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POTATO MOP TOP VIRUS- AN EMERGING THREAT TO THE POTATO CROP WORLD WIDE

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ABSTRACT:

Increase in the concern of potato diseases induced by various pathogenic bacteria, nematodes, fungi, viruses which reduces the quality and yield of Potato. Potato Mop Top Virus(PMTV), first incidence was reported in 1966, within the boundaries of Andean Region of South America then spread throughout the world and causes significant loss to the economy. PMTV has a rod-shaped, tubular structure containing tripartite positive-sense ssRNA genome structure. With the advancement in detection techniques such as microplate hybridization, widely used Reverse Transcription Polymerase Chain Reaction and Enzyme-Linked ImmunoSorbent Assay, and fluorescent amplification-based specific hybridization have successfully improved the detection of PMTV . Some studies suggest that interaction between the different segments of PMTV genome with some transport factor protein of plants that plays a key role in systemic movement and viral cell- to- cell movement. Databases result analysissuggeststhatPMTVsequencesshowhighsimilarityamongdifferentcountries isolates of potato. Tolerant cultivars are widely studied to suggest some agronomic characteristics which can be employed by commercial cultivars and will be combined with those cultivars which show the absence of symtopms such as tuber necrosis or little accumulation of Potato Mop top virus. Previous studies suggest that moisture of soil also play sacrucial role in developing the PMTV tuber symptoms and necrosis and thus improvement in irrigation management schemes may reduce the disease pressure. This review aims to present the detrimental effect on Potatoes worldwide by PMTV and by itsvector.

INTRODUCTION:

The most essential food crop within the world after wheat and rice is Potato (Solanum tuberosum) in terms of human consumption (1).An increase in the pathogenic bacteria, fungi, Nematodes, and Viruses that affect and reduced the Potato quality and yield(2). Potatoes impart high nutritional content and play a pivotal role in developed countries as compared to developing countries. The vital energy intake from potatoes ranges from 41kcal/day - 130 kcal/day which is consumed by a person in different countries around the world(3). Potatoes are highly rich in vital essential carbohydrates, potassium, and Vitamin C depending on the cultivar consumed by an individual(4). Availability of Vitamin C in the potatoes that can serve to protects folates from oxidative breakdown(3). Even, Potatoes provide a sufficient amount of intake of folate ,in European countries, like the Netherlands,FinlandandNorway(5).Genetically produced Potatoes which are rich in Carotenoid could also provide Vitamin A which generally contributes about some amount of recommended dietary allowance(RDA)(6). Potatoes also contain several secondary metabolites which showed antioxidants and other bioactivities as well(6). Several Viruses in Potatoes cause degradation of tuber quality and lead to a huge reduction in the market economyand about 20-90% of yield losses also have occurred (7). There are about more than 40 different viruses or virus strains that affect the potatoes in long run. Some previous study suggests that different viruses including Potato leafroll virus (PLRV), Potato virus X (PVX) , Potato virus S (PVS), Alfalfa mosaic virus (AMV),Potato virus A (PVA), Potato virus Y (PVY), Tobacco rattle virus (TRV), Potato mop-top virus

(PMTV),all these virus can show various symptoms which includes necrotic rings on potato tuber of a sensitive tuber, shortening of internodes, yellowing of leaves(8)(9).

