

Teikichi Fukushi, 1894-1991

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Teikichi Fukushi was born in Hakodate, Hokkaido, Japan, September 5, 1894. He received his early education at Hirosaki, Aomori Prefecture. After only 7 years in primary school (instead of the normal 8), he enrolled in the Hirosaki middle school. He continued his education, attending the 3-yr Preparatory Course at the College of Agriculture at Tohoku University in Sapporo, from which he graduated in 1919. The following year Fukushi became a lecturer at the Agricultural College,

Hokkaido Imperial University, and in 1921, was promoted to professor at the Tottori Agricultural College.

With the guidance of Kingo Miyabe, Fukushi began to study fungal diseases, discovering a species of *Phylospora* that causes canker disease of willow. In honor of Professor Miyabe, he named it *Phylospora miyabeana* Fukushi. By 1925, Fukushi found apple varieties resistant to *Gymnosporangium yamadae* Miyabe and as a result, saved apple orchards in Aomori Prefecture from destruction. He also carried out anatomical investigations on galls induced by this rust fungus.

From 1925 to 1927, Fukushi studied in the United States and Europe. At the University of Wisconsin, working with L. R. Jones, he became interested in aster yellows disease. He visited L. O. Kunkel at the Boyce Thompson Institute, Yonkers, NY, to become acquainted with leafhopper transmission techniques. While at Washington University, St. Louis, MO, he worked with B. M. Duggar on tobacco mosaic virus (TMV). In Europe, Fukushi visited plant pathologists in England, Germany, and the Netherlands. The 3 yr spent abroad with leading plant pathologists had a profound effect on his future research. The intense curiosity about the nature of viruses and plant-virus diseases, stimulated by L. R. Jones, L. O. Kunkel, B. M. Duggar, R. Salaman, M. W. Beijerinck, and others, led to Fukushi's most significant contributions to plant virology. In 1927, when he began his research on rice dwarf virus (RDV), there was no record showing congenital transovarial transmission of a plant virus in an insect vector, and the concept that a plant virus could multiply in an insect vector, proposed in 1926 by L. O. Kunkel, was almost a heresy. In 1931, Fukushi found inclusion bodies in rice leaves infected with RDV and confirmed that the rice disease was virus induced. In 1932, he demonstrated that cigarettes were a source of TMV infection in tobacco fields. In 1933, probably stimulated by B. M. Duggar's early experiments with TMV at Madison, WI, Fukushi succeeded in purifying TMV through kaolin filtration.

Fukushi's meticulous, classic experiments, described in 1933, 1939, and 1940, dealt with the interactions between RDV and its leafhopper vector, *Nephotettix cincticeps*. He demonstrated transovarial transmission and provided overwhelming evidence for multiplication of the plant-pathogenic virus in its leafhopper vector. He also found that not all leafhoppers were able to acquire and transmit the virus. Although the minimum acquisition feeding period was only 3 days, most insects acquired the virus after 10–50 days of feeding. Even after 50 days, however, certain individual insects failed to acquire RDV. The incubation period varied from 10 to 73 days, and most, but not all, vectors, retained infectivity throughout their lives. Only rarely did transmitting ability diminish with the age of the vector. Fukushi's brilliant demonstration that a plant virus can multiply not only in plants but also in insect vectors gained him worldwide recognition. By 1960, together with his former student and later successor, Eishiro Shikata, Fukushi found by electron microscopy RDV particles

in both the rice plant and the insect vector, providing further confirmation of RDV multiplication in leafhopper vectors. Fukushi's work was enormously important for control strategies, as well as for the field of virology. His findings indicated for the first time that certain invertebrate vectors of plant-pathogenic viruses are not fortuitous carriers of viruses, but that they play a primary role in the evolution of plant and animal viruses, acting as alternate hosts and reservoirs.

Fukushi was not only a remarkable researcher but was also a distinguished teacher. In 1929, he was promoted to associate professor of Botany at the Faculty of Agriculture, Hokkaido University, and in 1934, he was named professor of Botany. In 1932, he offered the first lecture series on plant viruses and virus diseases in Japan. In 1934, Fukushi was awarded a doctorate after presenting his thesis, "Studies on the Dwarf Disease of the Rice Plant." He became director of the Botanical Garden at Hokkaido University in 1947. In 1952, he published *Plant Viruses*, the first Japanese textbook on plant virology. In 1958, the year he became an emeritus professor, Fukushi was an invited participant at the Fiftyth Anniversary Meeting of the American Phytopathological Society in Bloomington, IN. He remained active in science and in 1960, accepted the position of professor at the private Dairy College Rakuno Gakuen. Long after his official retirement and despite advanced age, he continued to inspire and advise many of his younger colleagues as well as graduate students. He retained his remarkable memory and keen interest in virology until his death. In 1986, at the age of 92, jointly with E. Shikata, Fukushi published the 514-page second edition of *Plant Virology*. Afterward, he moved from Sapporo to Tottori but continued to maintain close contact with former students and friends. His handwritten letters showed that his steady hand and perfect command of English were not affected by his age. On September 2, 1991, feeling a sudden pain, Fukushi walked to a nearby hospital for a check-up but lost consciousness and fell on the street. The pain most likely was caused by a heart attack. On September 4, 1991, a day before his 97th birthday, Fukushi died and was interred in Tottori.

Fukushi was an emeritus member of APS as well as a member of several other scientific societies. Throughout his career, Fukushi received numerous awards and honors. In 1941, he received the Japan Agronomy Prize for his studies of rice dwarf disease, and in 1958, he received the Japan Academy Prize for his research on insect transmission of plant viruses. He was recognized for distinguished service by the Aomori Prefecture in 1961 and was decorated in 1965 with the Second Order of the Sacred Treasure by the Japanese government in recognition of his outstanding contributions to education and science. In 1964, he was elected a member of the Japan Academy.

The magnitude and excellence of Fukushi's accomplishments place him among the greatest plant pathologists of this century. His scientific rigor and dedication continue to inspire his former students, associates, and others who were privileged to know him personally. He will be remembered as a brilliant experimenter, a great scholar, an excellent teacher, and a man whose inspiring example set the goal of activities for many younger followers. Until his death, Fukushi was particularly devoted to helping younger investigators. His painstaking attention to the smallest details and his profound studies on interactions between plant viruses and leafhopper vectors influenced virologists not only in Japan but throughout the world—truly this was his bequest to plant virology.

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