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A review on aphid-borne virus (Potato Virus Y)

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Abstract
Potato virus Y (PVY) is distributed worldwide and is most important plant virus affecting solanaceous crops in particular potato and tomato. PVY cause 10-100% yield loss on potato and 39-75% on tobacco crops worldwide. PVY has different strains which cause variety of symptoms on different parts of the host plant species. Initially three chief strains of PVY *viz*. PVY^{C}, PVY^{N} and PVY^{O} were recognized. In recent years, new strains of PVY (Technically necrotic strains) such as PVY^{N} and recombinants PVY^{N-Wi}, PVY^{NTN}, and $PVY^{N:O}$ have emerged in potato crop. PVY have a host range of 495 species in 72 genera of 31 families. The strains of PVY have different stability under dilution end point (DEP), thermal inactivation point (TIP) and longevity in vitro (LIV). PVY belongs to the potyvirus genus and currently thought to be largest genus of plant viruses. The genome of PVY is single strand of positive sense RNA (+ssRNA) which is in the order of approximately 9700 kb in length excluding the poly (A) tail. PVY is spread from plant to plant either by aphids in non-persistent, non-circulative manner and mechanical means. Among the aphids (family Aphidinae) *Myzus persicae* is the most important vector which is transmitting PVY efficiently. Breeding of resistant cultivars is considered best strategy to manage viral diseases in potatoes. PVY is also managed indirectly by controlling its vectors (aphids) with insecticides and mineral oils. Therefore to understand biology of PVY and to develop an efficient management strategy is very important.

Keywords: PVY, Potato, *Myzus persicae*, ss RNA, Vector control

1. Introduction
The cultivated potato (*Solanum tuberosum* L.) is the world's important food and vegetable crop and rate fourth in production. It contains 78% water, 18% starch, 2% protein, 1% vitamins and several trace elements. It is the world's leading crop and grown in approximately 140 countries [1, 2]. Since potatoes are vegetatively propagated, this creates exclusive opportunities for pathogens to establish and spread several diseases [3]. Among the plant pathogens, more than 37 viruses are reported to infect potato crops. Potato virus Y (PVY) is one of the major plant viruses in seed production in many countries worldwide, including Pakistan [4]. Crop management against plant viruses during seed potato production involves the use of number of practices, which often include insecticide treatments as an integral part of control, since aphid transmission is the most important mode of virus transmission in a field during a growing season [5]. Mineral oils are widely used to reduce transmission of PVY, because these oils change aphid's feeding behavior. Moreover aphid's style penetrations in a plant host could also be late when plants are treated with mineral oil [6]. Aphids are the most important and the most harmful as vectors of potato viruses [7]. More than 40 species of aphids are transmitting PVY in natural conditions [8]. *Myzus persicae* alone is a vector of more than 150 types of viruses [9]. This review will focus on occurrence and distribution of PVY, biological properties, physical properties, molecular properties and crop management strategies.

1.1 Occurrence and distribution of PVY
Potato virus Y (PVY) distribution is universal; however, some PVY strains are limited to certain continents [10]. Strains of PVY consist of PVY^{O} (common strains), PVY^{N} (tobacco veinal necrosis strain) and PVY^{C} (stipple-streak strain). PVY^{O} strains are distributed worldwide, PVY^{N} strains occur in South America, in Europe and in some parts of Africa. PVY^{C} strains have been reported from Australia, Europe, Pakistan and India [11]. In Pakistan, PVY is distributed throughout the country with an incidence of 2-25% [12] and incurring 58-83% losses in potato crop [13].

1.2 Biological properties of PVY

Symptoms vary from a mild to severe mottle on most hosts to streak or "leaf drop streak" caused by (PVY^O) with necrotic lesions along the veins on the underneath of leaflets (PVY^N) and stipple-streak (PVY^C) of some potato varieties [14]. When present together with potato virus X, PVY causes "rugose mosaic," in which the plants are dwarfed and the tubers are reduced in size. Symptoms in potato plants because of PVY infection vary, depending upon type of strain, genotype, environmental conditions and kind of infection, whether it is secondary infection (in this case tubers are infected) or primary symptoms (current season infection). Appearance of symptoms in the above parts of plants may be mild to severe mottling as well as crinkling (distortion) of the leaves. Moreover necrosis and yellowing occasionally appear in the old leaves. In few cases, middle leaves are dropping and few of them remain clinging to main stem. The plants which are grown from infected tubers, leaves become dwarf and brittle, with puckered and crinkled leaves. Depending upon cultivars, infected tubers become necrotic [15].