Potato Mop top virus(PMTV) belongs to genus Pomovirus and family Virgaviridaae. Potato Mop top virus(PMTV) originated within the Andean region of South America(10), and it is caused and transmitted by released zoospores of fungus Spongospora subterranean, which is the causal agent of potato powdery scab disease(10)(11). Now, Potato Mop Top Virus has spread throughout the world where potatoes are domesticated, including North America, Central Europe, and Asia regions (12). PMTV was first reported by Calvertand Harrisonin Britain (1966) (10), and there is a various study that suggests the development of PMTV disease through out the world (12). PMTV have general symptoms as other viruses such as raise dlinesan drings on the exterior tissues of tuber(11), and also show brown or necrotic arcs on internal tuber tissue(16), stunting, mottling, chevrons, and yellow rings that are also developed on infected potato tuber(16).PMTV also shows major symptoms that results in shortening of internodes which ends up in dwarfed appearance(generally called mop-top)(13)(14). A previous study also shows that there is a high frequency of occurring of a symptomatic PMTV primary infections (13). PMTV has some similarities in properties and behavior when compared to Potato spindle tuber and Tobacco rattle Viruses (9) (15) and also seems to be different from other viruses as well.Thehostrange of Pmtv's vector, S.subterranean is broader and it attacks diversity of plant species whereas the host range for PMTV is very narrow as the virus only infects the plant species which belongs to families Chenopodiaceae, Aizoaceae, and Solanaceae as suggested by a previous study (11) (15). New recorded hosts for S.subterranea are continuously being investigated in various studies (17).PMTV generally found within countries that have lower temperatures or cooler climates like the Andean Region of South America, Northern Europe, andJapan (12) and various other cases of PMTV have also been reported with in the USA, in Nordic Countries, Israel, China, Canadaand the CzechRepublic (18)-(22).

The genome structure of Pmtv consists of tubular rod-shaped particles having positive-sense,ss RNA having tripartite genetics egments.The RNA-repsegment of the PMTV virus which is in size ~6.1kb that encodes for RNA-dependent RNA polymerase (RdRp). RNA-Coat Protein segment of the virus which is in size~3.1kb encodesforCoat-proteinandRead-Throughproteinofdifferentsizes.RNA-TGBthird segment of the virus which is ~ 2.9kb encodes for three different proteins that are involved in viral cell-to-cell movement and it also consists of protein named cysteine-rich which appears as a suppressor of RNA silencing (23)-(25).In a previous study, more recent Detection Techniques such as reverse transcription-polymerase chain reaction (RT-PCR) and Enzyme-linked immunosorbent assay (ELISA) have been reported to detect PMTV in various samples of potato tuber isolate(26). In some recent studies, SYBR Green qPCR and nRT-PCR assays are also makingsome

Progress in the detection of PMTV, and thus evaluation of viral samples of infected tubers of the PMTV becomes a more convenient and faster method of detection(26)-(28).

