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A View on Potato Leaf Roll Disease and its Management

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Abstract

Potato leaf roll virus (PLRV) is devastating and widespread in potato fields. It is not only a cause of yield loss around the globe but also in Pakistan. Symptoms expression also characterize primary and secondary infection. Pathogen detection systems lead to the pathogen management system. Moreover, environmental conditions help make disease predictive model, leading to making plans to protect crops from the infectious virus infection. This review makes an overview of potato leaf roll transmission and its management. Symptomology and transmission of the virus through vector help are formulating the management strategies. The current literature helps the researchers to develop the genetical resistant and ecofriendly management against PLRV.

Keywords: Environmental conditions, Pathogen, Insect vector, Yield loss

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Introduction

Potato (*Solanum tuberosum* L; family Solanaceae) is the most popular vegetable and food crop worldwide. It attains 4th position after maize, wheat and rice in production. It is cultivated in more than 140 countries. It comprises 78% water, 2% protein, 1% vitamins, 18% starch, 1% vitamins and also contain several trace elements and fats (Haase, 2008), which show that it is more nutritive. It is also rich in carbohydrate (Iftikhar et al., 2020). It was originated from South America mountainous regions and from there it reaches to the all potato growing countries (Beukama & Eanderzaag, 1990). Spanish used the word patata wherefrom the word potato is derived. It is cultivated in tropical and subtropical zones of the world. It is highly nutritional and starch enriched food (Iftikhar et al., 2020). The potato originated from North America's mountains, and now it is being cultivated globally and consumed by more than one billion people daily (Haase, 2008). About 100 billion people are dependent on potatoes for their survival in the developing countries. Major potato producer countries are China, India, Russia, Ukraine, United States, Germany, Bangladesh, Poland, France and Belarus. It is believed that in Sub-continent (Indo-Pak), Purtgies introduced the potato and British encouraged the cultivation in the 19th century (Haq et al., 2016). In Pakistan, it is an important vegetable crop for the low-income community. Potato is dicotyledonous plant vegetative propagated through tubers (potato seeds) and grows 60cm high from the earth. Three crops, i.e., spring (Feb-April), summer (May-Aug) and autumn (Oct-Jan), are cultivated in Pakistan. Summer crop is cultivated in summer season in hilly areas (Qamar et al., 2015; 2016).

Potato is a cool-season and frost tolerant crop. Temperature plays an essential role in potato production. The optimum temperature for the growth of a young plant is 24ºC which produced tubers at 20ºC. Tuber production stops at the temperature of 30ºC. Tuber production is favoured by short day length. In Pakistan, climatic conditions for the production of potatoes are ideal. Potato is the most nutritious vegetable and cultivated throughout the world. In Pakistan, it is grown in both seasons, i.e., spring and autumn crop in plain areas and as a summer crop in cold hilly areas (Abbas et al., 2012).

The average world production of potato was 372 million metric tons (FAO, 2019). In Pakistan potatoes were cultivated on 179.3 thousand hectares with an annual production of 3849.5 thousand tons (Pakistan G.O, 2019). Potato is infected by several biotic and abiotic diseases (Khan & Abbas, 2008). Biotic factors include diseases caused by fungi, bacteria, nematodes and viruses. Among the biotic factors, forty viruses have been recorded which infect potato crop (Valkonen, 2007). In Pakistan, till now eight viruses have been recorded which are infecting potato crops. These eight viruses are Potato virus Y (PVY), Potato virus X (PVX), Potato leaf roll virus (PLRV), Potato mop top virus (PMTV), Potato virus S (PVS), Potato virus A (PVA), Alfalfa mosaic virus (AMV), and Potato virus M (PVM) (Mughal et al., 1988). Among these eight viruses, PVY, PVX and PLRV are causing severe losses to potato crop. Ahmad et al. (2003) recorded these

viruses in 169 potato fields of Pakistan. Among these viruses, potato leafroll virus (PLRV) is the most prevalent and severe viruses which causes 90% losses in the susceptible potato cultivars (Bhutta and Bhatti, 2002). Till now PLRV is a continuous thread to potato production worldwide including Pakistan (Peter et al., 2000; Zhang et al., 2010).

