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## **POTATO VIRUS Y: AN EVOLVING PATHOGEN OF POTATO WORLDWIDE**

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### **ABSTRACT**

*Potato virus Y* (PVY) is one of the important diseases of potato throughout the world wherever potatoes are grown. Yield losses in potato due to PVY are up to 70% if infection occurs at initial growth stages of plants. More than eight PVY strains have been reported worldwide which differ from each other based on symptoms they produce in the infected host plants and at their genetic makeup. In recent past years, new necrotic strains of PVY have emerged which are more damaging as they produce necrotic rings and arms on the tubers of infected plants. With increasing aphid population during last decade, incidence of PVY epidemics has increased worldwide. Managing PVY is difficult as some strains do not produce symptoms on infected potato plants and disease diagnosis becomes difficult. In Pakistan, work on strain differentiation of PVY and their aphid vectors are lacking and there is need of molecular research to identify PVY strains which are present in Pakistan.

**Keywords:** *Potato virus Y*, Necrotic Arcs, Resistance, Strains

*Potato virus Y* (PVY) belongs to the genus *Potyvirus* and family *Potyviridae*. Its genome is single-stranded RNA (ssRNA) which is 9.7 kb in size (Ward and Shukla, 1991). More than 10 different species of aphids transmit PVY in non-persistent manner. PVY is also called common mosaic of potato or potato severe mosaic. Green peach aphid (*Myzus persicae*) is most efficient vector in transmitting PVY in potato (Halbert *et al.*, 2003). In addition to potato, it infects tobacco, tomato, pepper, eggplant and several other plant species in the families of *Chenopodiaceae* and *Malvaceae* (Kerlan, 2006). Several new PVY strains have been discovered worldwide which produce different symptoms in infected potato plants and are different from each other at their genetic levels (Boonham *et al.*, 2002a). Three main strains of PVY are reported: PVY-C (common), PVY-O (ordinary strain) and PVY-N (tobacco vein necrotic strain). Several recombinant strains have emerged which include PVY-NTN, PVYNTN/N, PVY and N: Wi which have emerged as a result of recombination between ordinary and necrotic strains (Lorenzen *et al.*, 2006).

PVY was not considered a serious problem until the 1980's as the management was easy. However, after 1980's several necrotic strains have emerged which do not produce visible symptoms on potato plants. During the last two decades, new recombinant necrotic strains have made difficult the management of PVY. The symptoms of recombinant necrotic strains are not visible on infected plants which results in disease escapes during disease inspection surveys. PVY infection in potato crop may result in 10-100% yield reduction depending upon the stage of plant and virus strain. PVY recombinants have emerged due to recombination between ordinary (PVY-O) and necrotic strain (PVY-N) which are more devastating than the original strains. In potato, PVY is a serious yield constraint that can cause losses as much as 50-80% in heavily infected commercial potato fields. PVY persists in seed potatoes which are used for growing the next potato crop (Hane and Hamm, 1999). A novel recombinant strain of PVY-O was reported that reacts with PVY-N specific monoclonal antibody IF-5 and named as PVYO-05. The genome of PVY carries Hc-Pro (helper component protease) protein that is involved in vector transmission of PVY and mediates vector specificity (Karasev *et al.*, 2011).

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In addition to transmission through aphids, PVY is spread to healthy plants through mechanical means which can be a wound or insect injury resulting in the spread. Research has shown that plants growing next to infected plants also become infected at the end of the season possible due to mechanical spread or through the rubbing of leaves. From Pakistan, knowledge about different strains of PVY and its aphid vector is lacking. The necrotic strains of PVY: tobacco vein-necrotic strain (PVY-N) and tuber-necrotic strain (PVY-NTN) have become a serious problem in seed production areas as the plants do not produce visible foliage symptoms whereas the tubers of infected plants exhibit severe necrosis, which reduces the market price of the produce (Karasev *et al.*, 2011; Singh *et al.*, 2008; Boonham *et al.*, 2002b; Beczner *et al.*, 1984).

**Ordinary strain of PVY:** The ordinary strain (PVY-O) was prevalent in potato fields in North America and other countries of Europe until 1980. PVY-O produces mosaic, mottling and stunting symptoms on infected potato plants. Symptoms of PVY differ in different

potato varieties which show a range of symptoms whereas some varieties do not show visible symptoms in response to PVY infection. PVY-O infection was easy to diagnose from the symptoms during field inspection surveys. Diagnosis of diseased plants helps in management of the pathogen in potato crops (Nolte *et al.*, 2010).

