

CHAPTER IV

CASSAVA MOSAIC VIRUS TRANSMISSION CHARACTERISTICS OF THE WHITEFLY (*Bemisia tabaci* (Gennadius))

4.1 Abstract

SLCMV is transmitted by the whitefly *B. tabaci* and represents a major threat to cassava production. This study investigated the transmission characteristics of SLCMV by *B. tabaci*, focusing on the AAP, LP, and IAP. Transmission assays revealed that SLCMV acquisition by *B. tabaci* required a minimum of 24 h, with transmission efficiency increasing substantially after 48 h. The experimental results did not indicate the presence of a latent period. Inoculation followed a similar time-dependent pattern to acquisition, with SLCMV detected in cassava plants after a 24 h inoculation access period. Furthermore, cassava plants inoculated with SLCMV by *B. tabaci* during a 48 h inoculation access period developed CMD symptoms at 65 days post-inoculation. These findings demonstrate that successful transmission of SLCMV by *B. tabaci* depends on extended acquisition and inoculation periods and provide essential information for understanding SLCMV epidemiology and improving disease management strategies.

4.2 Introduction

Cassava is a starchy, nutty-flavored root crop native to South America and is now widely cultivated across the tropics. It is notable for its ability to thrive in poor soil conditions and withstand drought, making it a vital food and industrial crop in many developing regions. Cassava is processed into diverse products, including food, flour, animal feed, starches for paper and textile industries, sweeteners, alcohol, and biodegradable materials. Despite its economic and nutritional importance, cassava productivity is seriously constrained by pests and viral diseases, particularly CMD.

CMD is recognized as one of the most devastating diseases of cassava, with widespread impacts reported in Africa, India, Sri Lanka, and SEA (Legg et al., 2015; Wang

et al., 2019). Within SEA, CMD has been documented in Vietnam, Thailand, and China (Wang et al., 2019). The causal agent in CMD-affected samples from the region has been identified as SLCMV (Saunders et al., 2002). The virus spreads through infected stem cuttings and via whitefly vectors, particularly *B. tabaci* (Calatayud et al., 1994a). CMD symptoms include leaf distortion, chlorotic mosaic, mottling, and severe stunting of plant growth compared with healthy plants (Chikoti, 2011). Yield reductions may reach 40%, and under severe epidemics, total crop failure can occur (Legg and Fauquet, 2004).

The whitefly *B. tabaci* (Hemiptera: Aleyrodidae) is a principal vector of CMD (Legg et al., 2011) and is also responsible for transmitting more than 200 plant viruses, most of which belong to the genus *Begomovirus* within the family Geminiviridae (Navas-Castillo et al., 2011; Lu et al., 2019). Economically important crops affected by *B. tabaci*-transmitted viruses include cassava, tomato, cucumber, cotton, cowpea, crucifers, eggplant, tobacco, potato, soybean, sweet potato, okra, lettuce, pea, bean, pepper, poinsettia, and chrysanthemum (Jones, 2003). Examples include CCYV, which causes CCYD (Okuda et al., 2010); TYLCSV, which causes TYLCD (Navas-Castillo et al., 2011); and MYMV, the causal agent of MYMD (Malathi and John, 2009).

Successful virus transmission by insect vectors depends on three critical phases: the AAP, the LP, and IAP (Purcell, 1982). For instance, transmission of ICMV by cassava-biotype *B. tabaci* requires both an AAP and an IAP of 48 hours, as confirmed by serological and PCR assays (Antony et al., 2006). In contrast, ToLCBV transmission occurs within 15–30 minutes of an AAP, with transmission efficiency reaching 100% when the AAP exceeds 16 hours (Chowda-Reddy et al., 2012). Similarly, transmission of ToYVSV involves an LP of 16 hours and an IAP as short as 10 minutes in *B. tabaci* (Firmino et al., 2009). These parameters illustrate how vector-borne biology strongly influences viral epidemiology.

