TRIBUTE

Contributions to Plant Genetics, Agricultural Innovation, and Food Security

Rajeev K. Varshney* and Rutwik Barmukh*

https://doi.org/10.25003/RAS.13.02.0015

The death of Professor Monkombu Sambasivan Swaminathan has created a great void in the world of Indian science (Figure 1). His departure on 28 September 2023, at the age of 98, has created an irreplaceable void. Professor Swaminathan dedicated extensive efforts to transform agriculture, aiming to guarantee worldwide food security and foster sustainable resource management. He played a pivotal role in enhancing crop yields, fostering growth with ecological sustainability, empowering smallholder farmers and advocating for gender equality. His unwavering spirit and visionary contributions will forever serve as a fount of inspiration for upcoming generations of aspiring scientists, influencing the trajectory of agriculture for years to follow.

Contributions to Plant Genetics and Crop Improvement

M. S. Swaminathan was born on August 7, 1925, in Kumbakonam, Tamil Nadu. His quest for knowledge led him to a B. Sc. in Zoology from the University of Kerala in 1944, followed by a B. Sc. in Agriculture from the University of Madras in 1947, and an M. Sc. from the Indian Agricultural Research Institute (IARI). In 1949, he went as a UNESCO fellow to the Institute of Genetics at the Wageningen Agricultural University in the Netherlands.

In the first three decades of a scientific career that lasted more than 65 years, Professor Swaminathan focused on fundamental research in life sciences, particularly genetics, with the goal of addressing specific challenges in stress management in crops and optimising their productivity.

* Western Australia State Agricultural Biotechnology Centre, Centre for Crop and Food Inovation, Murdoch University Rajeev.Varshney@murdoch.edu.au

His groundbreaking research on understanding the mechanisms of speciation in the genus *Solanum*, section *Tuberarium*, earned him a Ph. D. from the University of Cambridge in 1952. By unravelling the genomic affinity of the cultivated tetraploid potato (2n = 4x = 48), *Solanum tuberosum*, with its wild diploid counterpart (2n = 2x = 24), Professor Swaminathan facilitated inter-specific hybridisation and gene transfer. This work aimed at conferring resistance against various abiotic and biotic stresses to potatoes. The significance of Professor Swaminathan's fundamental research in *Solanum* species extended to the broader public through its contribution to the development of numerous new potato varieties with increased resistance to diseases and tolerance to frost, suitable for cultivation in the northern USA. For example, a potato hybrid carrying the frost resistance gene from a tetraploid wild relative, *S. acaule* (2n=48), developed by Professor Swaminathan during his post-doctoral research at the University of Wisconsin, Madison, USA, was utilized to develop a frost-resistant potato variety known as "Alaska Frostless," subsequently released for commercial cultivation in Alaska.

In a crucial decision, Professor Swaminathan declined a faculty position in the USA, choosing instead to return to India in 1954 with a commitment to bring about transformative change in his homeland. Professor Swaminathan joined the Central Rice Research Institute, where he was given the task of contributing to the indica–japonica rice hybridization programme, which focused on developing fertilizer-responsive rice varieties suitable for Indian rice-growing regions. Professor Swaminathan was a trailblazer in his field, and he pioneered efforts to enhance the yields of delicate indica rice varieties by crossbreeding them with sturdier japonica varieties. His research at CRRI resulted in the development of several rice varieties, including ADT27 and RASI, that were cultivated widely in Tamil Nadu. In October 1954, he joined the Botany Division of the Indian Agricultural Research Institute (IARI), New Delhi. Here, his outstanding fundamental research spanned from elucidating the structure of the chromatid, understanding mechanisms of ionizing radiation and chemical mutagenesis, exploring the effects of low and high LET (linear energy transfer) ionizing radiations on diploid and polyploid wheats, to studying Drosophila genetics and human cytogenetics.

While at IARI, Professor Swaminathan shifted his focus from rice to the development of high-dose fertilizer-responsive wheat varieties. At that time, locally adapted and farmer-preferred wheat varieties were tall and prone to lodging when heavy grains were produced in response to nitrogenous fertilizer applications. None of the hexaploid cultivated wheat varieties (*Triticum aestivum*; 2n = 6x = 42) possessed the "genes" responsible for dwarfing the height of wheat plants without reducing earhead length. However, a closely related hexaploid wheat species (*T. sphaerococcum*) was comparatively short and also had a short and compact earhead. Professor Swaminathan employed fast neutrons as high LET and gamma rays from Cobalt-60 and Cesium-137 gamma cells as low LET ionizing radiation in high dose-rate acute exposures of plant seeds to induce artificial transmutation of

genes (alleles). His work shed light on how induced mutations in wheat expedited the development of desired traits, contributing to a better understanding of the effects of food irradiation, a process that enhances food safety without altering yield.

The Force Behind India's Green Revolution

While Professor Swaminathan's intellectual curiosity propelled him towards excellence in fundamental research, his sense of social responsibility shifted his focus to applied research. The objective of the applied research was to achieve greater food and nutritional security, while also reducing dependence on food imports. In the context of dire predictions of famine in the 1960s, the central question was how to boost the productivity and production of staple food grains, specifically wheat and rice.