**Necrotic strains:** PVY-N was reported from Europe and United States after the 1980's. "N" stands for necrosis produced in tobacco plants in response to infection whereas necrosis is not shown on potato plants. Most potato varieties do not show any symptoms in response to PVY-N infection PVY-N produces necrosis on tobacco leaves but symptoms on potato plants are very mild (Karasev *et al.*, 2011; Singh *et al.*, 2008). In case of PVY-NTN infection, tubers of some varieties show necrotic rings which renders them unmarketable. Tubers infected with PVY-NTN are unfit for human consumption that results in huge economic impact (Karasev *et al.*, 2008; Beczner *et al.*, 1984).



Figure 1. Potato plant showing mosaic and stunting symptoms due to infection with *Potato virus Y*.

(a) Desiree plant showing mosaic symptoms due to PVY infection (b) mild mosaic exhibited by potato in response to PVY infection

**Status of PVY in Pakistan:** Different studies have been conducted which report prevalence of different potato viruses in Pakistan including *Potato virus X*, *Potato leaf roll virus*, *Potato virus Y*, *M* and *Potato virus A* (Abbas *et al.*, 2012). From Pakistan, PVY-O and PVY-N strains have been reported and data about other strains is missing. There is need to characterize PVY strains in potato fields in Pakistan in order to develop better management strategies. Mixed virus infections are common in potato and synergism as well as antagonism has been observed in mixed virus infections in potato (Hameed *et al.*, 2014). In a study from Pakistan, determined the incidence of major potato viruses was checked in spring, autumn and summer crops from different ecological zones of Khyber

Pakhtunkhwa. From 76 fields, 1338 samples were collected and tested by dot-blot immunoassays using antisera to six potato viruses: PLRV, PVY, PVX, PVS, PVM and PVA. PVY and PLRV were detected at high incidence from all districts and three other viruses PVS, PVX and PVM were also detected from summer crop and PVX was detected from spring crop (Ali *et al.*, 2012). Abbas *et al.*, (2012) reported the infection by six potato viruses: *Potato virus Y* (PVY), *Potato leafroll virus* (PLRV), *Potato virus S* (PVS), *Potato virus X* (PVX), *Potato virus M* (PVM) and *Potato virus A* (PVA) in potato growing areas in Punjab. PVY incidence was high in all potato fields followed by PVX, PVA, PVS, PVM and PLRV. In another study, *Potato virus Y* (PVY), *Potato virus S* (PVS) and *Potato virus X* (PVX) were detected in major potato growing areas: Faisalabad, Pakpattan and Sahiwal using ELISA and PCR. The data showed the presence of all three viruses in potato plants and PVX was detected from all districts followed by PVY and PVS. There was also varietal difference in the distribution of three viruses: PVX was found in Desiree and Diamont samples whereas PVY was recovered maximum from Cardinal and Desiree (Burhan *et al.*, 2007). Another research group surveyed potato fields in Pakistan by focusing on two major potato cultivars being grown in Pakistan: samples from Desiree and cardinal were collected and checked for the presence of different potato viruses: PVS, PVM, PVA, PVY, PVX and PLRV. The data showed multiple virus infection in single plants. PVY, PVS and PVX were detected in many potato fields and co-infections were found in case of PVS and PVY (15.5% incidence). Doubly-infected plants showed higher virus titres in comparison to singly infected plants (Hameed *et al.*, 2014).

Recently, Abbas *et al.*, (2014) reported PVY necrotic strains from Pakistan. Potato samples were collected from potato fields of Rawalpindi, Islamabad, Sahiwal and Faisalabad during 2010-11 and 2011-12. Samples were tested through double-antibody sandwich enzyme-

linked immunosorbent assay (DAS-ELISA) which showed the presence of PVY in samples. According to ELISA results, PVY incidence increased during the year 2011-12 than the previous year by 9%, 10%, 17% and 22% in potato fields in Sahiwal, Islamabad, Faisalabad and Rawalpindi respectively. The phylogenetic analysis of coat protein of PVY showed that the isolates belonged to the group of PVYNTN /PVYNTN:N with the minimum genetic diversity whereas PVY-C group showed maximum genetic diversity. Potatoes harvested from previous season are mostly used for growing the next season crop in Pakistan. Symptoms of PVY are not visible on seed tubers and farmers sow the infected seeds which results in PVY infection in the new crop.

