

***Japan Academy Prize to:***

Teruo SANO  
Emeritus Professor, Hirosaki University

for “Studies on Viroid”

***Outline of the work:***

Viroids are a new class of small RNA pathogens discovered in 1971 from potatoes suffering from spindle tuber disease. Dr. Teruo Sano has been working on viroid research for over 40 years, since the dawn of viroid research in 1979.

**1. Discovery of Hop Stunt Viroid Variants**

For the first time, hop stunt emerged around 1940–1950 in commercial hop cultivation in Japan. The causative agent was identified as hop stunt viroid (HSVd) in 1977. Dr. Sano began elucidating the origin and the source of the infection. He searched for viroid diseases in fruit trees and detected new viroids in grapevines, citrus, plums, and peaches. He identified all of these viroids as HSVd variants based on pathogenicity and complete nucleotide sequences, and named them as HSVd-grapevine, HSVd-citrus, HSVd-plum, and HSVd-peach. He also clarified that the grapevine and citrus variants caused asymptomatic infection with an extremely high infection rate in cultivated grapevines and citrus worldwide. The plum and peach variants caused a fruit disorder called “dapple fruit disease” in some Japanese plum and peach cultivars (refs. 1–4, 6). Initially, viroids were thought to be highly localized pathogens, but Dr. Sano’s research changed this concept by revealing that HSVd is an important etiology that is widely distributed across the world.

**2. Natural Source Plants for Hop Stunt Disease**

Dr. Sano then continued his research in the Tohoku region, a major area of hop production in Japan, to study the epidemiology of hop stunt. He found that the major endemic strain of HSVd-hop was closely related to HSVd-grapevine on the basis of molecular phylogenetic analysis (ref. 10). For over 15 successive years, he has been studying the effects of infection in virus- and viroid-free hops with major HSVd variants from hop, grapevine, citrus, and plum to analyze their pathogenicity and changes in their nucleotide sequence. These studies indicate that 5 out of 297 nucleotides at the positions 25, 26, 54, 193, and 281 of HSVd-grapevine had changed sequentially and finally converged into one adapted mutant containing all five mutations. Surprisingly, the adapted mutant completely matched the dominant variant found in the hops of the Tohoku region (ref. 13). These findings are acclaimed as excellent research that is supported by a long-term, continuous investigation, which revealed that the HSVd-grapevine that asymptotically infecting cultivated

grapevine was the origin for hop stunt epidemics (ref. 18). This result had an implied warning that viroids in unknown asymptomatic carriers can act as reservoirs to emerge periodically with new diseases and may cause enormous economic damages.

### **3. Molecular Mechanisms Controlling Viroid Pathogenicity**

In the mid-1980s, a model was proposed in which viroid molecules consisted of five structural domains and virulence was determined by a “pathogenicity” domain. Dr. Sano found that several domains other than this putative pathogenicity domain are also involved in virulence, and he proposed a universal model for the viroid structural domains that regulate pathogenicity (refs. 7, 9, 22, 31).

### **4. Mechanisms Underlying Viroid Pathogenesis, Symptom Expression, and Development of Viroid-Resistant Crops**

Dr. Sano analyzed the mechanisms of how these viroids, which are non-coding RNA pathogens, express pathogenesis. He found that a viroid-derived small RNA suppresses the host’s defense by inhibiting callose synthase gene expression (refs. 12, 15, 19, 28, 34, 35). He also demonstrated that the failure to control reactive oxygen species through abnormal expression of microRNA-398a-3p incited by viroid infection or disturbance of plant hormone signal transduction pathways is involved in the development of necrosis, dwarfism, and leaf-curl characteristics of viroid disease (refs. 23, 24).

He also succeeded in developing viroid resistant potatoes, chrysanthemums, and tobacco plants by expressing the double-stranded ribonuclease Pac1 or viroid-specific small RNAs (refs. 8, 20, 33).

### **5. Identification and Discovery of New Viroids and Viroid Diseases in Japan**

Dr. Sano worked on elucidating viroid ecology to understand the potential risks of viroid diseases and found 14 viroid species in 5 genera and 2 families, including 8 species/variants that he reported for the first time in the world and 6 species/variants that were reported for the first time in domestic crops (refs. 14, 16, 21, 25, 26, 29, 32). Based on this knowledge, he conducted a number of international collaborative research studies and played a leading role in the study of viroids in Asia (refs. 17, 27).

### **6. Control**

Dr. Sano has been developing diagnostic methods for viroids and has introduced new technologies into cultivation sites (refs. 5, 30). In hop cultivation, in particular, he has been conducting field surveys for over 20 years and has provided technical guidance for testing and maintaining production of virus- and viroid-free hop plants (ref. 11), which has made a significant contribution to the stable production of hops and agricultural crops.

As a pioneer in viroid research in Japan, Dr. Sano has taken a comprehensive approach to understanding the full picture of viroids and the diseases they cause, and has strongly led the world viroidology research. His research achievements have not only made remarkable contributions to

sciences, such as in the field of plant pathology, but also have contributed to practical fields, such as plant protection and plant quarantine. These research achievements have been highly regarded worldwide, and he was recognized by The Phytopathological Society of Japan and presented with the Young Scientist (1987), Society Fellowship (2008), and Paper of Excellence (2017) awards.

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