



**University of Jaffna**

**Prof.Somasundaram Kandiah  
Memorial Lecture-2025**

(First Dean of the Faculty of Agriculture  
and Professor in Agronomy)



**“Natural Products Chemistry Using  
Tropical Resources and the Potential Application”**

by

**Professor Tohru MITSUNAGA (Ph.D.)**

JICA Expert, Project Chief Advisor  
Professor Emeritus, Gifu University, JAPAN,

on

*Wednesday, 10<sup>th</sup> September 2025 at 10.30 a.m*

at

**Main Auditorium, Faculty of Agriculture,  
University of Jaffna,  
Ariviyal Nagar, Kilinochchi.**



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**Prof. Somasundaram Kandiah**

## Message from the Vice-Chancellor

**Prof. S. Srisatkunarajah**  
**Vice-Chancellor**  
**University of Jaffna**  
**Sri Lanka**



It gives me a great pleasure to honour the late Prof. Somasundaram Kandiah, who was appointed as the first Dean of the Faculty of Agriculture at the University of Jaffna in October 1990. Prof. S. Kandiah was born 9<sup>th</sup> September 1936 in Ariyalai, which is located to the east of the Jaffna peninsula. He completed his secondary school at St. John's College in Jaffna before enrolling in the University of Colombo's Bachelor of Science program. Late Prof. S. Kandiah received his doctorate from the University of London after doing doctoral research on producing dwarf apple tree varieties through plant breeding. The late Prof. Kandiah returned to Sri Lanka as a young PhD holder, and joined as a research officer at the Tea Research Institute of Sri Lanka. Due to his outstanding research and academic qualifications, late Prof. S. Kandiah selected and started his academic career as Senior Lecturer in Botany at the Faculty of Science, University of Jaffna in 1978. At the Faculty of

Science, he served as the Head of the Department of Botany and later promoted as associate Professor in Botany.

In 1990, late Prof. Kandiah has accepted to serve as a Professor in Agronomy for the newly established Faculty of Agriculture in Kilinochchi, even though many Tamil academics were leaving from the country due to the worsening of civil war in Northern Sri Lanka. Thereafter, he was unanimously elected as the first Dean of the Faculty in October 1990. Many of his very first batch students of the Faculty of Agriculture remember him as a humble, simple, noble and dedicated academician teacher, outstanding researcher, and committed administrator. He was very keen to understand and solve students' problems. He has supervised many research students on the areas of improvement of horticultural crops and initiated the dwarf palmyrah breeding program in the Northern, Sri Lanka.

During the Sri Lankan civil war, he commuted by bicycle from Kilinochchi to Jaffna along the Poonakary route. On March 23, 1991, Prof. Kandiah died of a heart collapse while riding back to Kilinochchi from a senate meeting at the University of Jaffna. The Faculty of Agriculture was concerned because it had unexpectedly lost a great academic while on duty. His passionate

committed service to the Faculty of Agriculture will always be remembered by the University of Jaffna.

The Faculty of Agriculture consecutively conducts memorial lecture every year since 2022 to commemorate the services of its first dean late Prof. Somasundaram Kandiah, and I am happy that it has been materialized successfully. This year, we are delighted to have Japanese eminent scientist Emeritus Professor Tohru MITSUNAGA from Gifu University University, Japan to deliver this 4<sup>th</sup> memorial lecture of Late Prof. Somasundaram Kandiah under the title of "Natural Products Chemistry Using Tropical Resources and the Potential Application".

Toru Mitsunaga commenced his career as researcher at the paper making company, Nippon Paper Industries Co., Ltd., and then he was hired as an assistant professor at the Faculty of Bioresources Mie University where he studied the pigment structure of wood and received Japan Wood Research Society Award for his study in tannin and other polyphenol chemistry.