The host range of PVY is very wide, comprising many crop species in the family Solanaceae. Severe symptoms are also observed in the economically important crops such as potato, tobacco, tomato, pepper and ornamental plants. Weed species belonging to families Asteraceae, Brassicaceae, Chenopodiaceae, Commelinaceae and Fabaceae are suitable hosts of PVY [16].

The PVY is transmitted naturally by several species of aphids through non-persistent manner. The green peach aphid (*Myzus persicae*) has been found to be most effective in its role as viral vector. PVY can be transmitted mechanically, but this means of transmission is generally of minute importance in the field conditions [17]. Aphids, the vectors of PVY, acquire PVY within short time i.e. few seconds then begin to feed on healthy plant and transmit the virus immediately to other plants. Moreover the aphids have capability to retain the PVY for an hour [18]. The transmission of PVY by aphid vectors occurs in non- circulative and non-persistent manner which reveals the significant interaction between the virion and the vector [19].

1.3 Physical and molecular properties of PVY

PVY is a member of Potyvirus genus which belongs to family Potyviridae [20]. Genus potyvirus consist of non-enveloped, flexuous rod structures that are 680-900 nm in length and 11 to 15 nm in width [21]. The PVY particles encode a large poly protein of about 340-360 KDa which is translated by three viral encoded enzymes (Proteases). However the nucleic acid (RNA) genome of PVY is a positive sense and is approximately 9700 bp excluding the poly A tail [22]. There are two distal non-coding regions. The length of the 5' non-coding region is 184 nt [23]. This includes blocks of sequences conserved in potyviruses, referred as the "potybox", box "a" (a 9 nt sequence, part of the potybox) and box "b". PVY has a potybox motif (UCAACACAACAU), in which 11/12 nucleotides match the consensus sequence, and a perfect copy of the consensus sequence motif of box b (UCAAGCAA). The potybox starts 12 nt from the 5'end and is separated from box b by a 39 nt sequence [22]. Coat protein can be divided into three regions i.e. i: a core of 218 amino acid which is highly conserved among the pot viruses ii: a surface-exposed N-terminus which is variable in length and iii: a surface exposed C- terminus of 19 amino acids. The N terminal and C terminal regions of PVY genome don't play significant role in virus assembly. The PVY isolates from the infected potatoes were found to be two main serotypes: the O serotypes, which consist of PVY^O, PVY^C and PVY^{NW} and the N serotype that includes PVY^N and PVY^{NTN} [24]. Viral genome of PVY is translated into a polyprotein, consisting of 3,061 amino acids and then cleaved into ten multifunctional proteins byP1 serine, HC-Pro cysteine and NIa-Pro cysteine proteinases. In addition, a small polypeptide (PIPO) is translated by +2 nucleotide frame shifting from the P3 region, resulting in a P3-PIPO fusion product [21]. The length of pipo is very inconsistent among PVY isolates, and this intraspecific variation in length may be maintained by host driven adaptation [25].

2. Crop management strategies

Potato virus Y disease can be managed by using several management practices such as by using resistant varieties if available, transgenic crops, roughing, removing alternate hosts, sanitation, use of insecticides and mineral oils. Mineral oils are widely used to reduce transmission of PVY, because these oils change aphid's feeding behavior. Moreover mineral oils are cheaper than other pesticides and are less harmful to the environment.

2.1 Mineral oils

Numerous reports revealed that there is steady effect of mineral oil on the transmission of PVY, which makes mineral oils one of the effective chemicals in control of non-persistent virus spread [26]. However mineral oils intervene with virus retention in the aphid's stylet [27]. A progressive reduction in the transmission of PVY was acquired by spraying mineral oil on solanaceous crops [28]. Moreover, application of mineral oil on aerial parts reduces the transmission of PVY to [6] and *Cucumber mosaic virus* to pepper plants [29].