Occurrence and Distribution

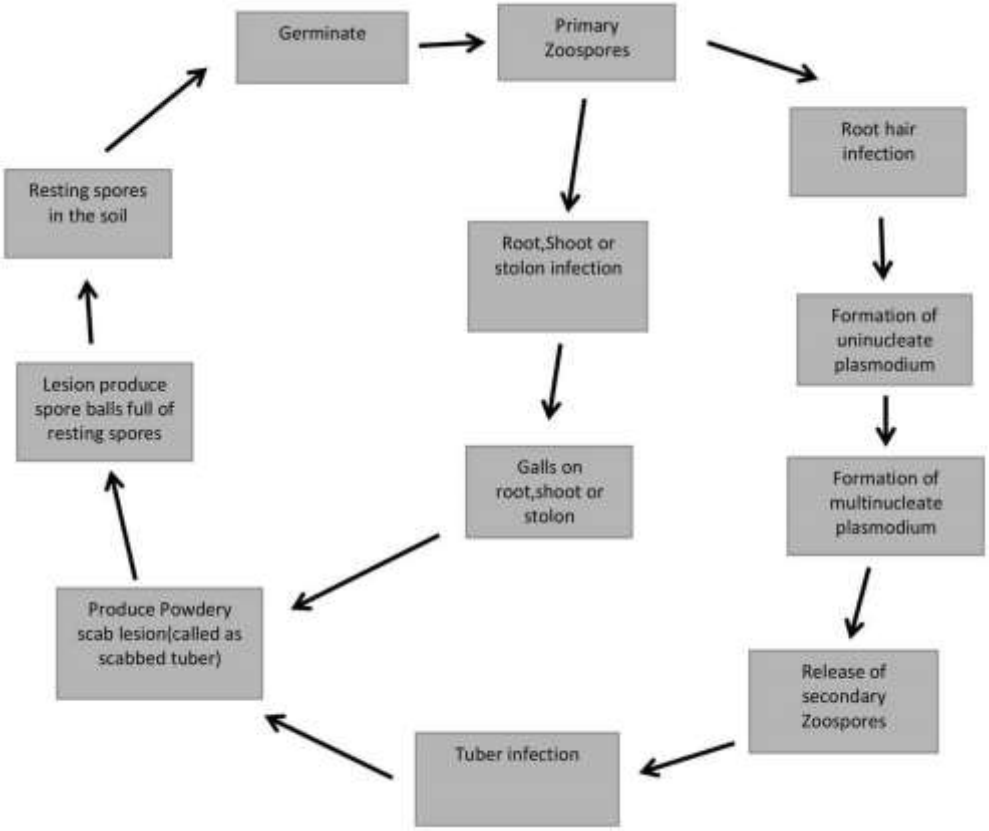
The first report of the Potato mop-top virus(PMTV) was in 1966 in the Andean region of South America(10) and thus from there, it spread throughout the world causing huge loss in market(11).In European countries, PMTV was first identified in the Netherlands in 1969, which is the largest exporter of potatoes seed(19).Followed to this PMTV was detected in the Scandinavian region first detections made in Norway (1969) in Sweden and Finland (1989), Denmark (1966), Bolivia (1975), Venezuela (1989) and Columbia (2011). The PMTV virus was also developed in Costa Rica in Central America(in 2008), and within the USA and Canada in North America(in 2002). In the Czech Republic, the virus was found in 1982 and then again in 2002. In Ireland, this virus was found in 1980, and Poland's first detection made in 2010. In Asian countries, PMTV was first reported in Japan in 1986, followed by China (2013) and thereafter in Pakistan (2014).Recently, New Zealand also made their first report of development of PMTV, it comes from Oceania (Government of NZ, 2018) (12)-(14) (19)-(22) (29)-(32) (55).PMTV is distributed among different countries across the world and its causes lead to reductions in yield andquality.S.subterranea, which causes powdery scab disease, a disease that extended through worldwide history (14)is the vector of PMTV. The literature study shows that Powdery scab disease was first detected in Germany in 1841 and thereafter reported throughout Europe in 1855, and this results in believed that it spread from South America(14)(33). Because of the present of fungal vector of the virus in soil worldwide, and hence the potential spread of the virus is additionally around the world (14) (33).

Vector and its Life Cycle:

S.subterranea belongs to uncertain taxonomy within the family plasma diophoridae (33).S.subterranea is like a protozoan organism and its complete life cycle is not known, major facts are known. The life cycle of S.subterranea is closely related to the well-studied Plasmodiophora brassicae life cycle. The life cycle isdivide into two distinct phases: Asexual Phase and Sexual Phase shown in (Figure 1) (14) (33).In the asexual phase, zoospores form the uninucleate plasmodium which eventually multipliesand develops into multinucleate plasma diumthatcan infect the root and encyst. The multinucleate plasmodium then evolves into a narrow-walled zoosporangium which contains identical(n) zoospores, which act as a crucial source of secondary inoculum that can affect the root and encysts. As compared to the sexual phase of the life cycle which involves the hypothesis that two zoospores(n) fuses to form dikaryotic zoospores and then it infects the roots. It forms binucleate plasmodium when it infects the root and encysts, then Karyogamy occurs and binucleate plasmodium will rapidly divide into several resting spores within a sporospori (cystosori). These resting spores can persist and survive in the soil for a longer period of times of more than 10years. Spore’s cell wall is made up of three layers which provide in spore’s longevity. These spores can be seen via microscope in thet issue where some lesions are already been developed and restingspores have