In his academic journey, Tohru Mitsunaga served as visiting researcher at the University of Wisconsin, United States; associate professor, professor, vice dean and dean for 10 years at Faculty of Applied Biological

Sciences Gifu University. His deep and extensive researches focused on characterization of phytochemicals and its industrial application. He has published more than 155 research papers in high impact Q ranking Journals, 10 book chapters, delivered 20 invited talks, and presented research findings in international and national conferences and forums. Tohru Mitsunaga has retired from Gifu university with the title of Professor Emeritus in March 2025.

University of Jaffna would extend its appreciation to Professor Tohru Mitsunaga for agreeing to deliver the late Prof. S. Kandiah memorial lecture for the year 2025 from his expertise area of research. I hope his talk will add new knowledge in the field of Natural Chemistry and open new regional agricultural research plan focusing to UN's SDG goal of zero-hunger in year 2030.

All Glories to Almighty

# **Natural Products Chemistry Using Tropical Resources and the Potential Application**

## **1. Introduction**

More than 40 years ago, when choosing a laboratory for my graduation thesis, I was forced by my grades to be assigned to unpopular Wood Chemistry Laboratory. I was researching on my thesis without any interest in wood chemistry. For a while, Emeritus Professor Tamio Kondo, Kyushu University, came to my lab for an intensive lecture. He told me, "More than 95% of wood's chemical components are cellulose, hemicellulose, and lignin. The remaining 5% or less are extractives. The first three are like the skeletal components found in most trees, like blood, muscle and bone in humans. Meanwhile, extractives are like a person's personality. Just as even twins have different personalities, even trees of the same species contain different extractives." This revelation completely transformed my interest in wood chemistry. Since then, I have been dedicated to teaching and researching plant extracts for approximately 40 years, until my retirement from Gifu University last March. In this article, I would like to share, as much as space allows, some of my experience in plant extract research.

## 2. Purple Pigment Components of Precious Woods

Wood is generally considered a light and soft material, but there are rare and generally highly valued hard, heavy, and dark-colored precious woods. These are used in a variety of ways, from tangible objects such as high-end furniture and musical instruments to building and interior materials. Among these, the three most prestigious woods, Rosewood, Ebony, and Ironwood, which have a rich color combined with the striped patterns of annual rings, resulting in precious and elegant wood products. As a master's student in the Wood Chemistry Laboratory at Kyushu University, I was assigned by Late Professor Hiroyuki Imamura to research the "color components of purple sandalwood heartwood." I focused on exploring the structure of purple and related pigment components and elucidating the color change mechanism. Immediately after sawing, the heartwood of the purple sedge (*Millettia pendula* Benth.) is pale yellow. However, upon exposure to air, it rapidly changes to a vibrant purple. Within a few weeks, it turns deep purple, and within a few months, it turns to a dark purple with a distinct grain. This rich color is why the wood is used for high-quality Buddhist altars, furniture, and transoms (Fig. 1).

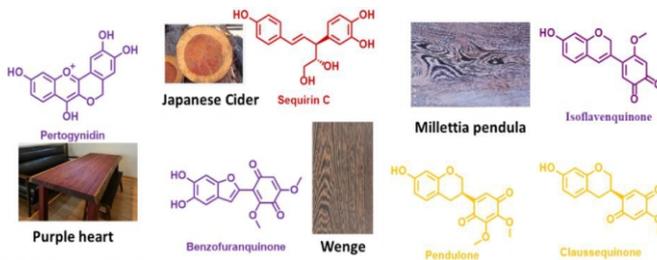


Figure 1: Pigment components of colored high-quality wood

Identifying the pigment components is tricky. If left unattended after TLC, the colorless spots turn into multiple purple and yellow components. Many obstacles hindered progress, including determining the timing of component fractionation and the color state of the wood to be extracted. After a year of struggling to obtain data on the components, Late Professor Imamura offered some advice: "Since the components are likely quinone compounds, why not reductively acetylate the crude extract and then track the components that turn purple upon deacetylation?" The experiments proceeded smoothly, and I was able to isolate and identify over 20 components, primarily isoflavonoids, and discovered a novel compound, 7-hydroxy-2'-methoxy-isoflavenquinone, as one of the purple components (Mitsunaga, 1987). Furthermore, since this discoloration is accelerated by exposure to light in the presence of oxygen, we predicted that singlet oxygen extracts H

radicals from the phenolic hydroxyl group, resulting in the production of low-molecular-weight pigment components and their polymerization, resulting in the deep purple color.