Despite the global significance of CMD, information regarding the transmission characteristics of CMV and the host preference of *B. tabaci* for cassava cultivars in Thailand remains scarce. Such knowledge is crucial for understanding vector–pathogen–host interactions and for designing effective disease management strategies. Therefore, this study was conducted to (i) determine the transmission characteristics

of *B. tabaci* as a vector of CMV and (ii) evaluate the host selection behavior of *B. tabaci* on cassava cultivars. Insights from this research will support the development of targeted control strategies for *B. tabaci*, help reduce CMD incidence, and ultimately improve cassava productivity.

4.3 Materials and methods

4.3.1 Insect colonies

Adult *B. tabaci* were collected from a cassava field at Suranaree University of Technology, Nakhon Ratchasima Province, Thailand, using an aspirator between 09:00 and 16:00 h. After collection, the insects were transferred to cucumber plants (*Cucumis sativus*), a suitable host for *B. tabaci*, and maintained in plastic mass-rearing cages (5.5 inches in diameter × 30 inches in height). The whitefly colony was mass-reared under controlled conditions at 28 ± 2 °C and 65–73% relative humidity in the Entomology Laboratory, Suranaree University of Technology.

To ensure the genetic purity of the *B. tabaci* colony and to confirm the absence of *Sri Lankan cassava mosaic virus* (SLCMV), PCR screening was conducted every 3–5 generations using AV1 gene-specific primers, following the method described by Saokham et al. (2021). The primers used were AV1 forward (5'-GTT GAA GGT ACT TAT TCC C-3') and AV1 reverse (5'-TAT TAA TAC GGT TGT AAA CGC-3').

4.3.2 Maintenance of plants

The cassava cultivar CMR 89 was used for maintaining SLCMV isolates and for virus transmission experiments. Cassava stem cuttings used in this study were collected from a field in Nakhon Ratchasima Province, Thailand. Thirty-day-old cassava plants propagated from these stem cuttings were selected for experimental use. The presence of SLCMV was confirmed by PCR using AV1 gene-specific primers, following the method described by Saokham et al. (2021).

Following PCR confirmation of SLCMV infection, cassava plants were classified into infected and non-infected groups. Healthy and infected cassava plants were individually transplanted into plastic pots and enclosed in plastic mass-rearing cages (5.5 inches in diameter × 30 inches in height) to prevent unintended transmission of viruses by whiteflies. All plants were maintained under semi-greenhouse conditions

at the Entomology Laboratory of Suranaree University of Technology, for subsequent experimental use.

4.3.3 Acquisition Access Period (AAP) Study

A CRD was employed for the AAP experiment. Six acquisition time treatments (0, 4, 6, 12, 24, and 48 h) were evaluated, with each treatment consisting of 10 replications. Each replication included 10 adult *B. tabaci* (2–3 days old), resulting in a total of 600 whiteflies. The whiteflies were allowed to feed on 60 SLCMV-infected cassava plants, with 10 whiteflies confined to each plant per acquisition period. Whiteflies fed on non-infected cassava plants served as the control.

Following the acquisition period, whiteflies from each replication were collected and placed individually into tubes, preserved in acetone, and stored at –20 °C until further analysis. PCR was performed to detect the presence of SLCMV in both whiteflies and cassava plants. The number of PCR-positive samples was recorded and subjected to statistical analysis using the least significant difference (LSD) test at the 0.05 significance level. All statistical analyses were conducted using SAS® OnDemand for Academics.

4.3.4 Latent Period (LP) Study

The LP experiment was also conducted under a CRD with five treatments, 10 replications, and 10 whiteflies per replication (total of 500 adult whiteflies *B. tabaci*). The whiteflies were fed on 50 infected cassava plants at the optimal AAP time. After acquiring the virus, the whiteflies were transferred to non-infected cassava plants to determine the latent period. Then, 500 adult whiteflies were released onto non-infected cassava (1 cassava per 5 whiteflies) for 0, 1, 3, 5, and 7 days. At the end of each period, the insects were divided into two groups: one was preserved in acetone and stored at –20 °C for PCR detection of SLCMV. The second group (5 whiteflies per treatment) was transferred to cages containing non-infected cassava (1 plant per 5 whiteflies). After one month, symptoms of CMD were observed, and leaf tissue was collected and stored at –20 °C for PCR analysis. Data from both whiteflies and cassava were analyzed using LSD at the 0.05 significance level. Statistical analyses were conducted using SAS® OnDemand for Academics.

