Journal of Pharmacognosy and Phytochemistry
Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2017; 6(5): 1911-1914
Received: 10-07-2017
Accepted: 11-08-2017

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Papaya ring spot disease management: A review

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Abstract
Papaya Ring Spot Virus (PRSV) is one of the major obstacle for boosting papaya production in the country. Until now there is no absolute curative control measure available through conventional methods. Precautionary measures for PRSV incidence *viz.* rouging, cross protection, vector controls etc. are not much helpful. The, transgenic (GM) papaya varieties *viz*. Rainbow and SunUp were developed at Hawai in 1998. However, in the present scenario, in countries like India where there is legal restrictions on research on genetically modified (GM) food crops, introgression of the PRSV-P resistance gene into *C. papaya* from its wild relatives (species of *Vasconcellea*) is the one of the optimistic option available with researchers.

Keywords: Papaya Ring Spot Virus, papaya production, food crops

Introduction
Papaya (*Carica papaya* L) belongs to the family Caricaceae is one of the most important fruit crops of the country. The origin of papaya is Southern Mexico [1]. It is cultivated in the USA, India, Brazil, Mexico, Nigeria, Jamaica, Indonesia, China, Taiwan, Peru, Thailand, and the Philippines [2]. Papaya fruit is known for its high nutritive and medicinal value [3]. It is a richest source of vitamin A, B, C and proteolytic enzymes *viz.* papain, chymopapain *etc*. Beta carotene helps in prevention of cancer, diabetes, and heart diseases [4]. Ripend fruits are usually eaten fresh and can be processed into jam, jelly, marmalade and candy. It is also used in the pharmaceutical and cosmetic industries [5].

Presently not only counties but also worldwide papaya production industry is threatened by most serious disease i.e. papaya ring spot disease [6]. It is caused by papaya ringspot virus (PRSV), it is a member of the genus potyvirus [7]. Symptoms of PRSV are prominent mosaic pattern on the leaf lamina, wet-oily streaks on the petioles and on the tree trunk, and complete distortion of young leaves. The fruit exhibits bumps and the classic "ringspot". This leads to 50 % or even more reduction in fruit production.

PRSV has been recognized as a destructive disease in many tropical and subtropical areas *viz.* USA, South America, Africa [8], India [9], Thailand, Taiwan, China and the Philippines [10], Mexico [11], Australia [12], Japan [13], French Polynesia, and the Cook islands [14] resulting in the decline in fruit production. This disease leads to 100% losses of crops [15].

Genatics
Papaya ringspot virus (PRSV) is an aphid transmitted plant virus belonging to the genus Potyvirus, family Potyviridae, with a positive sense RNA genome. Its isolates belong to either one of two major strains, P or W. The P strains infect both papaya and cucurbits whereas, W strains infect only cucurbits Virions are filamentous, non-enveloped and flexuous measuring 760–800 x 12 nm. Virus particles contain 94.5% protein and 5.5% nucleic acid. The protein component consists of the virus coat protein, which has a molecular weight of about 36 k Da as estimated by Western blot analysis. Density of the sedimenting component in purified PRSV preparations was 1.32 g/cm 3 in CsCl. Its genome composed of a unipartite linear single stranded positive sense RNA of 10 326 nucleotides with a 5 terminus [6].

Transmission
This virus is transmitted by aphids in a non-persistent manner. It is a non-persistent virus, means it does not enter beyond the feeding mouthparts of the aphid and does not circulate or multiply within its insect host. Non-persistent viruses are transmitted quickly and easily between plants. Many species of aphid can transmit PRSV, particularly the *Myzus persicae* and *Aphis gossypii*. The acquisition and transmission of infectious PRSV virion particles occurs during the brief period when the aphid superficially probes into the plant. Two virus-encoded proteins, CP and HC-Pro, are required for this process [17-20].

In addition to this it is also reported that, this virus can also be transmitted mechanically, and stated that it is typically not seed-transmitted [6].

Hosts

This virus has limited number of hosts belonging to the families Caricaceae, Chenopodiaceae, and Cucurbitaceae. The propagation hosts of PRSV are *C. papaya, Cucurbita pepo,* and *Cucumis metuliferus*. The lesion assay hosts of PRSV are *Chenopodium quinoa* and *Chenopodium amaranticolor* [6].

PRSV management

There is no known resistance to PRSV, although certain varieties are more symptomatic than others. There are four main methods of control for PRSV, quarantine and geographic displacement, rouging and netting, cross-protection, and genetic modification of the host plant. Because PRSV is a non-persistent virus and is consequently transmitted to healthy plants by aphids within a very short time period, insecticidal control is difficult and impractical. Once symptoms have been observed, it is already too late to spray for aphids the disease has most likely already been transmitted to nearby healthy plants. In order to implement successful vector control, frequent preventative sprays are required.

Prevention through quarantine and geographic displacement of cropland is common and has occurred in Hawaii, the Philippines and Brazil [21]. When fields become infected, such as the case of Oahu papaya growers, attempts to relocate growing areas to virus-free fields are made. This is usually just a temporary avoidance of the disease, which eventually spreads to the new fields.

Roguing

Roughing or the removal and destruction of infected plants, is a way to control the spread of PRSV. However, it is difficult to control the spread of PRSV through rouging because it is spread very quickly and effectively by aphids. This method can also leads to heavy economic losses.