At the time, *Millettia laurentii* De Wild., a tree with a similar appearance to *M. pendula*, was extremely rare and its abundance was of concern in its native habitats in Africa and Southeast Asia. Therefore, African wenge wood (*Millettia laurentii* De Wild.), was often used as a substitute of *M. pendula*. Most of the extractives from wenge remained near the origin of normal-phase TLC (thin film chromatography), significantly different from those from purple serrata. However, I isolated and identified several flavonoid compounds, including a purple pigment, and identified one of the purple pigments as a benzofuranquinone. However, in those days, clarifying the absolute stereochemistry of the isolated compounds was a challenging task. However, advances in computational chemistry using theoretical ECD spectroscopy have recently enabled us to clarify the absolute configuration of the isolated compounds (unpublished data).

*Peltogyne mexicana* Martínez is a tree species native to South America, growing to heights of 30-40 m. Similar

to the discoloration process of purple serrata, the heartwood is brown immediately after felling, but rapidly changes to a vibrant purple upon exposure to air and sunlight. This vibrant color and high durability give it high market value and it is widely used for high-quality furniture and other purposes. Although the presence of anthocyanin-like compounds in heartwood extracts has been suggested, detailed elucidation of their molecular structure, including their precursors, has yet to be achieved. Another characteristic of this tree species is the abundant production of peltogynoids, in which the BC ring of a flavonoid is bridged with an oxymethylene to form a D ring. Based on these two characteristics, we hypothesized that peltogynoids are involved in the color change of purpleheart heartwood. Therefore, we isolated and determined the structures of pigment precursor compounds and pigment compounds. As a result, we confirmed the production of novel pigment compounds, peltogynidin and mopanidin, from their respective precursors. These precursors have a leucoanthocyanidin-like structure, and we predict that the color change occurs through autoxidation (Taga 2024).

### **3. Fascination of Condensed Tannins**

After completing my master's degree, I joined the Sanyo

Kokusaku Pulp (now Nippon Paper Industries) Production Technology Research Institute. However, I had no connection to wood or plants, and instead spent three years researching chlorinated polyolefins. This polymer was easily and inexpensively synthesized by purchasing virtually waste polyolefins from oil companies at low cost, dissolving them in carbon tetrachloride, and then introducing chlorine gas under photocatalysis. This excellent product, called SUPERCHRONE<sup>®</sup>, was widely used overseas in large quantities, including in ship body paints, car bumper paints, and food packaging inks, generating significant profits. This short experience taught me the concept of effectively utilizing unused resources and the importance of research that is useful in the real world.

Later, I was assigned as an assistant professor at the Faculty of Bioresources, Mie University, where I conducted applied research on wood adhesives using bark tannins under the supervision of Former Mie University Professor Isao Abe. The research sample was Siberian larch bark tannin, a highly viable tannin resource. At the time, tens of thousands of tons of Siberian larch bark were piled up at Toyama Port. Abe's

laboratory was exploring the possibility of applying condensed tannins, approximately 10% of which is contained in bark, to adhesives, in order to make effective use of unused resources. Condensed tannins are polyphenols formed by the polymerization of flavan-3ols via flavanoid bonds. Because of their highly reactive A-ring with formaldehyde, they were attracting attention around the world at the time as an alternative raw material for phenolic resins. Research by Dr. Pizzi of South Africa and Dr. Yazaki of Australia, among others, had already advanced to the point of practical application. Professor Abe's mission to me was to modify the condensed tannin molecule so that the A-ring, which is highly nucleophilic, is embedded in the helical structure of the tannin molecule, resulting in a low-density resin with poor thermosetting properties. This was due to the high molecular weight of procyanidin-type larch bark tannins, and the resulting A-ring is buried within the helical structure of the tannin molecule, meaning that only the A-ring at the end of the molecule can react with formaldehyde. This resulted in the production of a low-density resin with poor thermosetting properties. Therefore, I thought that if I could open the heterocycle and moderately cleave the

