Integrating Rogueing, Stylet oils and Induced Resistance for PVY Management

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Potato virus Y (PVY) has been a worldwide problem for many years but has become a greater threat to the potato industry with the evolution of new strains many of which cause little symptom development on common potato cultivars. Yield losses depend on the degree of seed infection, time of spread (early in growing season more severe than late), cultivar, and strain of the virus. While yield losses can be has high as 50-80%, losses are more typically in the 5-15% range. PVY^{NTN} (tuber necrotic strain, also known as PTNRD-potato tuber necrotic ringspot disease) besides causing direct yield loss also causes marketing problems due to internal and external necrosis. In Montana and many other areas, the old common strain "O" has nearly been replaced by recombinant $PVY^{N:O}$ strains and $PVY^{N\text{-}WI}$ (strain Wilga). The PVY^{NTN} strain still makes up only a relatively small proportion <10% of isolates identified. The lack of visible symptoms with some cultivar/strain combinations makes rogueing -- a key management tool -- nearly impossible for seed producers. PVY is very difficult to control because it is transmitted by more than 50 aphid species in a non-persistent manner. This means the virus is carried on the aphid stylet and transmission occurs as soon as the stylet penetrates the epidermal cells of the leaf -- **too soon for any insecticide to kill the aphid and prevent virus transmission**. For most stylet-borne viruses the virus is acquired immediately and can stay viable on the stylet for up to 2 hours.

Aphids that transmit PVY can be either be potato colonizers such as the green peach aphid and potato aphid, colonizing weeds such as hairy nightshade, mustards, ground cherry, tumble mustard, flixweed, shepherds purse, chickweed, mallow, horseweed, pennycress, redstem filaree, **volunteer potatoes,** and bedding plants; or they can be winged migrants originating from tens to hundreds of miles away. Control of aphids on bedding plants or over wintering host plants is an important component of any IPM aphid/virus control program since these plants can be sources of both aphid vectors and viruses. Other aphids that transmit PVY such as oat-bird cherry aphid, rose-grain aphid or pea aphid, will not colonize potato but are common in grain and forage crops. Non- potato colonizing aphids that transmit non-persistent viruses migrate as winged adults to potato fields from alfalfa or small grains as these crops are cut or mature. They will simply move through the potato planting, attempting to feed and moving on and thus can be major factors in spreading non-persistent viruses such as PVY. **Thus removing in-field sources of virus by rogueing is important.** Migrating aphids typically will land on edges of vegetation. Therefore, non PVY host border crops such as soybeans, cereals, etc. with no breaks between the border crop and potatoes, will serve as "aphid cleaning stations," since once the aphid probes the virus is removed from the stylet. In these trials aphid activity was greatest in late-June to mid-July, a time period coinciding with aphid migration from maturing cereal crops. Potato colonizing aphid found included the potato and green peach aphid and non-colonizing aphids included oat-bird cherry, cowpea, rose-grain and pea aphids. In all years of trials ELISA-detect of PVY was low until early July and peaked in early August.

Because PVY management for seed growers has become more difficult due to the lack of symptoms that reduces the effectiveness of rogueing, we began examining other potential control tools including induced resistance. All plants have the genetic machinery to protect themselves from pathogens including viruses, the problem is that plants typically react too slowly to protect themselves. This genetic resistance can be induced by a wide range of chemical agents and several different microbes including *Bacillus mycoides* isolate J which we identified as an inducer of plant resistance that provides control of bacterial, fungal, and viral plant pathogens in a wide range of host plants.

We have been researching the use of *Bacillus mycoides* isolate J (BmJ) induced resistance for the control of PVY since 2008, where greenhouse trials demonstrated 50-100% control of PVY by induced resistance whether mechanically inoculated or transmitted by green peach aphids. In recent trials we demonstrated that green peach aphids will only probe once for <2 seconds on plants induced by either BmJ or the chemical inducer Actigard (Syngenta) compared to 15-30 minute feeding periods on non-induced plants . Therefore induced resistance has been shown to reduce infection, virus titer in infected plants, and reduce aphid feeding.

In 2009, in a research trial at Hermiston, we demonstrated 46% reduction in PVY infection in winter tests. In larger tests in 2010 and 2011 we again showed reduction of PVY infection using BmJ-induced resistance and effects of rogueing and a no-gap insecticide program (Table 1). In 2012, we obtained a Western Region IPM grant (award # 2012-34103-20200) to study integration of BmJ with stylet oils, insecticides, and rogueing for control of PVY. All of our work has been done with the highly susceptible cultivar, Russet Norkotah, and all work has been done at the Hermiston Agricultural Research and Extension Center where PVY epidemics are common. We have used Montana-produced seed with either no detectible infection or <0.003% in untreated plots and at the end of the year infection levels have been 10->60% when tubers were tested by ELISA in winter tests depending on treatment. Table 2 shows data combined for the 2012 and 2014 trials. 2013 data were confounded by use of yellow plot flags and planting adjacent to a wheat field and by learning that stylet oils are toxic to BmJ when applied together.

