type member of the Potyvirus family. This group of viruses is distributed worldwide and PVY is an economically important virus in potato. Documented yield losses ranging up to 40% due to PVY have been reported (Hane and Hamm 1999; Nolte et al. 2004; Rykbost et al. 1999; Walkey 1991). The PVY^{O} or common strain typically causes a green and yellow mottle or mosaic pattern in infected foliage though the symptomatic expression in leaves can vary among cultivars. A mild "latent" infection has been observed in Russet Norkotah

Table 1 Planting, testing, and harvest dates of Russet Norkotah and Russet Norkotah Sel. 3 at Hermiston, Oregon

Year	Planted	ELISA tested		Harvested
		Early	Late	
2001	May 5	July 2	Aug. 21	Oct. 23
2003	May 1	June 5	Aug. 5	Oct. 10
2006	May 1	June 5	Aug. 2	Oct. 9

(RN), a fresh market cultivar released in 1987 (Draper et al. 2002; Henn et al. 2006; Johansen et al. 1988).

Russet Norkotah is planted widely across the U.S. and accounts for 13.5% of the total potato acreage planted in 2008 (NASS 2008). In 1989, improved RN line selection programs were initiated in Texas (Miller et al. 1999) and Colorado. The clonal selections that emerged from those efforts had increased vine vigor, some resistance to early dying (associated with *Verticillium dahliae*) and out-yielded the standard RN by 20–30%. The clonal line selections now account for 52% of all the RN planted for seed in 2008, up from 46% in 2003. Of the many line selections available as seed, RN selection 3 (RN3) is the most widely planted and accounts for 41% of the RN line selections planted for seed and 22% of the total RN seed acreage (PAA 2008).

Yield loss due to PVY has been documented in standard RN for both seed borne and current season infections, (Hane and Hamm 1999; Nolte et al. 2004; Rykbost et al. 1999; Walkey 1991). In addition, RN appears to be more likely to become infected by PVY during the season than in some other cultivars growing nearby (Hamm et al. 2010). However, the impact of PVY infection in RN clonal selections has not been studied where vines are more vigorous, stay green longer, and where yields are greater than standard RN. Rykbost et al. (1999) showed that 60–100% seed borne PVY in RN lead to yield reductions at three locations. A 40% reduction occurred at in the Columbia Basin (Hermiston, OR), while a 12% and 20% reduction occurred at Klamath Falls, OR and Tule Lake, CA locations, respectively. The Hermiston location is a high yielding production area while the Klamath and Tule Lake regions are higher elevation and have shorter growing seasons. Yield loss due to current season infection, while less than seed borne infection, has also been documented (Hane and Hamm 1999). A longer growing season would allow more time exposure to aphid-vectored PVY, particularly where RN clonal selections maintain a higher vigor over an extended exposure period. This aspect could not only impact yield in commercial fields but affect the production of virus free seed if vines were allowed to grow until natural vine death.

One objective of this study was to determine what impact PVY had on yield of a clonal line of RN as compared to RN. Of particular interest was to look at the time of infection (seedborne verses current season) and the subsequent impact on total and marketable yield. A second objective was to determine if the amount of current season infection (susceptibility) differed between RN and a RN clonal selection.

Materials and Methods

One seed lot each of RN and Russet Norkotah, Colorado selection 3 (RN3) were obtained from certified seed lots that exceeded allowable PVY levels for certification in the Idaho seed system in 2001, 2003, and 2006. Seed lots were sent to the Hermiston Agricultural Research and Extension Center, Hermiston OR, for yield trials. In 2001, all seed used was generation 4 (fifth field generation), while all seed used in 2003 and 2006 was generation 3.