4.3.4.1 Fluorescent In *Situ* Hybridization (FISH) in whitefly

This experiment included five treatments, three replications, and 10 whiteflies per replication. A total of 150 adult *B. tabaci* were fed on 15 infected cassava plants (10 per plant) at the optimal AAP time. After feeding, insects were sampled at 0, 1, 3, 5, and 7 days of LP and preserved in acetone.

Whiteflies were then immersed in PBS, and the abdomens were pricked under a stereo microscope to facilitate solution infiltration. Fixation was performed using Carnoy's solution (ethanol:chloroform : acetic acid, 6:3:1) overnight on a shaker. Autofluorescence was removed by immersing samples in 6% hydrogen peroxide in 100% ethanol in the dark for 1–3 weeks.

Subsequently, the samples were washed with 100% ethanol, PBST, and hybridization buffer for three rounds (each for 10 minutes). Hybridization with CY5-labeled probes against SLCMV was conducted overnight at 42 °C. After hybridization, samples were washed with PBST and mounted on slides using Prolong antifade reagent. The slides were stored overnight in the dark at room temperature and then analyzed using a confocal laser scanning microscope (Roddee et al, 2018a).

4.3.5 Inoculation Access Period (IAP) Study

This experiment was conducted using a completely randomized design (CRD) with six transmission time treatments (0, 4, 6, 12, 24, and 48 hours), each comprising 10 replications with 10 adult *B. tabaci* per replication. A total of 600 adult whiteflies were initially allowed to feed on 60 SLCMV-infected cassava plants, with 10 whiteflies per plant, under the optimal acquisition and latent period conditions determined from previous experiments (AAP = 24 hours; LP = 0 hours).

After the acquisition phase, the whiteflies were transferred to non-infected cassava plants at a density of one plant per 10 whiteflies and allowed to feed for the designated transmission periods (0, 4, 6, 12, 24, and 48 hours). Disease symptoms on cassava plants were assessed 1 month after inoculation. Leaf tissue samples were subsequently collected and stored at –20 °C for the detection of SLCMV using PCR.

4.3.6 Insect DNA Extraction

Ten whiteflies (whole body) were placed in 1.5 µl tubes, and DNA extraction buffer was added. The insects were ground, then incubated at 37 °C for 24 hours in a shaker. A phenol: chloroform: isoamyl alcohol mixture was added and mixed, followed by chloroform: isoamyl alcohol. Tubes were centrifuged at 13,000 rpm, 4 °C for 5 minutes.

Sodium acetate (3M) was added, and the mixture was stored at -20 °C for 30 minutes. DNA was precipitated using isopropanol and stored at 4 °C for 2–3 hours. The pellet was washed with 70% ethanol, centrifuged, and air-dried. TE-RNase buffer was added, and tubes were incubated at 37 °C overnight. DNA concentrations were measured for PCR analysis.

4.3.7 Cassava DNA Extraction

Leaf tissues were cut into small pieces, washed with 4% Clorox, rinsed with DI water, and ground into powder. About 0.1 g of tissue was transferred into a microtube containing 600 µL of 2% CTAB buffer. The mixture was incubated at 65 °C for 1 hour, then cooled to room temperature and mixed with 500 µL of chloroform: isoamyl alcohol (24:1).

After centrifugation (13,000 rpm, 10 minutes, 4 °C), the aqueous phase was transferred to a new tube, and 350 µL of cold isopropanol was added. DNA was precipitated, washed with 70% ethanol, and air-dried. TE-RNase buffer (100 µL) was added, and the tubes were incubated at 37 °C for 24 hours. They were then stored at -20 °C for future PCR use.