been burst, and it appears white and powdery appearance which give its name, Powdery Scab of Potato which leads in yield reduction (14). Resting spores are highly resistant to environmental stresses as compared to zoospores. Lower temperatures (such as 12-20^{o} C) and high soil moisture content can trigger these resting spores to develop and thus release viruses carried by zoospores. These released zoospores only move to small distances in soil and also, for the movement they also require free water and develop the virus into potato plants that can infect the roots, younger tubers, and stolons(17)(33). The virus infection is passed on as secondary contamination when infected Potatoes tubers are planted as a seed which serves as secondary infections for progeny tubers. Hence, spread via fungus vector, S.subterranea is the most significant means of transmission ofPMTV (14) (17) (34).

Figure 1: Life-cycle of powdery scab, Spongospora subterranea (14) (33)



Genome organization and Its Variability:

Complete Genome structure of PMTV was reported in a previous study (23)-(25). PMTV, the virus consists of rigid, tubular and rod-shaped particles that contains tripartite, positive sense ssRNA genome structure (23) (Figure 2-Genome organization

of PMTV). Database analysis shows that complete nucleotide sequence of RNA1 is of 6043 nucleotides (nt) which was characterized from Swedish sample(isolate) and it is the largest segment of PMTV genome structure, RNA1 encodes for RNA dependent RNA polymerase(RdRp) which helps in viral replication and formation of replicas subunits(23)(24), followed by the second-largest segment of PMTV, RNA2 nucleotide sequence consist of 3100nt, and it is also referred as RNA-CP, RNA-CP encodes Coat protein(CP) of the virus, produced by translation of Read-through CP stop codon(24). In a previous study, it was shown that probably CP-RT is required for vector Transmission (24) (35). RNA3 nucleotide sequence

consists of size 2900nt which contains three overlapping ORFs(shown in figure 3)which forms the Triple gene block(TGB) which encodes for three different proteins(TGB1,TGB2,TGB3) that play a significant role in viral cell-to-cell movement(25). Also, an ORF of RNA3 encodes for 8K protein which appears to be viral suppressor of RNA silencing. This 8k protein is rich in Cysteine(25)(36)-(38).These three different segments also contain some identical 3'terminal tRNAs like structures with well conserved 5'-untranslated region. It was shown that interaction between the two segment, CP-RT segment and the TGB1 segment of PMTV also helps in the systemic movement of PMTV fragments as visions(24)(25). Several detection techniques such as the nucleic acid hybridization test show that none of the species is derived from others. The genome organization in PMTV is novel (39) and nucleotide sequence of other isolate accessed through the NCBIdatabase (Table-1).

In a previous study, It was shown that PMTV RNA is moved either as ribonucleoprotein (RNP) complex which additionally contains TGB1 or even enclose in visions containing TGB1 (29). Also, it was shown that TGB1 interacts with in-vivo with different nuclear transport factor of plant such as importin α, that allows viral cell-to-cell movement(involving RNA complexes) and show systemic movement(40).There is not enough study that shows about the viral RNA traffic in Plants species, hence thus screening and detection of TGB1 protein as bait may show more insight into the interaction of TGB1 and host factor proteins(25)(40).Some studies have also been enabled to recognize two different domains of TGB1 that plays an important role in TGB1 self-interaction and viral cell-to-cell movement and importin-α interaction in plants for long-distance movement(40). Some viruses such as beet necrotic yellow vein virus (BNYVV) which show resembles with PMTV RNA 2 arrangement in possessing 3'- terminal tRNAs, but unlike BNYVV RNA, PMTV RNA seems not to be polyadenylated (37).In a previous study, it was shown that the adoption of the GUG start codon as compared to the AUG codonthat helps this virus to limitits production of various CRP protein at a suitable level. Also, a previous study shows that PMTV existed in two distinct strains: S(Severe) and M(Mild) strain; and the study suggests that genetic diversity of Severe(S) strain is more diverse as compared to Mild(M) strain(16)(41). However, there is not enough information on the structure of population, incidence and its distribution, typeof strain available in the soil. 8K Protein which acts as RNA silencing suppressor evolve faster than other genes of PMTV, variation in 8k gene might be virus strategy to evade from the RNA silencing pathway and thus lead to suppression and increase in viral replication and spread (36)-(39). It was shown that genetic diversity of PMTV is less, and the replacement of the AUG start codon with less- efficient GUG codonof