PLRV is the type species of the genus *Polerovirus* in the family *Luteoviridae* (Robert & Lemaire, 1999). The virus structure is icosahedral with the diameter of 24nm (Harrison, 1984). The genome of PLRV is positive-sense single-stranded RNA (+ssRNA) of about 5.9 kb size (Miller et al., 1997). Leaf-roll is the most predominant and disastrous potato disease that causes substantial harm in many countries worldwide. In the start of the present century, it was considered that the virus transmits this disease through grafting (Quanjer et al., 1916). After a few years, it was identified that the primary vector for this disease are aphids (Botjes, 1920). In Japan, this disease was first identified and reported by Hori (1920). Still, the occurrence of PLRV in potato by the tubers, by grafting, juice immunization and aphid vectors were first revealed by Kasal (1922). This virus is phloem limited, and it was also experimentally proving that it is also transferred through grafting or punching (Harrison, 1984). The occurrence of *Myzus persicae* was 1st reported in Pakistan during 1978 (Mirza, 1982). Symptoms caused by PLRV include the rolling of upper leaves in the current season by aphids also called primary infection. However, when the infected tubers are grown in the next season all the leaves including the tubers are infected by PLRV and the infections are known as secondary infections (Gul et al., 2013). In addition of the leaves rolling the leaves become yellow, dry, leathery, papery stiff and crispy. The quality and quantity of tubers are also reduced due to net necrosis (Ragsdale, 2001). In Pakistan, PLRV has become an emerging disease because of its high incidence in the field that is detected through ELISA (Mughal & Khan, 2003).

Potato leaf roll virus (PLRV) can be effectively managed by producing certified, healthy and virus free seeds, removing alternate hosts (weeds and other crops), and the diseased plants removal at the initial stages. The aphid management is also most essential to reduce the PLRV incidence (Alani et al., 2002). The best control of PLRV needs a combination of risk assessment and management strategy (Iftikhar et al., 2020). Knowing the catastrophic behavior of PLRV, it is necessary to regularly check the incidence in the potato fields as well as the population of aphids for the production of virus free potato crop and management of disease in the future.

Potato leaf roll virus

PLRV has now disseminated in all potato growing regions of the world. It is the extremely damaging virus of seed potato, fresh potato and processed potatoes. Moreover, the virus is transmitted by the aphids as well as through the infected tubers (Robert &

Lemaire, 1999). Previous studies have shown that 10 aphid species are involved in the transmission of the virus. Among these aphid species, *Myzus persica* has been known to be effective and efficient vector of PLRV. PLRV results in stunted plant growth which results in reduced tuber numbers and size. It also results in net necrosis which makes the tubers unsuitable for use and processing in the industry. PLRV infection in the seed potato also results in rejection of seed from the seed certification department (Radcliffe & Ragsdale, 2002).

Occurrence and distribution

Potato leaf roll virus damages tubers of the potato, fresh and processes potatoes of world. PLRV results in potato crop stunting and tuber number and size reduction, which results in low yield and quality. PLRV also results in internal net necrosis, resulting in a poor quality of potato and making it unfit for consumption and industrial processing (Radcliffe & Ragsdale, 2002). PLRV was first reported in Denmark and Germany in 1905. In Pakistan, it was the most damaging virus and yield-reducing agent in potato crops of Punjab (Ahmed & Ahmed, 1995). Later it has also disseminated to other provinces including Khyber Pakhtunkhwa, Sindh, Baluchistan and Gilgit-Baltistan (Khan & Abbas, 2008).

PLRV has severely damaged potato growing areas of Khyber Pakhtunkhwa province i.e. Peshawar (9.44%), Swat (9.45%), Dir (14.33%), Abbottabad (14.43%) and Mansehra (17.68%) of potato yield (Halim, 1999). The potato cultivation from infected tubers results in 60% potato yield reduction (Bhutta and Bhatti, 2002). PLRV results in 20-60% damage of potato crop in Punjab and Sindh (Batool et al., 2011). Abbas et al. (2012) reported 52.3% of average incidence of Potato virus M (PVM), Potato virus A (PVA), Potato virus S (PVS), Potato virus X (PVX), and Potato leaf roll virus (PLRV) from Faisalabad, Rawalpindi, Sahiwal and Islamabad.