Professor Swaminathan proposed that plant types should be customised to be functionally responsive to external fertilizer application. He aimed to reduce the height of plants without compromising the length of grain-bearing panicles. This goal drove his pursuit of interspecific hybridization, induced radiation, chemical mutagenesis, and the use of plant growth regulators. While these efforts significantly contributed to the understanding of biological processes and responses induced by physical and chemical agents, the initial objective of obtaining dwarf/semi-dwarf wheat plants with normal spikes proved elusive. However, his commitment to staying informed about global innovations allowed him to identify the *Norin-10* dwarfing genes from Japan in wheat and *Deejee-woo-jen* dwarfing genes from China in rice. Collaborating closely with Dr. Norman Borlaug, who introduced high-yielding dwarf wheat varieties, the Swaminathan–Borlaug partnership played a crucial role in India's Green Revolution.

Professor Swaminathan initiated breeding programmes that incorporated dwarfing genes into wheat, resulting in shorter yet stronger plants that significantly increased yields. A parallel effort in rice breeding led to the development of basmati strains that stood tall even when bearing heavy grains. These new crop varieties played a pivotal role in the remarkable increase in crop yields between 1960 and 1970, steering India towards self-sufficiency in food production and averting the spectre of famine. India's wheat production doubled in just four crop seasons, surging from 12 million to 23 million tonnes. The Green Revolution, characterized by innovative approaches like "crop cafeterias" and flexible crop distribution agronomy, transformed India from a country reliant on foreign staple food grains to a self-sufficient "bread basket". Professor Swaminathan earned the title of the Father of India's Green Revolution for his monumental efforts, preventing millions from hunger and reshaping India's global image from a 'begging bowl' to a 'bread basket'.

Impact on International Agricultural Research and Development

Professor Swaminathan's contributions to agricultural research transcended national boundaries. His distinguished career included roles as Director of the Indian Agricultural Research Institute (IARI) from 1966 to 1972, as Director General of the Indian Council of Agricultural Research (ICAR) and Secretary to the Government of India, Department of Agricultural Research and Education, 1972 to 1979. Subsequently, he assumed responsibilities as Principal Secretary in the Ministry of Agriculture from 1979 to 1980, Acting Deputy Chairman and later Member (Science and Agriculture) of the Planning Commission from 1980 to 1982, and Director General of the International Rice Research Institute (IRRI) in the Philippines from 1982 to 1988. Professor Swaminathan served as the President of the International Union for the Conservation of Nature and Natural Resources (IUCN), making history as the first Indian President in the organization's 75-year history. His global perspective and collaborative ethos garnered admiration and respect from colleagues worldwide.

Actively engaging with international bodies such as Consultative Group on International Agricultural Research (CGIAR), Food and Agricultural Organization (FAO), and United Nations Educational, Scientific and Cultural Organization (UNESCO), Professor Swaminathan utilized his extensive knowledge to address global food security challenges. His influence extended to the establishment of various institutes, including the International Crop Research Institute for the Semi-Arid Tropics (ICRISAT) in India, the International Board for Plant Genetic Resources (now Bioversity International) in Italy, and the International Council for Research in Agro-Forestry (ICRAF) in Kenya. Professor Swaminathan's guidance played a crucial role in shaping institutions in countries such as China, Vietnam, Myanmar, Thailand, Sri Lanka, Pakistan, Iran, and Cambodia. As the Chairman of the UN Advisory Committee for Science and Technology, Swaminathan played a pivotal role in establishing the International Centre for Genetic Engineering and Biotechnology (ICGEB) in New Delhi. His multidimensional research work and contributions to agriculture earned him recognition both in India and abroad. Notably, he was honoured with the first World Food Prize, the Shanti Swarup Bhatnagar Award, Fellowship of the Royal Society (FRS) of London, and fellowships from science academies in India, the USA, the UK, Italy, Germany, Japan, Bangladesh, Pakistan, China, the Philippines and Soviet Union.

He was the founder president of the National Academy of Agricultural Sciences (NAAS) in New Delhi and the general president of the Indian Science Congress Association (ISCA) in Kolkata. Additionally, he served as a member of the upper house (Rajya Sabha) of the Indian Parliament and was in charge of agriculture and rural development in India's Planning Commission. A watershed moment in his career occurred in 2004 when he assumed the role of Chairman of the National Commission on Farmers, established in response to escalating farmer distress and

alarming suicide rates. The Commission made significant recommendations, notably advocating a minimum support price (MSP) that was at least 50 percent above the weighted average cost of production.

Sustaining the Legacy

M. S. Swaminathan comprehended the intricate relationship between science and society, and his insights extended beyond the realms of academia. He took the lead in introducing community-based strategies for gene, seed, and grain management. This approach prioritised local involvement and sustainable practices to safeguard food security. He participated actively in discussions with critics, including those opposing genetically modified organisms, and advocated a balanced perspective on biotechnology. He emphasized the importance of safety and ethical considerations in these discussions.

As we contemplate the life and legacy of Professor Swaminathan, let us carry forward the torch he ignited. Honouring his memory involves continuing the journey he initiated—a journey toward a world where no one sleeps hungry. He epitomized how science can act as a catalyst for positive change, and showed that research can be directed toward addressing tangible challenges. His legacy continues to inspire researchers and policymakers to tackle the pressing challenges of our time, from climate change to sustainable agriculture.

Figure 1 *Professor M. S. Swaminathan at the 5th International Conference on "Next Generation Genomics and Integrated Breeding for Crop Improvement," ICRISAT, Hyderabad, February 2015.*