Use of aphicides

PRSV is transmitted through the aphids. Hence, control of aphids spread in the orchards is one of the ways to control spread of the virus. The aphid management at regular interval should be started at nursery stage. It can be done by using systemic insecticides. These systemic insecticides *viz.* carbosulphan, imidacloprid, acetamiprid *etc.* should be used in low concentrations at nursery stage and at regular concentrations at field stage. This can be a effective way of PRSV control at its source. However, it is very difficult to control the aphids at field level. Hence, this method is not much effective.

Netting

This can also be used to prevent insect vectors from spreading the virus. Production under netting is prohibitively expensive for subsistence and small-scale producers [22] but was used effectively in Taiwan because geographical displacement was not possible on such a small island [23].

Planting time

Planting time also plays a key role in PRSV disease management. It was observed that during lean period of vector population there was less incidence of the disease. An experiment conducted to study the aphid population and its impact on incidence of papaya ring spot virus by planting papaya during different months of the year. The population monitoring of aphid vectors of PRSV-P indicated peak population of aphids in January and low population from March onwards till September. Papaya (Red Lady) planted from February to April showed significantly less incidence of PRSV-P compared to those planted from September to January [24]. In a similar experiment on planting papaya during the lean period of aphid-vectors population (spring season), PRSV infection was delayed till monsoon, by that time plants had crossed fruit bearing stage. PRSV infection till flowering was minimum on plants transplanted in early spring (18.25%), followed by mid (22.91%) and late (33.33%) spring. Border crop of banana reduced aphid population in papaya plantation from 31 to 18 aphids/trap. Papaya production increased marginally in the vicinity of uprooted infected plants [25].

Cross protection

Cross protection was used to control PRSV which involved the use of a mild virus strain against economic damage caused by severe strains of the same virus [26, 27]. Development of cross-protection in papaya was researched in Hawaii starting in 1979. A delay in the onset of symptoms was achieved, as well as a reduction in the severity of symptoms. However, inoculation of the mild strain also caused pathogenesis on the papaya plants [28]. Cross protection depends on the availability of mild strains that can be used for effective protection against the target virus. Cross protection needs extra agricultural practice and care. However, strain specificity and the technical difficulties associated with propagating pure strains of mild forms of the virus and the unavailability of such mild strains limit the benefits of this [29].

Convectional breeding

Resistance levels of PRSV differ with environmental factors and plant development stages. Broad spectrum resistance against different PRSV isolates depends on the homology of transgenes with viral target genes and the genetic divergence of different PRSV strains which are correlated with their geographical distribution [30]. The papaya varieties resistant to PRSV against different viral strains must be developed individually for various papaya growing regions. The development of PRSV resistant lines is generally considered the best strategy for efficient PRSV disease control in papaya for long-term protection [31], Introgression of the PRSV-P resistance gene into Carica papaya from its wild relatives (species of *Vasconcellea*) is the most optimistic option available with researchers. In this context, PRSV resistance from *Vasconcellea* cauliflora has been transferred to papaya cultivar Washington to some extent in Maharashtra, India [32].

Transgenics

Resistance to viral disease may be developed through genes derived from viral sequences providing pathogen derived resistance (PDR), genes from various other sources that can interfere with target virus, and natural resistance genes. The concept of pathogen derived resistance (PDR) is a new approach for PRSV management. Pathogen derived genes interfere with the replication process of viruses in their host plants in different ways. So far, PRSV-resistant transgenic papaya has been developed through coat protein (CP), RNA silencing, and replicase gene technology.

There are two transgenic varieties of papaya, both of which were created by Dennis Gonsalves and his team and were introduced for production in May 1st 1998 [33]. Rainbow (created by Dennis Gonsalve) is an F_1 hybrid, which is a cross between the yellow fleshed Kapoho and the red-fleshed SunUp. Rainbow is produced on 76% of Hawaiian papaya acreage, while SunUp is hardly grown commercially. SunUp is thought to be more resistant to exotic strains of PRSV, while Rainbow has shown susceptibility to such exotic strains of the virus. (Fermin *et al* 2010) Transgenic varieties have been shown to be extremely effective against Hawaiian strains of PRSV, showing complete resistance to the virus compared to 100% infection of susceptible strains in some trials [34].

Biosafety issues concerning GE papaya

Even after 17 years of release of transgenic papaya, there is no report on its adverse effect on environmental biosafety issues. The emergence of undesirable virus isolate due to transgenic papaya has not been observed so far. Recombination refers to the exchange of genetic materials between two RNA molecules during virus replication.

A recombinant virus has potentially negative effects on the environment such as increasing pathogenicity, expanding host range and changing the vector [35]. The Thai transgenic papaya lines containing PRSV-P *cp* gene were tested for possibility of infection by PRSV-W super infecting strain under containment [36] However, ELISA results revealed complete absence of PRSV-W. It was clearly found that transencapsidation in the GE papaya lines did not occur during artificial PRSV-W conditions [37].

Conclusion

PRSV is the major threat for papaya industry worldwide. Transgenic papaya through gene technology has been used for PRSV disease management. The breakdown of PRSV resistance is the major challenge facing transgenic papaya cultivation. The adoption of PRSV-resistant transgenic papaya is still slow and it depends upon the demand for papaya, biosafety regulations, and social acceptance of the technology. Earlier studies indicate that PRSV-resistant transgenic papaya is environmentally safe and has no adverse effects on human health. Review conclude in addition to convectional breeding methods it is necessary to develop PRSV resistant transgenic papaya using their own PRSV strains.

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