The plots each year consisted of a randomized block design with four replications, each containing 50 plants in 2001 and 2003 and 100 plants in 2006. Each replication consisted of a border row of Russet Burbank, followed by a

Table 2 Yield and grade of Russet Norkotah lines infected with PVY in g per plant

Yield	Russet Norkotah (Standard)			Russet Norkotah Selection 3		
	2001	2003	2006	2001	2003	2006
Total						
ANOVA sig.	*	ns	*	*	*	**
NoY[a]	2369a[b]	1878	3582a	5295a	2773a	–[c]
CS	2546a	1556	2094a	4120a	2173a	2454a
SB	1364b	826	1105b	2037b	1423b	1210b
Marketable (113–283 g)						
ANOVA sig.	ns	ns	ns	ns	ns	*
NoY	1056	999	1083	684	956	–
CS	913	840	843	469	870	877a
SB	582	528	481	629	637	395b

[a] NoY-PVY free, negative ELISA test; CS-current season PVY infection; SB-seed borne PVY infection

[b] Numbers followed by the same letter within a column and yield category are not significantly different at *$p \leq 0.05$. ns-not significant

[c] "NoY" plant numbers were insufficient for analysis

Table 3 Average tuber size (individual tuber weight) and number of tubers per hill in Russet Norkotah lines infected with PVY

Total	Russet Norkotah (standard)						Russet Norkotah Selection 3					
	2001		2003		2006		2001		2003		2006	
	Grams	No.	Grams	No.	Grams	No.	Grams	No.	Grams	No.	Grams	No.
NoY[a]	193.3	13.0a[b]	204.4	10.0	190.8	20.0	331.0	17.6	253.8	11.6a	–	–
CS	226.7	12.3a	156.7	10.3	170.6	12.8	401.4	11.5	193.1	11.8a	226.8a	11.4
SB	184.0	7.9b	114.9	7.0	142.7	8.4	270.0	9.2	173.3	8.9b	128.0b	9.5
ANOVA	ns	*	ns	ns	ns	ns	ns	ns	ns	*	**	ns

[a] NoY-PVY free, negative ELISA test; CS-current season PVY infection; SB-seed borne PVY infection

[b] Numbers followed by the same letter within a column and yield category are not significantly different at *$p \leq 0.05$, **$p \leq 0.01$. ns-not significant

random assignment of either a RN3 or RN followed again by a border row of Russet Burbank. The plot area was fumigated each year with 374 l/ha of metam sodium the fall prior to planting to reduce yield variability due to *Verticillium dahliae*. Seed pieces were cut (70.9–92.1 g) the day prior to planting and treated with Fludioxonil and Mancozeb (Maxim MZ®, Syngenta) at 5.2 ml/kg. Plant spacing within rows was 30.5 cm and between rows 86.4 cm. Plots were planted in early May and imidacloprid (Admire®, Bayer CropScience) was applied at planting at an in furrow rate of 1.5 l/ha. Best management practices were also utilized each year for fertility, herbicides, fungicides and irrigation decisions. At full emergence all plants were individually staked and numbered and tested by ELISA for PVY using a polyclonal antiserum produced by Bill Daugherty, Oregon State University, Corvallis, OR (diluted 1:1000). Samples were tested in duplicate wells and absorbance readings (A_{405}) were taken 1 h to 2 h after substrate was added. ELISA detection of virus was only for PVY and was not strain specific. All plants that tested negative at the first sampling (full emergence) were again sampled and tested later in the season. Table 1 identifies planting, testing, and harvest dates. Individual hills were harvested and tubers were separated into infection categories based on when PVY infection was confirmed; seedborne (SB), current season (CS), or "no PVY detected" (NoY). Infection categories were determined based upon the following; SB = ELISA positive at first sampling date; CS = ELISA negative at first sampling date but positive later; NoY = ELISA negative at all sampling dates. PVY susceptibility was measured by the percentage of plants infected during the growing season (i.e. current-season infection). Up to ten plants of each infection category were harvested, tuber numbers counted, and total and marketable (113–283 g) yield were determined as shown in Table 2.

Yields were compared within each RN selection and within each year based upon the time of infection. Analysis of variance was conducted using JMP software (JMP 2006) with the model using a weighted average for yield based on the number of plants in each infection means category. Sample sizes were based on PVY infection determined after emergence. When the ANOVA was significant, Tukey's HSD tests were used to separate time of infection means. A student's T test was used in 2006 where there were only two categories to compare due to insufficient sample numbers for the NoY treatment. This same method was used to compare the tuber size and number of tubers per hill in Table 3.

