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Controlling PVY in Seed: What Works and What Does Not

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Abstract Potato Virus Y (PVY) has again emerged as one of the primary pests of potatoes in North America. While difficult to manage, the PVY complex has taken on a whole new level of importance with the recent emergence of the PVY^N and $PVY^{N:O}$ strains along with the PVY^O strains. Additionally, several cultivars have been released and are widely grown which express symptoms to PVY in a latent manner and show increased transmission of the virus into seed stocks. Certification schemes have long been utilized to control virus diseases. Under the current situation, however, programs have been struggling to get a handle on this problem. Specific strategies to manage this disease include the use of strict disease tolerances, roguing of infected plants, production practices such as field and/or lot isolation, manipulation of planting and killing dates, timely insecticide applications and border cropping, as well as, cultivar resistance. Use of limited generation greenhouse material has demonstrated minimal effectiveness in keeping PVY infections low within 1 to 2 years of initial field growth. Roguing has not been effective in reducing the population of PVY infected plants in latent cultivars such as Russet Norkotah. Aphid control has been largely ineffective in stopping late season infections. Planting and killing date manipulation has demonstrated some effect in controlling spread as have isolation of seed lots from infected stocks and growth of resistant cultivars. Utilizing strict tolerances has not been effective in controlling spread of PVY, especially for re-certification, but has allowed growers to maintain reasonable levels of PVY in seed stocks utilized for commercial production.

Resumen El virus Y de la papa (PVY) ha emergido nuevamente como una de las enfermedades primarias de papa en Norteamérica. Mientras que es difícil su manejo, el complejo PVY ha tomado un nuevo y completo nivel de importancia con la reciente aparición de las variantes PVY^N y $PVY^{N:O}$ junto con las de PVY^O. Además, varias variedades se han liberado y es ampliamente conocido que expresan los síntomas de PVY de manera latente y muestran aumento en la transmisión del virus al interior de lotes de semilla. Los esquemas de certificación se han utilizado por largo tiempo para controlar enfermedades virales. Ante la situación actual, no obstante, los programas han estado batallando para manejar este problema. Las estrategias específicas para manejar esta enfermedad incluyen el uso de tolerancias estrictas de la enfermedad, aclareo o eliminación de plantas infectadas, prácticas de producción como aislamiento de campos y lotes, manipulación de fechas de siembra y de quema de follaje, aplicaciones oportunas de insecticidas y cultivos de bordo, así como resistencia en las variedades. El uso de generaciones limitadas de material de invernadero ha demostrado efectividad mínima respecto al mantenimiento bajo de las infecciones por PVY dentro de uno o dos años de cultivo inicial en el campo. La eliminación de plantas enfermas en el campo no ha sido efectiva en la reducción de la población de plantas infectadas por PVY en variedades latentes como Russet Norkotah. El control de áfidos ha sido inefectivo por largo tiempo para detener las infecciones tardías. La manipulación de fechas de siembra y quema de follaje ha mostrado algún efecto en el control de la dispersión, así como el aislamiento de lotes de semilla respecto a lotes infectados y la siembra

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de variedades resistentes. La utilización de tolerancias estrictas no ha sido efectiva en el control de la dispersión de PVY, especialmente para re-certificación, pero ha permitido a los productores el mantenimiento de niveles razonables de PVY en lotes de semilla usados para la producción comercial.

Keywords PVY control · Certification

Introduction

Potato certification programs throughout North America have been the first line of defense in the management of virus diseases in the potato crop for decades. Through the use of many key certification principles, seed lots have annually been identified which contain levels of seed borne diseases that will not have a significant impact on production of commercial or seed potatoes the following season (Bohl and Johnson 2010). These principles include the use of : 1) a limited generation program which keeps seed lots in the certification program for only a set number of years, 2) tissue-culture stocks as the origin of all certified seed potatoes, 3) disease testing at key stages of the certification cycle to help manage various disease issues, 4) comprehensive lot inspections during the season and in storage by well trained certification personnel, 5) stringent disease tolerances for each class of seed, and 6) accurate and accessible records of individual seed lot histories (Knutson 1998; Sather et al. 2012)