4.3.8 PCR amplification for insect and cassava tissue

PCR amplification was carried out in 20 µl reaction volumes containing 1x PCR buffer, 0.2 µM of each primer, and ~50 ng of DNA template. The thermal cycling conditions were as follows: initial denaturation at 94 °C for 5 minutes, followed by 35 cycles of denaturation (94 °C, 40 s), annealing (55 °C, 40 s), and extension (72 °C, 40 s), with a final extension at 72 °C for 5 minutes. A 1% agarose gel was prepared by dissolving 1 g of agarose in 100 mL of TAE buffer. The solution was microwaved, mixed with Safe-Red (4 µl), and then poured into a gel box, where it was allowed to solidify.

After gel casting, the PCR products, mixed with loading dye, were loaded into the wells. Electrophoresis was performed at 100 V for 40 minutes. Gels were then visualized.

4.4 Results

4.4.1 Acquisition access period (AAP) study

The different AAPs for the percentage of virus-infected whiteflies were evaluated. As shown in Table 1, no whiteflies were found to be infected after 0, 4, 6, or 12 hours of AAP (0/100; 0%). In contrast, 40 out of 100 whiteflies (40%) were infected after 24 hours of virus acquisition, and this number increased to 80 out of 100 whiteflies (80%) after 48 hours of exposure.

Table 4.1 Transmission of SLCMV by *B. tabaci* after different AAP

Acquisition Access Period (Hours)	Whiteflies infected/ Whiteflies tested (No.)	Whiteflies infected (%)
0	0/100	0
4	0/100	0
6	0/100	0
12	0/100	0
24	40/100	40
48	80/100	80

4.4.2 Latent Period (LP) study

The latent period (LP) of *B. tabaci*, as assessed by PCR, showed no increase in the detectable amount of SLCMV at 0, 1-, 3-, 5-, and 7-days post-acquisition. In addition, the fluorescence in *situ* hybridization (FISH) assay failed to detect the presence of the virus in the whitefly samples at any of the tested time points.

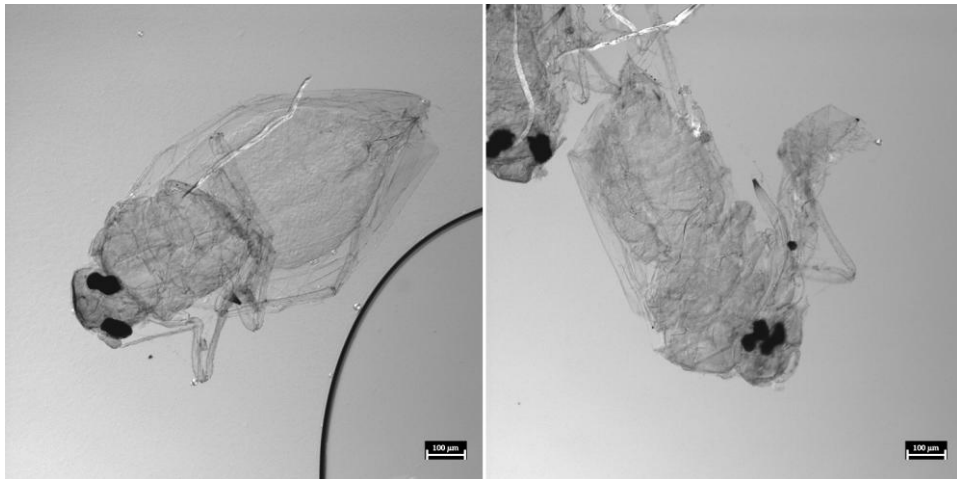


Figure 4.1 Whiteflies by using the Fluorescent in *Situ* Hybridization (FISH) technique

4.4.1 Inoculation Access Period (IAP) Study

The effect of the IAP on SLCMV transmission to cassava plants is summarized in Table 2. No infections were detected when whiteflies were given IAPs of 0, 4, 6, or 12 hours. In contrast, virus transmission was observed when the IAP was extended to 24 and 48 hours. After 24 hours, 2 out of 10 cassava plants became infected, representing a 20% transmission rate. A higher infection rate was recorded at 48 hours, with 6 out of 10 plants infected, corresponding to 60%.