Several studies show a direct effect of mineral oils on aphid's survival [30]. Mineral oil caused 83.3% mortality in soybean aphid adults and 100% mortality in soybean aphid nymphs [31]. Foliar application of mineral oil reduced the transmission of PVY to potatoes [32]. The success of mineral oil applications in avoiding PVY transmission during seed potato production was also accounted by [33]. Mineral oils may be washed off by rain or sprinkle irrigation and must be re-applied when new tissue develops and moreover mineral oils were observed to persist for 10-14 days on potato crop [34].

2.2 Insecticide and mineral oil application

Insecticides and mineral oils were used to control potato viruses even before the exact vectors responsible for virus transmission were discovered [35]. In 1957 described in the review "Insecticidal control of plant viruses" early attempts to manage plant viruses chemically [36]. Reported that cypermethrin an insecticide was effective and efficient in reducing PVY acquisition by 23.8% compared with the untreated control. Insects are responsible for direct damage to potato crop, therefore insecticides can be used to control as well as to reduce their population below damaging threshold. Moreover, the indirect damage cause by vectors of PVY is not possible to prevent, because the vectors especially both winged and wingless can come from a variety of sources such as from the field and outside of the field [37]. Fast acting pesticides are utilized to control non-persistent virus [38]. Moreover the research revealed that aphids were paralyzed after 2.5 minute exposure to infected treated source, thus virus inoculation was restricted when acquisition access period was greater than 2.5 minutes [39]. Moreover the insecticides which

lower the aphid's probing feeding behavior are the best to manage non persistent viruses. The chemicals cypermethrin, pyrethroid and deltamethrin reduced non-persistent virus spread in potato crops. Control of viral diseases is dependent on the means of virus transmission by vectors [40]. This declaration is attributable to the fact that PVY is transmitted in a non-persistent manner. Insecticides have greater efficiency in preventing the transmission of viruses from the interior source of infection than from the exterior source [41].

Mineral oils give effective management of PVY by preventing the infection of potato plants with the virus in the field. They can be combined with further management practices to look after seed potato crops against the virus. By changing aphid's feeding behavior mineral oils have the abilities to reduce viral transmission in plants and stylet penetration is delayed on plant host after mineral oil application [6]. In Spain, [42] reported that combination of mineral oil and Imidacloprid reduced PVY transmission in potato fields. In the USA, combined application of insecticide with mineral oil application, were efficient in the management of non-persistent viruses such as PVY in the fields [43]. Mineral oils are useful in intervening with the transmission of the non-persistent viruses. Two weeks after planting of crops, mineral oil must be applied to control transmission of PVY by aphids as they are known to colonize plants shortly after germination. However insecticides are also suggested to control non-persistent transmitted virus [44] Moreover, oils have been reported to have a repulsive effects on aphids, however the repulsive effects remain only for a shorter period of time [45].

It has been reported that Bifenthrin and Dimethoate which are synthetic insecticides were found to be more effective in reducing aphid infestation, whereas the Neem extract and mineral oil (DC-Tron) had no significant difference. However, mineral oil sprayed plots recorded the lowest PVY incidence while Bifenthrin applied plots had the lower PVY incidence [34].

3. Conclusion

Since PVY and its aphid vectors are detrimental to potato production worldwide. Therefore their management is essential to reduce potato yield losses. Breeders develop resistant varieties against PVY but these are costly to develop and need to be robust source of resistant. In addition to resistance characteristic the yield as well as firmness also need to be incorporate into the new potato cultivars. For aphids unluckily only wild potato species are found to be resistant. Immediate roughing of plants upon expressing symptom may also reduce PVY. Further volunteers potatoes and weeds must also be eliminated because these plants may be sources of PVY and aphids. For commercial production isolation is an important strategy to curb the spread of PVY. Isolation also consist of modified planting dates and harvesting dates Mechanical barriers such as polyethylene sheets and barrier crops will also reduce the spread of PVY. Early warning system can also be provided to farmers by counting apterae aphids on potato leaves or alate aphids in traps. Crop mulching and crop covers can also reduce PVY spread but increased temperatures under covers can also affect the plants.

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