Virus diseases have long been a primary focus of the certification effort in potatoes and for many years, the various potato viruses were kept at low levels. Recently, *Potato Virus Y* (PVY) has made a major resurgence as the single most problematic virus in seed potatoes across North America (Davidson, personal communication with U.S and Canadian certification officials during PAA Certification Section Annual meeting). This resurgence has been fueled by the growth of several cultivars which exhibit latent symptoms or transient symptoms (plants which express visual symptoms only at certain times of the season based upon environmental factors, level of nitrogen in the crop, or decrease in virus titer as the season progresses). These cultivars include Russet Norkotah and Russet Norkotah Selections, Silverton Russet, Shepody and Gemstar Russet to name just a few (McMorran 2012). For example, since its release in 1987 (Johansen et al. 1988), Russet Norkotah has been widely grown in the western U.S. and Canada. This cultivar has been problematic at best since its reaction to PVY is so subtle, and it often has latent or transient symptom expression. In 2011, 5866 ha of this cultivar were produced in the U.S. certification programs (Davidson 2011). However, because of its PVY reaction, many certification programs were overwhelmed by creating a situation where it was difficult to visually recognize virus infection in seed lots without costly lab testing procedures. Even though difficult to recognize, the effects of PVY are still real and often show reduction in tuber numbers and overall per plant yield (Hane and Hamm 1999; Whitworth et al. 2010). Additionally, these infected stocks are typically not recognized as infected by either certification officials or the growers, act as a reservoir for PVY and provide the inoculum for rapid aphid transmission of the virus to previously non-infected stocks. Many of the cultivars grown in the last two decades and into the present are quite susceptible to PVY infection and have proven difficult to keep virus levels low during the late season. This, in turn, resulted in the rejections of many seed lots from certification systems which had previously been relatively easy to manage.

Management Options

Cultivar selection can be a critical component in the control of PVY. Cultivars which demonstrate some resistance to PVY can be managed effectively in most regions and maintain their certification status. However, knowledge of each cultivar's reaction to PVY and the various strains of PVY is critical. A comparison of non-Russet Norkotah cultivars with Russet Norkotah in Colorado's seed program is very informative. Table 1 demonstrates 1 year of the certification program results for Colorado's acreage. The information in the table is a compilation of the mosaic readings from the post harvest testing of all of the lots which passed the summer visual field inspections at the < or equal to 2% mosaic level. The table shows the percent of lots which fell into each mosaic category. It clearly shows that Russet Norkotah lots demonstrated significantly higher levels of virus when compared with non-Russet Norkotah lots in the post harvest test. However, at the post harvest test over 87% of the non-Russet Norkotah lots maintained their levels of mosaic within the 2% range while only 30% of the Russet Norkotah lots fared that well. This situation held true even up to the 10% mosaic range where 98% of the non-Russet Norkotah lots fell within the 10% mosaic or less category while only 93% of the Russet Norkotah lots met this

Table 1 Mosaic comparisons by cultivar from the Colorado certified seed potato program

	Inspection readings (percentage of lots within each category)			
	Summer field	Post harvest test		
	< 2%	<2%	<4%	<10%
Non-Russet Norkotah	100.0	87.4	92.7	98.0
Russet Norkotah	100.0	30.1	55.4	92.9

Compilation of 576 lots with Russet Norkotah representing approximately 45% of the total seed produced condition. This is a clear indication that PVY can move readily into certain cultivars and, conversely, remain at relatively low levels in others. Thus, cultivar selection is an important component in management of PVY infection.