Typical SLCMV symptoms were only observed in cassava plants subjected to the 48-hour IAP. The first visible signs, including mosaic leaf patterns and lamina deformation (Figure 2), appeared approximately 65 days after inoculation. These symptoms progressively intensified over time, confirming systemic infection and the establishment of viral replication in the host. In contrast, cassava plants exposed to IAP of 0, 4, 6, 12, and 24 hours remained symptom-free throughout the observation period.

Table 4.2 Transmission of SLCMV by *B. tabaci* after different inoculation access period (IAP)

Inoculation Access Period (Hours)	Cassava infected/ Cassava tested (No.)	Cassava infected (%)
0	0/10	0
4	0/10	0
6	0/10	0
12	0/10	0
24	2/10	20
48	6/10	60



Figure 4.2 The cassava shows disease symptoms after being inoculated

4.5 Discussion

The present study demonstrates that the successful acquisition and transmission of SLCMV by *B. tabaci* requires extended feeding periods, with transmission efficiency markedly increasing after 48 hours. Specifically, no infections were detected at shorter IAPs, while a 20% infection rate was recorded at 24 hours and a 60% rate at 48 hours. These results underscore the importance of prolonged acquisition and inoculation access periods in facilitating SLCMV transmission. This finding is consistent with previous studies on cassava mosaic begomoviruses. Antony et al. (2006) reported that Indian cassava mosaic virus (ICMV) required 48 hours of both AAP and IAP for effective transmission. Similarly, Duraisamy et al. (2013) and Kumar et

al. (2014) showed that SLCMV acquisition is most efficient within the 24–48-hour range. In contrast, ACMV can be acquired within as little as three hours, although higher transmission efficiency is achieved after longer feeding durations (Legg, 2008). Taken together, these findings highlight the central role of sufficient acquisition and inoculation time in the epidemiology of cassava mosaic begomoviruses.

Interestingly, the LP of *B. tabaci* in relation to SLCMV transmission revealed no detectable increase in viral load over a 0–7-day period based on PCR assays, and no viral signals were observed in FISH analyses. This suggests that, unlike viruses with short or negligible latent periods, SLCMV does not replicate or accumulate detectably within *B. tabaci*. A similar pattern has been described for other plant viruses. For example, cassava brown streak virus (CBSV) has an LP of 5–10 minutes (Maruthi et al., 2005), whereas squash vein yellowing virus (SqVYV) requires approximately 3 hours (Wintermantel et al., 2008). Semi-persistent viruses, such as criniviruses (e.g., lettuce infectious yellows virus), typically exhibit no latent period at all, as viral particles are retained in the foregut or stylets and can be transmitted almost immediately (Ng and Falk, 2006). The absence of a detectable LP in this study indicates that SLCMV may share features with persistently transmitted begomoviruses in which the virus requires prolonged acquisition but does not multiply within the vector.

Our inoculation data also align with previous reports of extended IAP requirements for begomoviruses. Firmino et al. (2009) demonstrated that tomato yellow vein streak virus (TYVSV) required an incubation period of at least 24 hours for successful inoculation. Likewise, both ICMV and SLCMV have been shown to require 24–48 hours for efficient inoculation (Antony et al., 2006; Kumar et al., 2014). In the current study, while 20% of cassava plants exposed to a 24-hour IAP tested positive for SLCMV, none developed CMD symptoms during the observation period. This suggests that infections initiated under shorter IAPs may remain asymptomatic due to low initial viral titers or delayed systemic movement. Similar symptomless infections have been described in earlier studies, in which latent or low-titer infections went undetected solely on the basis of symptom expression (Thresh et al., 1994; Legg and Fauquet, 2004; Maruthi et al., 2017). The detection of such pre-symptomatic infections emphasizes the risk of “silent carriers,” which may act as hidden reservoirs for further disease spread (Legg et al., 2011; Patil and Fauquet, 2009).