the fourth gene of the TGB encoding RNA, and codes for a cysteine-rich protein, which helps in evolving virus particles and can help them to survive in harsh conditions and remain in the environment for a longer period(36)(37)(41).

Figure 2: Genome organization of PMTV (42)

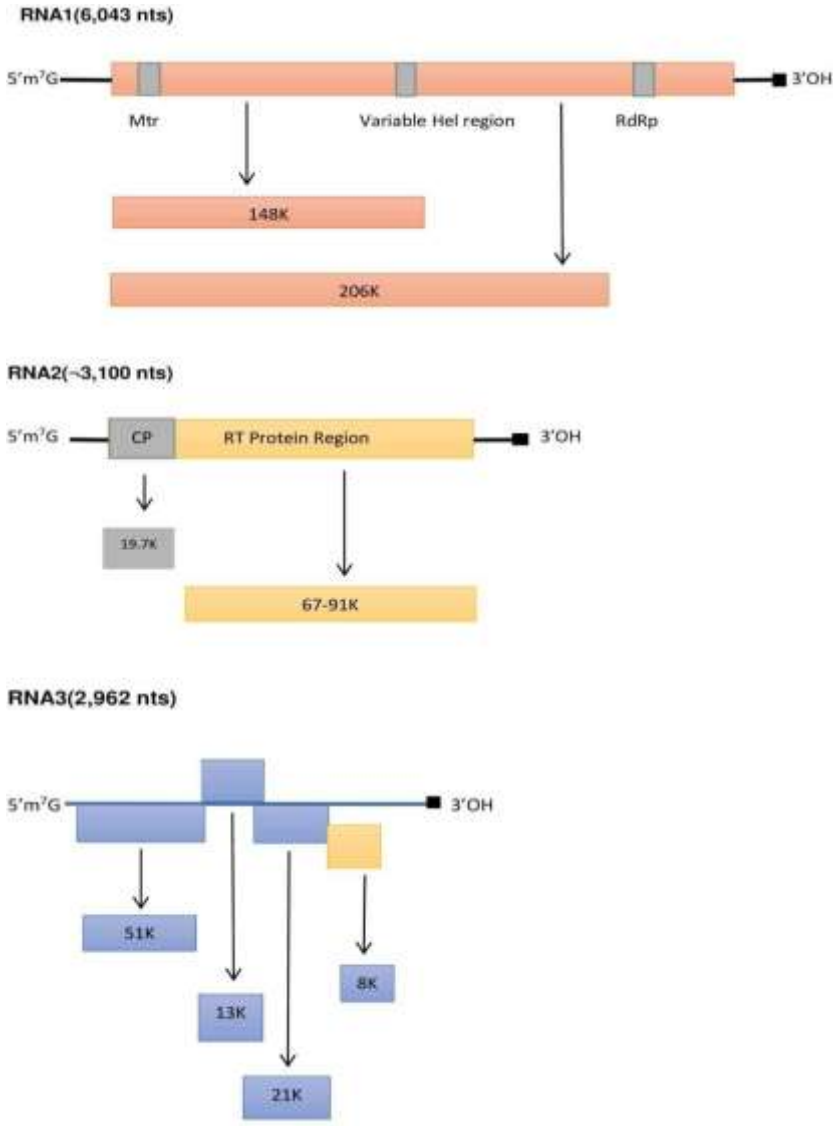


Table 1: Database analysis of different isolate and their origin

Isolate	Origin	RNA segment	Length(nt)	Accession No	References
Swedish (Sw)	Sweden	RNA1	6043	AJ238607	(23)
Swedish, (Sw)	Sweden: Halland	RNA2	3134	AJ243719	-