Research conducted in Colorado indicates that PVY expression in field grown Russet Norkotah is often transient or latent and will not express during the portion of the growing season that is appropriate for roguing infected plants. Ten and eight lots were tested for symptom development during the season in 2 years. Each lot was derived from a post harvest test sample from the previous year's crop. Tubers were planted and handled under normal production practices for potatoes grown in Colorado. Every emergent plant within each lot was tested for PVY at about 15 cm tall and infected plants were staked and visually observed for mosaic symptoms during the season. All field "visually" observed mosaic plants were confirmed as PVY positive by ELISA at the time of observation. Visual readings were taken within each lot at 48 to 55 days after planting (DAP), 59 to 61 DAP, 66 to 79 DAP and 86 DAP. Table 2 indicates how the lots performed in terms of ELISA testing versus visual readings. It is apparent that many PVY infected plants did not visually express until well after effective roguing could take place. Typically, effective roguing can take place up to 70 DAP and then tuber size and vine closure in the rows makes roguing difficult to ineffective. In the first year of testing, the range of visual expression at 59 days after planting was from 45 to 98%. In the second year of testing, the range of visual expression at 61 days after planting was between 42% and 88%. In the first year, at 86 DAP, there were still 2–30% of the plants in the lots visually expressing at that time, well after effective roguing could take place. In both years, this left a good percentage of the plants which either expressed quite late into the season or never showed a visual expression during the season. This tendency to express late symptoms or latent symptoms provides a base of inoculum which is available in the later season, ready for the time when aphid vectors are typically at their highest levels.

Another research project conducted in Colorado examined the effectiveness of roguing Russet Norkotah Selection

Table 2 Lot by lot comparative screening for the presence of PVY based upon ELISA and visual readings during 2 years of testing in the San Luis Valley, Colorado

Cultivar[1]	ELISA (# plants +/Total # tested)	Visual[3] (days after planting coupled with percentage of plants + for PVY after each interval)						Percent + visually at end of season
Yr 1		48	59	%	79	%	86	%
RNK223	10/400	4	1	50	2	70	3	100
RNK8	9/237	0	8	89	0	89	1	100
RNK278	11/94	3	2	45	6	100	NT[2]	100
RNK 296	14/349	9	1	71	3	93	1	100
RNK112	48/373	31	12	90	2	94	3	100
RNK223	18/194	9	5	78	3	94	1	100
RNK296	21/199	12	2	67	4	86	1	90
RNK112	4/100	2	0	50	1	75	1	100
RNK112	22/97	21	0	95	0	95	1	100
Gem Star	51/99	46	4	98	0	98	1	100
Yr 2		55	61	%	66	%	NT	%
RNK8	16/295	7	4	69	5	100		100
RNK3	17/346	2	10	71	5	100		100
RNK223	82/322	28	41	84	13	100		100
RNK112	36/308	11	16	75	9	100		100
RNK3	22/360	5	13	82	4	100		100
RNK3	12/236	5	0	42	7	100		100
RNK296	16/302	14	0	88	2	100		100
RNK8	30/303	21	0	70	9	100		100

[1] *RNK* Russet Norkotah with Selection designation following; Gem Star Russet

[2] *NT* Not tested

[3] Plants were scored as visual positives for mosaic at each time interval with only new plants being added after the initial readings. For example in year 1, RNK223, 10 plants out of 400 were found ELISA (+) for PVY. At 48 DAP 4 plants were visually (+). At 59 DAP another 1 was (+) resulting in 5 out of 10 with visual symptoms for a 50% rating. At 79 DAP another 2 were (+) for 7 out of 10 or 70%. At 86 DAP a final 3 were (+) representing 10 out of 10 scored positive with ELISA and visually in the field or 100%.