In contrast, cassava plants subjected to a 48-hour IAP not only tested positive for SLCMV but also developed typical CMD symptoms approximately 65 days post-inoculation. Although this incubation period is longer than the commonly reported 3–8 weeks (Thresh et al., 1994; Fargette et al., 2006; Duraisamy et al., 2012; Maruthi et al., 2017), it remains within the plausible biological range. The extended symptom onset may reflect a low initial inoculum load or inherent host tolerance. Moreover, the gradual intensification of symptoms confirmed systemic infection and viral establishment. Such variability in incubation periods has also been reported for cassava-infecting viruses; for example, Anitha et al. (2020) observed SLCMV symptom expression ranging from 6 to 49 days, depending on host genotype. This variability highlights the complex interplay between virus load, host susceptibility, and environmental factors in determining disease outcomes (Legg et al., 2015; Kumar et al., 2014).

Overall, the results of this study confirm that SLCMV transmission by *B. tabaci* depends on extended acquisition and inoculation periods, whereas latent period dynamics differ from those of semi-persistent viruses. Importantly, asymptomatic infections detected at shorter IAPs underscore the limitations of symptom-based surveillance and the potential role of molecular diagnostics in CMD management. These findings not only advance our understanding of SLCMV–vector interactions but also provide insights essential for developing integrated disease management strategies to reduce the spread of CMD and improve cassava productivity.

4.6 Conclusion

This study confirms that the acquisition and transmission of SLCMV by *B. tabaci* require extended feeding and inoculation periods. A minimum of 24 hours is necessary for both acquisition and inoculation, with transmission efficiency substantially increasing after 48 hours. Notably, plants exposed for 24 hours tested positive for SLCMV without developing symptoms, suggesting pre-symptomatic or low-titer infections that may serve as hidden inoculum sources. No latent period was detected, further emphasizing the virus's rapid transmission potential once acquired. Symptom expressions in plants subjected to a 48-hour IAP emerged approximately 65 days post-

inoculation, confirming systemic infection within a biologically plausible timeframe. Collectively, these findings underscore the critical role of adequate feeding duration in CMD epidemiology and provide valuable insights for designing more effective vector- and disease-management strategies for cassava production.

4.7 Reference

- Anitha, R., Suresh, S., Rabindran, R., & Malathi, V. G. (2020). Host plant resistance and symptom expression of Sri Lankan cassava mosaic virus in cassava germplasm. *Journal of Plant Pathology*, 102(3), 753–762. doi:10.1007/s42161-019-00483-y
- Antony, B., Melzer, M. J., Uchida, J. Y., & Hunter, W. B. (2006). Transmission of Indian cassava mosaic virus by *Bemisia tabaci*. *Journal of Phytopathology*, 154(2), 93–97. doi:10.1111/j.1439-0434.2006.01064.x
- Calatayud, P. A., Peterschmitt, M., Thresh, J. M., and Fargette, D. (1994). The epidemiology of African cassava mosaic geminivirus: Reappraisal of the role of whiteflies and evidence for semi-persistent transmission. *Annals of Applied Biology*, 124(1), 1–12. doi:10.1111/j.1744-7348.1994.tb04117.x
- Chowda-Reddy, R.V., Kirankumar, M., Seal, S.E., Muniyappa, V., Valand, G.B., Govindappa, M.R. and Colvin, J. (2012). *Bemisia tabaci* phylogenetic groups in India and the relative transmission efficacy of Tomato leaf curl Bangalore virus by an indigenous and an exotic population. *Journal of Integrative Agriculture*, 11(2), 235–248. doi:10.1016/S2095-3119(12)60008-2
- Chikoti, P.C. (2011). *Development of Cassava (Manihot esculenta Crantz) Cultivars for Resistance to Cassava Mosaic Disease in Zambia*. Ph.D. Dissertation, University of KwaZulu-Natal, Pietermaritzburg, South Africa. Available from: https://ukzndspace.ukzn.ac.za/bitstream/handle/10413/8402/Chikoti_Patrick_Chiza_2011.pdf
- Duraisamy, R., Natesan, S., Muthurajan, R., Gandhi, K., Lakshmanan, P., Karuppusamy, N., & Chokkappanet, M. (2012). Molecular studies on the transmission of Indian cassava mosaic virus (ICMV) and Sri Lankan cassava mosaic virus (SLCMV) in cassava by *Bemisia tabaci* and cloning of ICMV and ICMV replicase gene from cassava. *Mol Biotechnol.*, 53, 150–158. doi:10.1007/s12033-012-9503-1