Swedish, (Sw)	Sweden :Halland	RNA3	2964	AJ277556	(24)
Guangdong	China	RNA1	6042	KM822695	Nie,X., Dickison,V., Singh,M. and Hu,X. 2016
Guangdong	China	RNA2	3134	KM822699	Hu,X., Lei,Y., Xiong,X. and Nie,X. 2016
Guangdong	China	RNA3	2964	KM822704	Hu,X., Lei,Y., Xiong,X. and Nie,X.2016
WA-Washington	USA	Triple-gene-block protein 1 , triple-gene-block protein 2 , and triple-gene-block protein 3 genes, their complete cds.	2964	KP420028	(56)
PMTV-Pl	Poland	coat protein (CP)gene	531	GQ503252	(19)
54-10	Denmark	coat protein gene	1386	AY277633	(57)

Molecular detection of PMTV:

Traditional methods that detect the virus such as using bait plants which can help to identify Potato Mop Top Virus in the soil sample which includes planting these bait plants(shown by Arif et al 1994) such as Nicotiana debneyi on soil test sample and which also leads to the proliferation of PMTV in the root sample of bait plants and thus leads to successful detection(43).Diagnosis through traditional methods leads to complication and due to unevenly distribution of PMTV in tubers, as this virus remain confined to either tissue can help to target this virus and thus sampling through these tissues will play a significant role in the detection of the PMTVin soil sample(43)(44).

Modern diagnostic techniques on nucleic acid hybridization are involved in the testing of a large number of samples and they are highly specific. The advancementof these nucleic acid-based assays will provide other aspects of virus detection. Advancements in these common techniques such as cDNA hybridization, Enzyme-Linked immunosorbent Assay(ELISA) and, Polymerase Chain Reaction, have been reported by many scientists for the detection of the

PMTV(26)(28). Major advancement occurred in 1989 when the researcher selected Polymerase chain reaction as one of the scientific development of theyear (46).

Various other virus-specific detection methods that include coat-protein(CP) specific antibodies, double antibody sandwich ELISA, and Immune capture reverse transcription-polymerase chain reaction(IC-RT-PCR). PMTV primers are used for the detection of PMTV reported in previous study (26)-(28) (46).In recent times, Reverse

Transcription polymerase chain reaction (RT-PCR) is evaluated as a powerful tool in Molecular biology. In biology, Serology testing was also used routinely for detection of plant viruses from infected tissues in the late 1980s, with development in biology and sequencing techniques have made some possible way to characterize the properties and behavior of PMTV strains and thus classify these strains which are supported by molecular detectiontechniques(26)(27)(46).

Several researchers have also used RT-PCR for the detection and identification of various viruses and thus made it possible for the detection of PMTV (26)-(28). Various applications of PCR for the detection of various Potato viruses have already been reported (46). For rapid identification of PMTV strains, restriction endonuclease digestion which is followed by amplification of the product could help in the detection of PMTV (47) (48). These Rapid molecular detection methods could also provide the potential for virus strain differentiation, its Restriction fragment length polymorphism (RFLP) which was reported in the previous study(47).