8 during the season. Two grower farms were utilized with six plots of 250 plants each established from the edge to the middle of each field. One set of three plots (replications) was a control which was un-rogued while the other set of three plots was rogued during the season. Each of the plots was screened visually for mosaic plants three times during the season and the final result calculated. On the rogued plots, plants with visual mosaic symptoms were removed three times during the time of normal roguing. Additionally, all remaining plants were numbered within those plots and had leaves picked twice during the season (once at 15 cm tall and a second at row closure) which were tested with ELISA for the presence of PVY. All positive plants based upon ELISA results were also removed, whether or not they had visual symptoms. Prior to harvest, 200 tubers representative of 200 different plants within the plots, were taken and grown out in a post harvest test plot in Hawaii. Visual readings were taken for mosaic at the time of optimum expression in the post harvest plots. Table 3 indicates the results of this project with results combined since statistical analysis using a standard ANOVA indicated that there were no significant differences in the mosaic readings between the plots. It is apparent that roguing of infected plants does not appear to be effective in reducing the overall mosaic levels in either lot. In fact, in Grower B's field, roguing actually appeared to increase the level of mosaic, most likely through current season spread during the roguing operation and vector transmission during the season. This has been verified repeatedly over time in many Russet Norkotah fields in the San Luis Valley. It is interesting to note that similar levels of PVY were present in the rogued and un-rogued portions of each field, representative of the field level of mosaic seen during the season. It is apparent that roguing certain cultivars will change the current visual readings, but may not have much effect on the final, end inoculum level for the lot.

Controlling aphid vectors that spread PVY is difficult at best. There has been varying successes utilizing border crops, different field configurations to help isolate earliest generation material, crop oils, etc. (Radcliffe and Ragsdale 2002). However, because of the rapid spread of this non-circulative, stylet borne virus by numerous aphid species, these practices have had limited impact. It is of note that there have been numerous growers utilizing a spatial approach to planting where the most susceptible cultivars or early generations of susceptible cultivars are planted within the field, away from the borders and inside of more non-susceptible type cultivars. In Colorado, this has shown excellent success with smaller lots, but tends to decrease in effectiveness as lots increase in size. Other growers have utilized isolated fields removed from the major production areas to produce susceptible cultivars. Again, this has had some good success under Colorado conditions, but is not always the solution. Additionally, use of planting date manipulation, that is early planting and early vine kill to avoid the times of the season when aphid vector numbers are highest, can work under ideal conditions, but is more limited if there are high numbers of non-potato type aphids which can spread PVY, even with lower transmission rates. For example, in the San Luis Valley, Green Peach Aphid and Potato Aphid populations rarely peak prior to the first or second week of August, but miscellaneous aphids often peak by the last 2 weeks of July. If they are PVY vectors, this does not really allow a grower the opportunity to kill vines and have appropriate tuber size by this time of the season. However, several growers in Colorado have stuck by this approach and have had some notable successes in keeping PVY levels down even in cultivars such as Russet Norkotah.

Table 3 Roguing effectiveness at two grower farms raising Russet Norkotah Selection 8 in the San Luis Valley, Colorado

Grower	Treatment	Percentage of plants with visual mosaic symptoms	
		Field Inspection	Post Harvest
A	Un-rogued	22.00	25.30
	Rogued	0.00	19.90
B	Un-rogued	3.50	10.00
	Rogued	0.00	12.70

Finally, certification programs have long used low disease tolerances as a mechanism for keeping virus levels low in the field (Knutson 1998). The problem with this approach has been that the most susceptible cultivars tend to be the ones most easily rejected from certification. This, in turn, limits the amount of seed available for replant which puts pressure on the system and the growers themselves to plant back less than satisfactory seed lots. As a result, the reservoir for PVY can be quite high in the commercial potato crops putting more pressure on the seed certification systems to keep PVY out of their seed. This cycle can be broken through the use of laws promoting the planting of only certified seed potatoes for the entire region, certified seed growers using all of the production and management options available to help control the spread and level of PVY in their seed operations, and the use of more resistant cultivars that have the appropriate horticultural characteristic for good marketing.

In summary, PVY in all its facets will be around for the foreseeable future. However, growers must take the opportunity to understand this virus, how it is spread, vector biology, possibility for current season spread, and the propensity for new strains within the virus population. Then, they must take specific steps to help manage this virus in their crop. Many of the steps and pitfalls have been outlined in this article. It is only through aggressive management and reduction of inoculum that growers will see ultimate success in managing this virus problem.

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