- Duraisamy, R., Selvaraj, K., Malathi, V. G., & Mohankumar, S. (2013). Studies on transmission and biology of Sri Lankan cassava mosaic virus in India. *Phytoparasitica*, 41(2), 141–151. doi:10.1007/s12600-012-0262-4
- Fargette, D., Fauquet, C., & Thouvenel, J. C. (2006). Yield losses induced by African cassava mosaic virus in relation to the mode and the date of infection. *Tropical Agriculture*, 63(2), 81–84.
- Firmino, A.A., Ramos-Sobrinho, R. and Lima, G.S.A. (2009). Transmission of tomato yellow vein streak virus by *Bemisia tabaci*. *Fitopatologia Brasileira*, 34(6), 491–497. doi: 10.1590/S0100-41582009000600001.
- Roddee, J., Kobori, Y., & Hanboonsong, Y. (2018a). Characteristics of sugarcane white leaf phytoplasma transmission by the leafhopper *Matsumuratettix hiroglyphicus*. *Entomol. Exp. Appl.*, 1–10. doi:10.1111/eea.12741
- Roddee, J., Kobori, Y., & Hanboonsong, Y. (2018b) Multiplication and distribution of sugarcane white leaf phytoplasma transmitted by the leafhopper, *Matsumuratettix hiroglyphicus* (Matsumura) (Hemiptera: Cicadellidae), in infected sugarcane. *Sugar Tech*, 20, 445–453. doi:10.1007/s12355-017-0559-x
- Jones, D. R. (2003). Plant viruses transmitted by whiteflies. *European Journal of Plant Pathology*, 109, 195–219. doi:10.1023/A:1022846630513
- Kumar, J., Rabindran, R., Singh, H., & Kumar, P. (2014). Molecular studies on the transmission of Srilankan cassava mosaic virus (SLCMV) in cassava and cassava based crops. *Journal of Cell and Tissue Research*, 14, 4559-4564.
- Legg, J. P. (2008). Epidemiology of a whitefly-transmitted cassava mosaic geminivirus pandemic in Africa. *Plant Virus Epidemiology*, 71, 233–257. https://doi.org/10.1007/978-1-4020-9210-9_13
- Legg, J.P. & Fauquet, C.M. (2004). Cassava mosaic geminiviruses in Africa. *Plant Molecular Biology*, 56, 585–599. doi:10.1007/s11103-004-1651-7.
- Legg, J.P., Jeremiah, S.C., Obiero, H.M., Maruthi, M.N., Ndyetabula, I., Okao-Okuja, G., Bouwmeester, H., Bigirimana, S., Tata-Hangy, W., Gashaka, G., Mkamilo, G., Alicai, T. and Kumar, P.L. (2011). Comparing the regional epidemiology of the cassava mosaic and cassava brown streak virus pandemics in Africa. *Virus Research*, 159(2), 161–170. doi:10.1016/j.virusres.2011.04.018.