Results

Total and marketable yields from SB infected plants were numerically lower than for CS infected or uninfected plants in all years except for marketable yield in RN3 in 2001 (Table 2). Plants infected during the season (current season) had no effect on total or marketable yield, regardless of RN selection. Regardless of statistical significance, a comparison of RN and RN3 total yields were higher in all years, except 2001, in the following order; NoY>>current-season>>seed-borne.

When average tuber weight and numbers were examined, RN and RN3 always showed a lower average tuber weight and tuber number per hill due to seed borne infections; significantly so in 2001 and 2006 (Table 3).

Table 4 Percent of current season infection in Russet Norkotah (RN) vs. Russet Norkotah 3 (RN3)

Year	% plants infected with PVY		
	RN	RN3	Difference in % plants infected
2001	48.9 a[a]	76.3 b	27.4
2003	50.6 ns	43.0 ns	–7.6
2006	73.3 ns	86.2 ns	12.9

[a] Numbers followed by the same letter within a row are not significantly different at *$p \leq 0.05$, ns-not significant

Current season infection resulted in no significant reduction in tuber size or numbers compared to "NoY".

Susceptibility, measured by percent of RN verses RN3 plants becoming infected during the season, indicated that RN3 was more susceptible (had higher percent current-season plants) during two of three years, but only significantly higher in 2001 (Table 4).

Discussion

Based on the information reported here, RN3 may be more prone to PVY infection compared to RN. Current season infection was numerically higher in RN3 in two of three years, and significantly higher in 2001. This situation is expected given the extended time vines are green and vigorous compared to RN and the greater likelihood of exposure to alate aphids late in the season. Miller et al. (2004) showed that RN3's had an average plant height of 65.0 cm compared to RN height of 61.0 cm, 68 days after planting. Texas selections of RN also show a later maturity rating when compared to the standard RN (Miller et al. 1999). In Springlake, TX, a commercial growing area with a similar number of growing days compared to Hermiston, OR, the maturity rating for standard RN was 4.0 and the average for 13 RN selections was 2.9 (scale 1=very late, 5=very early). Crosslin et al. (2006) further suggests that RN3 are more likely to be infected with PVY than RN. RN3 seed lots tested over 2 years were infected with detectible levels of PVY^{O}; 71.9% (n=32) of the RN3 seed lots had PVY^{O} compared to only 27.7% (n=83) of the standard RN lots. They recorded only seed borne infection; however, given the comprehensive survey of so many RN seed lots in their study, from many states with varying environmental conditions, the logical conclusion suggests that more current season PVY infection occurred during the seed growing year in RN3 than RN.

While a direct comparison of yields between RN and RN3 cannot be made in this study due to different seed sources and cultural practices during the seed production year, yield reduction in RN3 is subject to PVY as is RN. Higher susceptibility to PVY in RN3 and the subsequent yield loss due to PVY is more than likely offset by a higher yield of RN3 over the standard RN (Miller et al. 1999, 2004).

Yield losses measured in this study are not likely due to any other potato virus. All seed lots in the Idaho system originate from tissue culture stock that is PVX tested and held to a zero tolerance level for certification. The first three field generations are also PVX tested resulting in none to very low PVX levels in the seed stocks.

When determining yield reduction due to PVY, the general pattern is that the longer the plant is infected with PVY, the lower the yield. This was evident in this study in total yield where significant differences exist between seed-borne and current-season in two of the three years for RN and in all three years for RN3. Where significance reductions in total yield occur, there were concurrent reductions in average grams per tuber and lower average tuber number in both RN and RN3 (Table 3). This trend of yield reduction and reductions in tuber size and number also holds true even when differences are not significant. While yields may be higher with RN3's, even when PVY infected, the amount of PVY inoculum in an area may increase due to higher susceptibility of RN3. Increased PVY inoculum can present problems in seed production areas where other cultivars that are not as tolerant to PVY yield loss are grown in close proximity.

Yields due to PVY were reduced in RN and RN3, however overall higher yields consistently resulted in RN3 compared to RN, regardless of PVY infection. Given the yield reductions reported in RN due to PVY infection (Hane and Hamm 1999; Nolte et al. 2004; Rykbost et al. 1999; Walkey 1991) growing RN3 would seem more appropriate in areas where high levels of PVY can occur such as in a long season commercial production area.

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