**Genome organization of PVY:** PVY particles are filamentous and non-enveloped which are 680-900 nm in length and 11-15 nm in diameter. Its genome encodes for 9 different proteins which perform different functions during virus life cycle. Its genome is single-stranded positive sense RNA (ssRNA) which is 9.7 kb in size (Ward and Shukla, 1991). The 5' end of the genome is covalently linked to VPg protein and 3' end has a polyadenylated tail (Shukla *et al.*, 1994). The genome acts as messenger RNA and is expressed as a large polyprotein (3.5 KDa) and VPg enhances translation process. The polyprotein is cleaved into 10 different proteins which have different roles. Its genome encodes for three proteases which are involved in cleavage of large polyprotein resulting in the formation of several multifunctional proteins which perform various functions during virus life cycle. These include PI, helper component proteinase (Hc-Pro), P3, nuclear inclusion protein a (NIa), cytoplasmic inclusion (CI) protein, nuclear protein b (NIb), 6K1, 6K2 and coat protein (CP) (Fauquet *et al.*, 2005). Hc-Pro performs different roles and is involved in aphid transmission and determines vector specificity (Flasinski and Cassidy, 1998). P1, Hc-Pro and NIb are proteases which are involved in cleavage of polyprotein into smaller proteins.

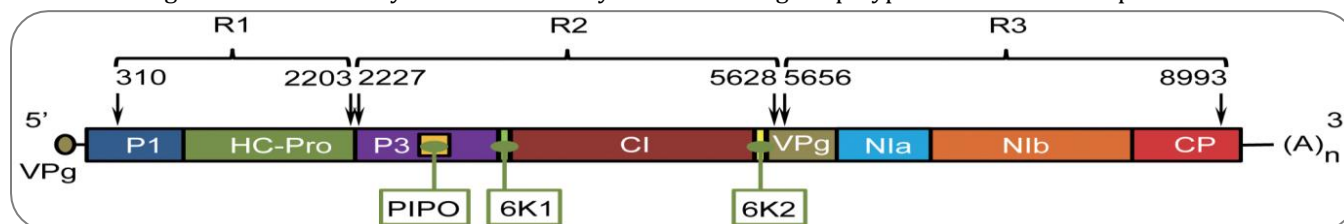


Figure 2. Genome organization of *Potato virus Y*. The genome is 9700 bp in size with ploy-A tail at the 3 end and VPg protein at the 5 end of the genome. Source Cuevas *et al.*, (2012). PLOS ONE.

**Management strategies for PVY:** For PVY transmission, the aphids don't need to colonize the plants in order to acquire and transmit the virus to healthy plants. Insecticide sprays are ineffective as the contact time between the aphid and the insecticide is very short that renders insecticides ineffective. Insecticides only show effectiveness after they enter into insect body in case of persistently-transmitted viruses. In case of viruses transmitted in persistent manner, aphids ingest the plant sap for longer periods of time and the virus circulates inside insect body before it can be transmitted to new plants. Insecticides have been found useful in case of *Potato leaf roll virus* (PLRV) which is persistently-transmitted virus and the aphids need to colonize the plants for longer hours in order to transmit the virus. Different insecticides are recommended to control PVY spread in fields which include imidacloprid, thiamethoxam, clothianadin, and acetamiprid. These insecticides can be applied in furrows, as foliar sprays and as seed treatments (Schramn *et al.*, 2012). Mineral oils have been found useful in the control of PVY spread in potato fields. Different studies suggest that the use of mineral oils is effective in reducing PVY spread. A study evaluated the efficacy of Superior 70 and Vazyl-Y against PVY. The result showed that in oil treated plots PVY was much less in comparison to control plots (Fageria *et al.*, 2014). Crop border is also effective in managing PVY in potato crops. Crop border acts as a virus sink in controlling PVY and if combined with mineral oils provides effective control of PVY spread. Field trials conducted over the period of 3 years showed that combining foliar mineral oil sprays with crop borders provides twice effective control of PVY in comparison to crop border alone (Boiteau *et al.*, 2008). Infected potato seed tubers result in PVY spread in new crop. Farmers in Pakistan are using the seed from previous crop for getting the next crop, so there is need to emphasize on the use of clean and virus free ELISA-tested seed. Seed certification departments should sell virus free potato seed tubers to potato growers on cheap rates. Farmers should be advised about the losses due to PVY as it can result in 70-80% yield losses in severe infections. RNAi technology can be used to generate resistance in potato cultivars against newly emerging necrotic strains in order to control the disease. Genetically-engineered resistance against field PVY isolates can provide long term control of PVY as new strains are emerging which result in resistance break down governed by R genes.

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