flavanoid bond to expose the A ring to the surface of the molecule, the reactivity would increase and I could create a highly thermosetting three-dimensional polymer. I studied the modification of condensed tannins using boron trifluoride-phenol complexes, and succeeded in developing a tannin-based adhesive that achieved my initial goal (Mitsunaga 1993). This series of studies formed the basis of my doctoral dissertation and was later awarded the Japan Wood Research Society Award. After obtaining my doctorate, I shifted my focus to exploring the added value of condensed tannins and studied their physiological functions. One of the main properties of tannins is their ability to adsorb proteins, which makes them highly compatible with biological components. Therefore, I focused on their enzyme inhibitory activity and conducted collaborative research with companies on their physiological activities, such as glucosyltransferase inhibition (anti-carries agent), tyrosinase inhibition (skin whitening agent), and  $\alpha$ -glucosidase inhibition (hypoglycemic agent). Attempts to clarify the mechanisms of these enzyme inhibition using computational chemistry, a method not widely accepted at the time, were only possible from the perspective of structurally optimized tannins, and a full

understanding was not achieved.

Recent physiological function studies have reported a number of physiological functions of tannins, including immunomodulatory effects (Lee 2012), anti-obesity (Quesada 2012), antidiabetic activity (Okuda 2011), and neuroprotective effects (Wang 2012). As mentioned above, these functions are thought to be closely related to the protein aggregation activity of tannins, but the aggregation mechanism remains unclear. The strength of tannin interactions with proteins was revealed in the 1950s (Judith 1963), and subsequently, tannins were shown to inhibit various enzymes through noncompetitive inhibition (Ozawa 1987). It has been reported that hydrogen bonds are important for this interaction, and tannins preferentially bind to proline-rich proteins (Hagerman 1980). Recently, Yamauchi et al. in our laboratory have successfully created a condensed tannin-protein aggregation model, utilizing NMR and docking simulations to visualize the binding state of tannins and proteins at the molecular level (Fig. 2) (Yamauchi, 2023). Thanks to advances in new techniques, scientific equipment, and information science, such as computational chemistry, previously unknown interactions between tannins and proteins are

becoming clearer. Further elucidation of the mechanisms of tannin interaction with biomolecules is expected to shed light on the full scope of tannin bioactivity.

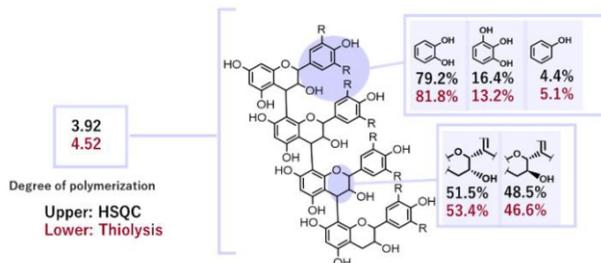


Figure 2: Structural analyses of condensed tannins trimer by NMR

#### 4. Connections with Overseas Universities through Tropical Medicinal Plant Research

While at Mie University, I conducted collaborative research with a cosmetics manufacturer, where I discovered that the skin-whitening component in the bean pods of Brazilian Jatoba (carob) is a proanthocyanidin oligomer, contributing to its commercialization. This experience sparked my fascination with tropical plants and my desire to visit tropical regions. Soon after transferring to Gifu University, I received this opportunity when two government-sponsored Indonesian students were accepted as exchange students. Using crude extracts from over 100 Indonesian medicinal plants (at the time,

restrictions under the Convention on Biological Diversity were still loose), I conducted a large-scale human-powered screening of various physiological activities. They were hungry for experiments, but also very adept at managing their lab time, starting experiments early in the morning and returning home early in the evening, a rhythm of research that Japanese people could learn a lot from. Subsequently, doctoral students from Sudan, Thailand, China, and Vietnam have continued to study tropical medicinal plants in their home countries, and after obtaining their degrees, they have devoted themselves to educating and researching the next generation as professors or directors at universities and research institutes in their home countries. Seeing their supervised students working hard in our laboratory as international students, I realize the sustainability of not only plant materials but also education.