Host range and symptomology

The most known PLRV hosts belong to the family *Solanaceae*. While few species were detected as host of PLRV which belongs to nine families of plants. These families include *Amarathaceae (Chenopodiaceae), Portulacraceae, Brassicaceae, Nolanaceae, Malvaceae, Lamiaceae, Asteraceae* and *Cucurbitaceae* (Tamada et al., 1984). Symptoms induced by PLRV includes rolling of upper leaves in the primary infection and rolling of all the leaves and net necrosis of the tubers in the secondary infections. In addition, the young buds become pinkish, purplish or yellowish in color. In severe condition, potato crops become stunted (Fig. 1).

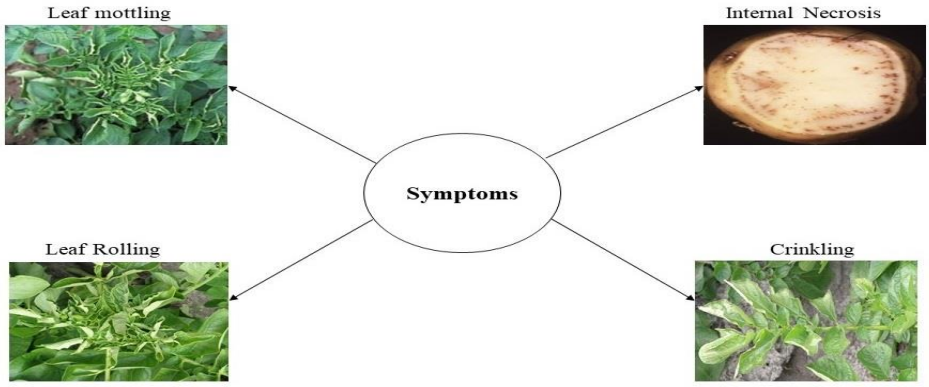

Figure 1. Characteristic symptoms of PLRV

Transmission of PLRV

The PLRV virus is not manually transmitted by inoculation with the cell sap nor transmitted through the seed but is transferred by the aphid vector or grafting. As PLRV is not transmitted through seed, the annual weeds were not considered an important source for transmitting the virus in spring season in cold regions (Thomas, 1983). In warm climate areas, the conditions were different, and the tuber forming and perennial weeds may serve as an alternate host for PLRV during the winter season (Fox et al., 1993). Potato leaf roll virus is transferred by aphid in the persistent, circulative, non-propagative manner (Harrison, 1984). As in the case with virus transmission persistently, the longer acquisition and time of inoculation, the higher the transmission rate of PLRV.

Virus transmission by persistently usually contains narrow vector range, are transferred on when vectors invade and require a period for infection. It was well understood that PLRV requires a host to replicate it in the vector (circulative-non propagative). For the transfer of PLRV, vectors must feed the potato plant phloem tissue. Naturally, PLRV only transmitted by a vector which is aphids and once acquire than the whole life it remains infective (Radcliffe & Ragsdale, 2002). *Myzus persicae* is the most efficient PLRV vector and can intake maximum viruses and abruptly transmit the virus to the plants event at warm climate (Syller, 1994).

Incidence of PLRV and disease

Potato leaf roll virus is the RNA virus which is single stranded (Harrison, 1984). The strains of potato, i.e., *Solanum tuberosum, Monita perfoliata* and *Physalis florida,* differ in disease severity and the ease in the attack of PLRV (Harrison, 1984). While the strains of potato were not antigenically different (Tamada et al., 1984). PLRV symptoms through primary infection (current season inoculation) in potato plants include pallor or

leaf tip reddening, leaf erectness and leaf rolling. Secondary symptoms from growing plants from potato tubers infected with PLRV include shoot stunting, moving leaflets upward, and the oldest leaves start rolling first.