Table 1. 2010-2011 Hermiston PVY Management trials

Treatment (all received Admire at planting)	Average % PVY winter test 2010+2011 combined (2010-2011 separate)
No post emergence treatment- **non rogued**	10.2 a (10-10.4)
BmJ WP 2.0 oz/A at 14 day interval emergence to vine kill**-non rogued**	4.8 bc (3.5-6.1)
BmJ WP 2.0 oz/A at 14 day interval emergence to vine kill**- rogued**	3.1 c (1.5-4.7)
BmJ WP 2.0 oz/A at 14 day interval emergence to vine kill**- rogued +** @ 60 days post plant Assail 1.7 oz, @67 days Fulfill 5.5 oz,@ 75 days Beleaf 2.8 oz and @87 days Leverage 3.8 oz	4.6 bc (3.0- 6.3)
rogued + @ 60 days post plant Assail 1.7 oz, @67 days Fulfill 5.5 oz,@ 75 days Beleaf 2.8 oz and @87 days Leverage 3.8 oz	6.1 b (4.5-7.6)

1. All plants tested by ELISA for PVY- 400 tubers per treatment-8 replications of 50 tubers

Table 2. 2012 and 2014 Hermiston PVY Management Trials-

Treatment- all plots treated with Admire at planting and **all plots rogued**	Average % PVY winter test 2012+2014 combined (2012-2014 separate)
No post emergence treatment	53.8 ab (56.8-60.9)
No gap insecticide-@ 60 days post plant Assail 1.7 oz, @67 days Fulfill 5.5 oz,@ 75 days Beleaf 2.8 oz and @87 days Leverage 3.8 oz	61.1 a (65.1- 59.0)
BmJ WP 2.0 oz/A at 14 day interval emergence to vine kill	59.7 a (65.8-55.0)
BmJ WP 2.0 oz/A at 14 day interval emergence to vine kill + No gap insecticide-@ 60 days post plant Assail 1.7 oz, @67 days Fulfill 5.5 oz,@ 75 days Beleaf 2.8 oz and @87 days Leverage 3.8 oz	53.3abc (61.5-46.3)
BmJ WP 2.0 oz/A at 14 day interval emergence to vine kill + stylet oil (2.0 % emulsion) at 14 day interval emergence to vine kill- applied separately	45.0 cd (43.7-47.0)
stylet oil (2.0 % emulsion) at 7 day interval emergence to vine kill-	40.0 d (34.5-45.5)
stylet oil (2.0 % emulsion) at 7 day interval emergence to vine kill + No gap insecticide-@ 60 days post plant Assail 1.7 oz, @67 days Fulfill 5.5 oz,@ 75 days Beleaf 2.8 oz and @87 days Leverage 3.8 oz	43.3 cd (48.1- 39.2)
BmJ WP 2.0 oz/A at 14 day interval emergence to vine kill + stylet oil (2.0 % emulsion) at 7 day interval emergence to vine kill- applied separately + No gap insecticide-@ 60 days post plant Assail 1.7 oz, @67 days Fulfill 5.5 oz,@ 75 days Beleaf 2.8 oz and @87 days Leverage 3.8 oz	46.6 bcd (45.1-50.3)

1. All plants tested by ELISA for PVY- 400 tubers per treatment-8 replications of 50 tubers
2. JMS stylet oil used in 2012 and Glacial Spray Fluid used in 2014.

Conclusion

In 2010 and 2011 BmJ-induced resistance plus rogueing and a no gap insecticide program provided good control of PVY as measured by PVY winter test results. In 2012 and 2014 trials where all plots were rogued, stylet oil applied at a 7 day interval provided the best control with stylet oil + no gap insecticide, BmJ + stylet oil or BmJ + stylet oil + no gap insecticide being statistically equal in control. The no gap insecticide program was equal to the untreated check. These trials show that an integrated program will provide reductions in PVY even under severe disease pressure

In these trials we measured only PVY. It should be pointed out that while no *Potato leafroll virus* (PLRV) was seen, stylet oils do not control circulative viruses like PLRV. Stylet oils are only effective on stylet-borne viruses such as PVY.