Tropical plants synthesize a wide variety of secondary metabolites as self-defense substances to overcome harsh environmental factors, and it is easy to imagine their high physiological activity. Below, we introduce some of the particularly interesting physiologically active compounds that we have studied so far (Fig. 3).

**I.** The effect of methoxyflavones in the rhizomes of Thai black turmeric (*Kaempferia parviflora* Wall.) on the dendrite outgrowth of PC12 cells. **II.** The anti-inflammatory effect of coumarins in the leaves of Indonesian jackfruit (*Murraya paniculata* L. Jack). **III.** The immunostimulatory activity of flavonoids in the leaves of Thai kaffir lime (*Citrus hystrix* DC.) (Hara 2021). **IV.** The anti-obesity effect of vanilloid compounds contained in Guinea ginger (*Aframomum melegueta* K. Schum.) seeds (Hattori 2019) **V.** The inhibition of inflammatory cytokine production by sesquiterpenes in Thai Mukko (*Saussurea lappa* Clarke) leaves (Choodej 2018) **VI.** The anti-oral bacterial activity of garcinonic acid contained in Ghanaian kola (*Garcinia kola* Heckel) seeds (Hioki 2020) **VII.** The anti-osteoporosis effect of flavonoid oligomers contained in Indonesian dragon's blood tree (*Dracaena draco* L.) (Tsuchiya 2024) **VIII.** The iNOS inhibitory activity of melptelchromenes contained in the Vietnamese herbal medicine *Melicope pteleifolia* Champ. (Kakumu 2023). The search for these natural compounds employed standard methods: extracts from each material were purified using multiple column chromatography runs, isolated using preparative HPLC or recrystallization,

and structural determination was performed using instrumental analysis. However, in the search for VIII, MS2 data obtained from mass spectrometry of crude extracts was subjected to a library search. Detailed information about the compound group was obtained by visualizing nodes and edges obtained through molecular network analysis, demonstrating the rapid discovery of novel natural product molecules using computational chemistry (Kakumu 2023). Through this research, I felt that the good old days of painstakingly isolating and identifying active compounds, which required a lot of time, effort, and money, may soon be forgotten. However, at the same time, I was grateful for advances in analytical instrumentation.

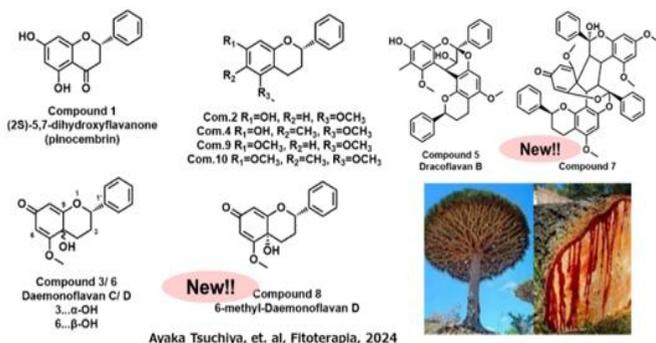


Figure 3: Polyphenols from Dragon's blood

## 5. Effects of Wood Aroma Compounds on Biological Functions

While investigating the insecticidal and repellent effects of wood aroma compounds against termites in a collaborative study with the late Professor Tsuyoshi Yoshimura of Kyoto University, we encountered Australian cypress (*Callitris glaucophylla* Joy Thomps. & L.A.S. Johnson), a member of the Cupressaceae family that originated in Australia and is widely distributed throughout Europe and the Americas. Australia is one of the world's leading termite habitats, particularly infested by Rhinotermitidae, known for their destructive power against wooden structures. Despite this, New South Wales boasts a number of century-old homes constructed from *Callitris* timber, including cypress, demonstrating its high bioactivity against termites. The main components of the essential oil obtained by steam distillation of cypress wood are (-)-citronellic acid, guaiol, and  $\alpha$ ,  $\beta$ ,  $\gamma$ -eudesmol, accounting for approximately 80% of the total oil.