The plants containing primary infection transmission is occurred from tubers variable portion, while the tuber plants containing secondary infection are viruliferous (Harrison, 1984). Kotzampigikis et al. (2010) studied the relationship between the potato leaf roll virus (PLRV) and *Myzus persicae*. The objectives were to determine the amount of inoculation, period of acquisition, retention and transmission time of PLRV by *Myzus persicae*. The plants jimsonweed and goose berry were used as indicator plants. It was found that after procurement of PLRV the *M. persicae* remains viruliferous for the whole period. The acquisition time was recorded as minimum 30 minutes to maximum 6 hours were recorded to acquire PLRV. Inoculation timing was about 30 minutes minimum to 120 minutes as maximum were recorded. Rahman and Akanda (2010) estimated the effect on the growth and yield of potato crop and incidence of PLRV after plantation of infected potato tubers. The treatments included seed tubers infected at the rate of 10, 20, 30 and 100% with the PLRV. It was found that inoculation of PLRV at all of this concentration significantly enhances disease incidence and reduced the plant height, number of tubers and tuber yield as compared to control nontreated potato crops. Ahmad et al. (2011) experimented on forty potato cultivars to investigate the influence of PLRV on them. They used serological method i.e. ELISA (Enzyme linked immune sorbent assay) to analyses the infection of potato crop caused by PLRV. Among the tested cultivars, four cultivars were recorded resistant while seven were recorded highly resistant and nineteen cultivars were found to be highly susceptible to PLRV. PLRV results in chlorosis, leaf rolling, leaf leathering, potato tubers net necrosis, reddening and potato crop stunting (Alani et al., 2002). The plants infected during the early growing season showed stunted growth and are dwarf. If the plants were affected by virus during the late growing season, they did not show any disease occurrence symptoms, even though they did not show foliar symptoms. With the passage of age, the plants showed resistance to foliar symptoms of virus, but the host cells contain virus particles in it (Erik et al., 1993). PLRV transferred by phloem of the plant to the tubers. After that virus reduces potato size and results in net necrosis. Tuber necrosis or net necrosis is the browning or darkening of vascular bundles which extends through the tubers of potato. Tubers of potato containing net necrosis symptoms had low quality and undesirable fries and chips processing (Scagliusi, 2000).

PLRV is transmitted by aphids in a circulative, non-propagative and persistent manner (Thomas, 1987). PLRV is restricted to phloem a cell that's why it requires maximum time to transfer in aphids (Ragsdale et al., 2001). Kotzampigikis et al. (2010) estimated the relationship between virus-vector in potato. The optimum time of *Myzus persicae* acquisition of PLRV is 6 hours, while the 30 minutes is minimal time. While the virus

completes 6 hours in the host as a latent period and then optima period of PLRV inoculation is 120 minutes in *Myzus persicae* is and 30 minutes is minimal.

Role of environment on disease development

Environmental factors play an important role in disease development (Mubeen et al., 2017). Mirza et al. (1982) revealed that that Aphid (*Myzus persicae*) present in yellow traps toward the finish of October in 1977, mid of January 1978 and mid of December in 1981. From July to September, there was no aphid action recorded. There were low flights of aphid in October and December, and this was the pre-winter trim season. Ismail (1983) directed a varietal trial for yield potential and aphid population. He found that verity chieftain, patroness, and Atlantic show better performance than others. Aphid was collected from two areas on yellow traps. In early August, the aphid starts appearing.

The most significant number of aphids was recorded on yellow traps during the august and concluded that virus chances were maximum this month. Muhammad (1990) reported significant potato infection, i.e., potato infection Y, potato infection X and potato leaf roll infection in the entire potato sowing ranges of KPK i.e., Bunair, Swabi and Pabbi. Le Romancer and Kerlan (1991) coined that Potato infection Y causes shallow ring spot putrefaction in potato tubers. The first time this illness was seen in Lebanon in 1988 on Lola potato seeds. Ahmad et al. (1995) inspected many fields. They observed that Potato Virus (PVY), Potato leaf roll infection (PLRV), and Potato infection X (PVX) was a severe danger of Punjab region in pre-winter season. From the 169 fields, they collected 1277 samples of viral infections. ELISA test was performed to appraise illnesses and found that PLRV, PVX, and PVY were available in all areas. Khan (2001) studied three most deleterious potato infections PVY, PLRV, PVX and their vectors. He additionally finds the relationship of PLRV and PVY vector with natural conditions. Aphid population and severity of disease in five different varieties were recorded and subjected to relationship examination with various ecological conditions.