- Legg, J. P., Lava Kumar, P., Makeshkumar, T., Tripathi, L., Ferguson, M., Kanju, E., Ntawuruhunga, P., & Cuellar, W. (2015). Cassava virus diseases: Biology, epidemiology and management. *Advances in Virus Research*, 91, 85–142. doi:10.1016/bs.aivir.2014.10.001
- Lu S., Chen M., Li J., Shi Y., Gu O., & Yan F. (2019). Changes in *Bemisia tabaci* feeding behaviors caused directly and indirectly by cucurbit chlorotic yellows virus. *Virology Journal*, 16, 106. doi:10.1186 /s12985-019-1215-2
- Malathi V. C. & John P. (2009). “Mungbean yellow mosaic viruses,” in *Desk encyclopedia of plant and fungal virology*. Van Regenmortel M. (Eds.), Mahy B. London: Academic press, 217–226.
- Maruthi, M.N., Jeremiah, S.C., Mohammed, I.U. and Legg, J.P. (2017). The role of the whitefly, *Bemisia tabaci* (Gennadius), and farmer practices in the spread of cassava brown streak ipomoviruses. *Journal of Phytopathology*, 165, 707–717.
- Maruthi, M.N., Hillocks, R.J., Mtunda, K., Raya, M.D., Muhanna, M., Kiozia, H., Rekha, A.R., Colvin, J. and Thresh, J.M. (2005). Transmission of Cassava brown streak virus by *Bemisia tabaci* (Gennadius). *Journal of Phytopathology*, 153(5), 307–312. doi:10.1111/j.1439-0434.2005.00974.x.
- Navas-Castillo, J., Fiallo-Olivé, E. and Sánchez-Campos, S. (2011). Emerging virus diseases transmitted by whiteflies. *Annual Review of Phytopathology*, 49, 219–248. doi:10.1146/annurev-phyto-072910-095235.
- Ng, J. C. K., & Falk, B. W. (2006). Virus–vector interactions mediating nonpersistent and semipersistent transmission of plant viruses. *Annual Review of Phytopathology*, 44(1), 183–212. doi:10.1146/annurev.phyto.44.070505.143325
- Okuda, M., Okazaki, S., Yamasaki, S., Okuda, S., & Sugiyama, M. (2010). Host range and complete genome sequence of Cucurbit chlorotic yellows virus, a new member of the genus Crinivirus. *Phytopathology*, 100, 560–566. doi:10.1094/PHYTO-100-6-0560
- Patil, B.L. and Fauquet, C.M. (2009). Cassava mosaic geminiviruses: actual knowledge and perspectives. *Molecular Plant Pathology*, 10(5), 685–701. doi:10.1111/j.1364-3703.2009.00559.x.
- Purcell, A.H. (1982). Insect vector relationships with prokaryotic plant pathogens. *Annual Review of Phytopathology*, 20, 397–417.

- Saokham, K., Hemniam, N., Roekwan, S., Hunsawattanakul, S., Thawinampan, J., & Siriwan, W. (2021). Survey and molecular detection of Sri Lankan cassava mosaic virus in Thailand. *Public Library of Science One*, 16(10), e0252846. doi:10.1371/journal.pone.0252846
- Saunders, K., Salim, N., Mali, V. R., Malathi, V. G., Briddon, R., Markham, P.G., & Stanley, J. (2002). Characterisation of Sri Lankan cassava mosaic virus and Indian cassava mosaic virus: evidence for acquisition of a DNA B component by a monopartite begomovirus. *Virology*, 293, 63–74. doi:10.1006/viro.2001.1251
- Thresh, J. M., Otim-Nape, G. W., Legg, J. P., & Fargette, D. (1994). African cassava mosaic virus disease: The magnitude of the problem. *African Crop Science Journal*, 2(4), 533–543. doi:10.4314/acsj.v2i4.17632
- Wang, D., Yao, X.M., Huang, G.X., Shi, T., Wang, G.F., & Ye, J. (2019). First report of Sri Lankan cassava mosaic virus infecting cassava in China. *Plant Disease*, 103, 1437. doi:10.1094/PDIS-09-18-1590-PDN.
- Wintermantel, W. M., Hladky, L. L., Fashing, E. J., & Natwick, E. T. (2008). Host range and transmission efficiency of squash vein yellowing virus, a novel ipomovirus infecting cucurbits. *Plant Disease*, 92(5), 637–643. doi:10.1094/PDIS-92-5-0637