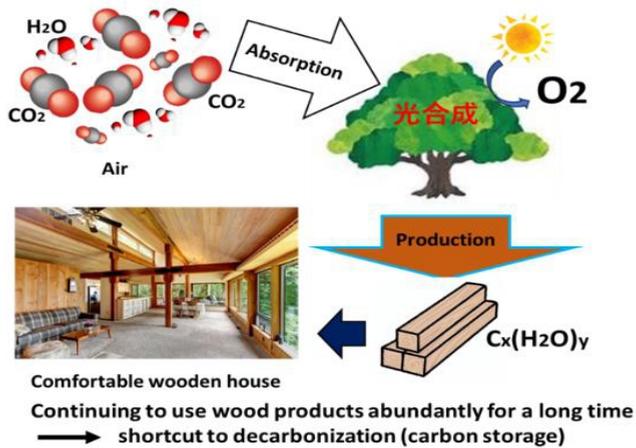


Figure 4: Wood production addressing greenhouse effect

These major components possess antitermite and decay-resistant properties. Columellarin and dihydrocolumellarin, in particular, possess potent repellent properties and exhibit bacteriostatic properties against wood-decaying fungi, making them environmentally friendly bioactive compounds (Watanabe 2004). Termites exposed to cypress essential oil became sluggish, lost their directional walking habits, and suffered from neuroparalysis. After learning that the receptor structure for odorants present on the antennae of termites is a seven-transmembrane G protein similar to the mouse olfactory receptor, we became curious about the role of cypress aroma compounds in mice. We reared mice on cypress wood chips. We found that

weight gain, even when fed a high-fat diet, was suppressed, particularly the accumulation of triglycerides around the testes. Furthermore, sniffing cypress essential oil stimulated sympathetic nervous activity, promoting the production of norepinephrine and ultimately promoting the breakdown of triglycerides. This clarified part of the mechanism by which the aroma compounds in cypress essential oils inhibit obesity (Mitsunaga 2008). Meanwhile, we found that the aroma compounds from Japanese cypress (*Cypress cypress*), Japanese cedar, and Japanese hiba (*Thujopsis japonica*) woods did not have an anti-obesity effect in mice; instead, they suppressed sympathetic nervous activity, resulting in a parasympathetic-dominant state. The effects of the aromatic components of cedar wood essential oil were particularly pronounced, with inhalation of the essential oil providing stress relief and relaxation, as well as improving memory and learning declines, reducing brain-derived neurotrophic factor (BDNF) levels in the hippocampus, and inhibiting hippocampal neuronal loss. To elucidate the contributing components and mechanisms, cedar wood essential oil fractions were inhaled into a mouse model of stress-induced memory and learning deficits, and their effects

on hippocampal function, structure, and memory and learning were examined. The order of memory impairment improvement was found to be: 1) cadinene complex (CDS) > 2) sesquiterpene hydrocarbons > 3) cedar wood essential oil (SEO) > 4)  $\delta$ -cadinene. Furthermore, immunohistochemical staining of BDNF in hippocampal tissue revealed that inhalation of the complex component consisting of  $\delta$ -cadinene,  $\alpha$ -muurolene, and  $\beta$ -cadinene improved BDNF decline in the DG and CA3 regions. Western blot analysis confirmed that inhalation of cedar wood essential oil aromatic components enhanced signaling proteins involved in BDNF function expression. There are few studies on the direct effects of wood's aromatic components on biological functions, and this field remains largely unexplored. It is hoped that further research will demonstrate the new value of wood "fragrance" on the wood industry.

## **6. JICA's Initiatives and Expectations for the Future of the Faculty of Agriculture University of Jaffna**

Japan International Cooperation Agency (JICA) supported the reconstruction of the Faculty of Agriculture from 2016 to 2021 as a grant aid project.