The general relationship of least and most extreme air temperature and wind speed with extreme infection of PVY, PLRV, and PVX was high; however, relative humidity and precipitation negatively connected with disease incidence. Al-Mutahid et al. (2001) directed two distinct examinations for delivering infection-free (tissue cultured) plants by utilizing heat treatment from grew tubers and from sprouts of controlled potato plantlets. Four groups of contaminated plantlets with potato infection y, potato infection s, potato infection x, and potato leaf roll infection were made visible to temperatures of 25ºC-40ºC for the day, and they applied the heat treatment of 4 hours for 15 days in each group. They recorded 100% removal of PVY, PLRV, PVX and 91.7% of PVS under varying temperature. Ahmad (2003) utilized 15 lines against Potato virus Y (PVY) and

Potato leaf roll infection (PLRV), and none of the assortment was observed to be resistant against PVY and PRLV. The lines i.e., FSD-Red, Desiree x juse B, 384636-1, Cardinal, 9616 and 9620 was Moderate resistance to PLRV. Moderate susceptible reaction to PLRV was appeared by the lines, TPS-9801, Dura, TPA, 9808, Sante, 3384093-844, 384640-3, SH-5, Desiree and 9804. The weekly association of least and greatest air temperature, wind speed, relative humidity, the direction of wind and evaporation pan with PLRV incidence was checked at a different level. None of the lines showed a significant association with the direction of wind and wind speed. High temperature showed a significant correlation in 13 lines. Relative humidity showed association with eleven lines. The most extreme disease incidence was recorded at 80-86% relative humidity 11-13ºC the least temperature and 25-28ºC most significant temperature, and evaporation pan was 2-2.9mm.

Control measures of PLRV

PLRV can be managed by different strategies mentioned in Table 1.

Table 1. Disease management strategies

Disease Management								
Genetic Resistance		**Vector Control**			**Cultural Practices**			
Resistant Varieties	Grafting	Plant Activators	Plant Extracts	Synthetic Product	Crop Rotation	Sowing Time	Nutrient Management	Soil Sterilization

Many ways can control green peach aphid; all of these ways rely on chemical use. The optimum threshold level of green peach aphid is when the population reaches five adult aphids with wings caught from each trap (i.e., Moericke's or yellow water trap) per week. The other ways are the presence of 5-10 wings, fewer aphids from 100-leaves (Schreiber et al., 2003). In recent years, it was observed that most insects are showing resistance against the insecticides (Gelski, 2001). While the use of extensive chemicals also results in loss of natural enemies, which resulted in an increased population of aphid (Rowe, 1993).

The use of granular and systemic insecticides applied during planting time develops resistance in plants against aphid during the most susceptible and critical growth stages of potato (Powell & Mondor, 1976). The use of biological control (aphid natural enemies), i.e., parasitic wasps, lacewings, lady beetles, predacious midges and ladybugs and some pathogenic fungi reduced the population of and maintained their threshold level (Bailey, 1993). Conditions of weather also contributed to control the population of

aphids. So, the crop plantation during the period, which is not suitable for aphid productivity is the most important to control its population (Barlow, 1962). The most effective physical method for controlling PLRV is the isolation of potato seed tubers from the commercial potatoes. This will control the PLRV speeds to the next crop (Radcliffe & Ragsdale, 2002).

The distance of separation different for different locations and environments, but it is suggested that the distance should be greater than 30 km (Radcliffe & Ragsdale, 2002). Isolation can be achieved by fluctuation in planting and harvesting from the seed tuber potatoes and commercial potatoes (Ragsdale et al., 2001). Late plantation (*Myzus persicae* colonizing flight) is the best way to control the spread of PLRV (Hanafi et al., 1995). But the drawback of the delayed plantation is the reduced tuber size and yield of the tuber. Roughing of diseased/infected plants is also proved as the best strategy for the control of PLRV.

It was observed that in the USA, the removal of PLRV infected plant removal from the field saves the other plants from PLRV infection and appearance of disease symptoms (Mowry, 1994). But this way is only applicable in field conditions, where the file is large, and PLRV symptoms are minute (Mowry, 1994). Whitewashes also reduced the incidence of PLRV in tubers, but whitewashes showed less control efficacy than covers of the white net (Marco, 1986). However, covers of crop result in yield reduction (Marco, 1986). If any aphid penetrates in covers, it results in virus spread, and sometimes virus spread may be harmful due to delayed control measures. So, this crop cover strategy is not liked among farmers due to the abrupt spread of virus and high crop cover expenses. The 38% reduction if PLRV incidence was also reported from mechanical barriers (polyethene sheets with sticky material) (Marco, 1981).