Several detection techniques which include fluorescent amplification-based specific hybridization (FLASH-PCR) has also improved the detection of PMTV (48). Even, RT-PCR that consist fluorescent in the test has rapidly improved the accuracy indetection and diagnosis of the Potato Mop Top Virus and combining these techniques such as ELISA and RT-PCR with traditional methods such as bait method to trapped Sss has proved effective in the detection of PMTV reported by the various researcher(21)(25)(27). RT-PCR assay that is used recently has targeted the Coat Protein gene in RNA2, which is secondary evidence for the detection of PMTV which was obtained by using primer set specific to target RNA2(44). It was shown that the RFLP analysis of RT-PCR products showed the confirmatory test that these products are derived from PMTV genes (27) (44) (47). Infected tissue when going through RT-PCT amplification has also been reported successfully for the detection of various plant viruses that infect the potato tuber. Variations within the other isolates of PMTV and recombination events between other isolates and strain could lead to the rapidly evolving of this virus (39). Analysis of the PMTV genome at the nucleotide level by using various molecular biology methods helps us in understanding the PMTV. Several researchers are also investigating the specific method which depends on the extraction of total macromolecule (TNA) from plant tissue and thus helps in the diagnosis and detection of various other plant viruses (46) (49).To manage such virus disease, proper identification, detection, and diagnosis plays a significant role in developing those practical solutions which can protect the plant from these pathogenic viruses.

Crop management strategies:

Crop management approaches such as using resistant varieties, transgenic crops, eliminating alternate hosts, use of mineral oils and, the use of insecticides, are previously reported by the researcher in various plant diseases(50).With the

advancements in molecular detection techniques which play a crucial role in controlling and managing PMTV in potato crops worldwide. PMTV show wide variation in symptoms of other cultivars of potatoes and uneven distribution of PMTV in plants and tubers show systemic infections in plant tissues and also other diagnostic assays of samples in plant tissues could help us to address the different stages of transmission of Sss(33)(43)(44). For effective control measures, implementation of diagnostic methods against soil-borne pathogens like PMTV, and other viruses mentioned by the various researcher (46) (48) (49). Availability of various commercial cultivar, ranging from sensitive to tolerant and these potato cultivars which are resistant to PMTV should be encouraged to use, tolerant selections should be done to get desirable agronomic characteristics and should be planted and be combined with those which lack tuber necrosis and used in various breeding programs that can introduce the resistance and tolerant species into Potato cultivars to market. Growers should avoid potato that is highly sensitive to PMTV tuber necrosis development (51) (52).To protect from these pathogens, strict action measures should be put in place which can prevent overspread of these soil-borne diseases. Evaluation of available cultivars for sensitivity should be highly encouraged to understand the biology of tolerant cultivars as well (51).

Control Strategy for PMTV:

Some control strategy for PMTV is mentioned below:
Soil moisture management could play an important role in reducing PMTV tuber necrosis symptoms in those cultivars which are highly sensitive to PMTV(51), To reduce disease stress, improving irrigation techniques, and improving drainage methods should be encouraged(52). Spores of Sss can swim in the water and thus this point should be kept in mind to use any appropriate methods. The use of certified seeds by government agencies /private industries should be encouraged sothat infection should be kept at a minimal rate and growers should avoid planting the potatoes seed where the history of viral infections has already been reported.
Also, a previous study shows that increase in nitrogen manure in the soil could help in the development of this disease (54). Don't utilize the manure from animals who have been fed with disease potatoes, the spores can often spread to fields or if this manure is used so it should be well composted (53). Crop rotation method should be used(53), use of various cultivars which are resistant to PMTV such as Russet(reddish-brown), proper information should be checked before planting the potatoes(51) as such there is no effective chemical treatment but the use of mancozeb may be useful to reduce the number of spores to control the disease(53)(54). Integrated disease management should be encouraged for control of PMTV disease.

CONCLUSION:

This review aims to show the detrimental effect of PMTV and its vector on potato which leads to reductions in yield and quality of tuber. The advancements in the diagnosis of PMTV could help to speed up the detection process and could help in controlling this damaging disease. The insecticide is ineffective against PMTV their impact measure to stop the vector from feeding and transmitting the disease to roots, encysts are less. Thus available evidence from genome analysis suggests that interactions between RNA genome components, their translation proteins and factors, and host elements are highly suitable for virus replication and transmission. To

minimize PMTV spread in potato crops integrated disease management methods should be encouraged as a management practice with low level or zero levels of PMTV. The interactions and evolution of PMTV understanding and its management strategy are going to be a crucial part of research in the next few years.

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