Under this cooperation, JICA supported the construction of Research & Training Building, farm and other facilities including the provision of equipment. Project for Research & Education Capacity Improvement in Dry Zone Agriculture at University of Jaffna (PRECIDA-UOJ) involves long-term experts from Japan staying in FOA, provision of equipment, training of counterparts, and technology transfer and sharing expertise are enhanced by Japanese short-term experts.

Foundation for practice-oriented education and research is enhanced in FOA by the activities of education, research, outreach/social engagement and management with cooperation of counterparts.

As I have mentioned in this paper, I have been involved in collaborative research on many Southeast Asian plants. As a result of this collaborative research, over 100 papers have been published in international journals, enhancing the production of many doctorates, and obtaining a cooperative budgets, so on.

Agriculture is a comprehensive science whose goal is human survival and happiness. The environment, food, and life surrounding humans are essential elements for human survival and happiness. To achieve this, we must

understand the environmental problems facing the Earth this century and engage in environmental conservation efforts to repair them. We must also understand the issue of food waste and the productivity, functions, and physiological functions of the plants and animals that provide our food. We must also acquire knowledge and skills that can contribute to the SDGs and develop future and preemptive diets. Furthermore, we must utilize the latest technology to elucidate the life phenomena and functions of humans, animals, and plants, as well as the utilization of biomass resources, and engage in world-class research and development not only in agriculture but also in a wide range of life sciences, including drug discovery and development. Thus, without any one of the environment, food, and life, human survival and happiness cannot be achieved; they are closely linked and work in harmony. Wood and plants, which I have studied and educated about, are not only living organisms that address environmental issues as renewable resources, but also important as everyday materials. Trees are also a source of food, including fruit. Furthermore, the chemical components obtained from trees can serve as raw materials for functional natural polymers, pharmaceuticals, and chemical products. In

other words, I believe that agricultural science research will be a field that can tackle challenges such as addressing a decarbonized society, implementing smart agriculture and forestry, working toward Future Green and the SDGs, and taking on the challenge of realizing Next Society 5.0.

I hope that the faculty and students of the Faculty of Agriculture University of Jaffna, who have great potential in education and research, will further strengthen their abilities to play an active role in the international community and become people who can meet the needs of society in the future.

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Toru Mitsunaga completed his master's degree at Kyushu University's Faculty of Agriculture in 1984, and after three years of research at the paper making company, Nippon Paper Industries Co., Ltd., he was hired as an assistant professor at the Faculty of Bioresources Mie University. He completed his PhD from kyuushuu University in 1995. During his 15 years at Mie University, he studied the pigment structure of wood

and the structure and physiological function of condensed tannins contained in wood bark. This achievement has built the foundations of tannin and other polyphenol chemistry, as the result led to him receiving the Japan Wood Research Society Award. During that time, he spent approximately two years as a visiting researcher at the University of Wisconsin in the United States, where he learned the basics of computational chemistry, which he has put to good use in his research since returning to Japan. Tohru Mitsunaga served as an associate professor and professor at Faculty of Applied Biological Sciences Gifu University, where he boldly explored the physiologically active components of southeast asian tropical medicinal plants and the complex structure of tannins using nuclear magnetic resonance equipment, resulted in elucidating many chemical structures and the mechanisms of protein aggregation. He also conducted research into the effects of scents on the biology and physiology of humans and animals, including the stress-relieving mechanisms and obesity-suppressing effects of wood's aromatic components. In University administration in Gifu, he served as vice dean and dean for 10 years, demonstrating great skill in faculty management and faculty reorganization. Tohru Mitsunaga has retired Gifu university in March 2025, and was awarded the title of Professor Emeritus at Gifu University. He has published more than 155 research papers in high impact Q ranking Journals, 10 book chapters, delivered 20 invited talks, and presented research findings in international and national conferences and forums.



**PRECIDA-UOJ**

Project for Research & Education Capacity Improvement  
in Dry Zone Agriculture at University of Jaffna