Weeds and wild potatoes are most important alternate host for aphids and also play role in the dissemination of PLRV (Thomas & Richards, 2004). Many natural plant species in South African are the efficient source of the inoculum of the virus. However, it was found that potato plantation in the field containing 1-4% PLRV infection served as inoculum for the spread of PLRV in these areas compared to weeds (Ragsdale et al., 2001). Therefore, the fields of potato are likely to be greatest PLRV inoculum source in South Africa. Rotation of crop is also the most important way to reduce the incidence of PLRV (Mowry, 1994). The storage conditions of tubers are also observed as a source for the spread of PLRV. It was observed that potato storage for longer periods might result in disease spread in potatoes, which can serve as a source of disease spread to the next crop. The net necrosis probability in tubers was maximum when the storage exceeded to 90 days (Marsh et al., 1998).

Systemic insecticides or foliar insecticides applied at an accurate time are best to minimize within-field PLRV spread, especially when the aphid's virus-free aphids' colonies have arrived. Some insecticides like carbamate aldicarb control the PLRV

within-field spread compared to apteral, but it does not prevent the transmission compared to alatae (Ragsdale *et al.*, 2001). The chloronicotinyl insecticides classes imidacloprid and new insecticides pymetrozine showed the best control for within-field PLRV spread (Ragsdale et al., 2001). Imidacloprid systemically applied reduces the spread of PLRV (Boiteau & Singh, 1999). The biology of aphid and its arrival time determines the insecticide application timing for controlling PLRV incidence on seed potatoes (Ragsdale et al., 2001). The control of vector (*M. persicae*) is primarily considered as it is most efficient among vector colonizing species of potatoes (Ragsdale *et al.*, 1994).

The threshold of *M. persicae* should be checked 10 per 100-leaves, but this threshold may vary from region to region (Mowry, 1994). The weekly survey was done to prevent the aphid population (Radcliffe & Ragsdale, 2002). But some authors recommend that instead of weekly a 3-4-day monitoring program for aphid is essential and most practical (Mowry, 1994). As at 3-4 days monitoring the insect attack was monitored on time, and the farmers get maximum time to adopt the control measures against aphids spread and control the PLRV incidence (Mowry, 1994). To prevent the PLRV spread, the potato seeds policy of zero-tolerance was adopted in Idaho (Mowry, 1994). Such a strategy may be harmful to the environment and develop insects' resistance against insecticides (Mowry,1994). But there is a drawback for the extensive use of chemicals that pollute the environment and increase the production cost of potato, resulting in the farmers' economic losses. So, it is recommended that the use of chemicals should be minimized and the new and economical ways should be used to control these insects and reduce the PLRV incidences (Marsh et al., 1998).

Some biochemical and repellents like neem (azadirachtin), morinaga leaf extract, biter gourd extracts and other allelochemicals obtained from plants should be used and shown better results toward control of PLRV incidences on potato (van den et al., 1998; Nisbet et al., 1996). These extracts may be used in essential oils and sprayed on the plant leaf surface (Cranshaw & Baxendale, 2005). Commercial cultivars of potato did not show resistance (immunity) to the incidence of PLRV, but few (Norgold Russet) are resistant against the net necrosis of tuber (Thomas et al., 1987).

Genetically modified cultivars of potato showed resistance against the incidence of the PLRV and stopped its spreading to the other plats. Furthermore, these cultivars also showed resistance to *Myzus persicae* and prevent their occurrence on the plants by some morphological, physiological and biochemical feature of the plants which are not proffered by the insects or dangerous for the insects which feed on them (Thomas et al., 2004). The PLRV incidence in tubers is more in most of the areas of growing tubers. It will take many years to stop/decline the inoculum level of virus and stabilize the lower yield losses due to PLRV facing today (Radcliffe & Ragsdale, 2002).

Conclusion and future aspects

The above review suggested that the PLRV is a severe problem in the potato growing areas, and it should be adequately controlled on an emergency basis. If it is not controlled, then that is sure that in a few years. Genetically, modified cultivars of potato used for resistance against PLRV. The use of ecofriendly strategies may help to environment and also develops resistance against vectors. The biochemical and allelochemicals which will obtain from plants use toward control of PLRV.

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