

The knight of sugar industry: T. S. Venkatraman (1884–1963)

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*Tiruvadi Sambasiva Venkatraman (TSV) was a plant breeder. In response to a call from Pundit Madan Mohan Malaviya, he made it his mission to develop high-yielding varieties of sugarcane for manufacturing sugar and making it available as a sweetening agent and an energy source for the malnourished children of India. Using *Saccharum officinarum*, then under cultivation in India, as the female parent, he artificially fertilized it with pollen from *S. barberi*, which grew wild in Coimbatore. After 4–5 recurrent backcrossings of *S. officinarum* × wild *Sorghum spontaneum* with *S. officinarum* as the female parent, TSV selected the 'rare' interspecies hybrid cane varieties that resembled sugarcane and had approximately 2.5 cm thick juicy stems containing 16–18% sucrose – nearly 35 times more than what occurred in parent stocks. The hybrid canes matured quickly, were resistant to waterlogging, drought, and to the red-rot disease caused by *Glomerella tucumanensis* (Sordariomycetes: Glomerellaceae), and to the sereh-virus disease. Most importantly, they were amenable for propagation using stem cuttings. In recognition of the development of high-yielding sugarcane varieties, TSV was conferred the titles Rao Bahadur, Rao Sahib, and Sir by the British Government, and Padma Bhushan by the Republic of India. In the next few decades, consequent to TSV's work, India turned into the second largest sugar producer in the world, after Brazil. The hybrid sugarcane varieties developed are the foundational stocks for new sugarcane × bamboo hybrids, and for possible resistance to *Puccinia megalcephala* (Pucciniomycetes: Pucciniaceae) and *Ustilago scitaminea* (Ustilaginomycetes: Ustilaginaceae) using molecular techniques.*

The opening paragraph of an article in the *Journal of Heredity*¹, excerpted from *Nature* runs as follows:

'Hybridization in and with the genus *Saccharum* formed the topic of Rao Bahadur T. S. Venkataraman's presidential address to the Sections of Agriculture. Hybridization in the sugar-cane at the Imperial Sugar-cane Station at Coimbatore was the first attempt to improve the subtropical types of canes. This genetic work, which has been going on at the station for more than twenty-five years has involved six species of *Saccharum* and four genera.'

The 'Imperial Sugar-cane Station' referred here was the Sugarcane Breeding Station then, now the Sugarcane Breeding Institute, which celebrated its centenary in 2012. We, the authors of the present note, have endeavoured to bring to light the work in which T. S. Venkatraman (TSV; Figure 1) was engaged in for more than three decades in response to the clarion call of the educationist and freedom fighter Pundit Madan Mohan Malaviya:

'Undertake research to increase production of sugar, making it available, especially for the malnourished children.'

A nation can claim to be independent only when it has ensured food security by producing crops that are major sources of sugars, proteins and lipids. Sugar is necessary both as a sweetener and as a source of metabolic energy. In 1912–1942, the development of high-yielding cane varieties in India was a breakthrough, which matches with the development of high-yielding varieties of wheat in Mexico by the Nobel laureate Norman Borlaug (1914–2009). The goal of a breeder is to combine the useful features of two parental species into one genome. Historically, plant breeders

attempted to combine the preferred characters of wheat (*Triticum*, $2n = 6x = 42$) with rye (*Secale*, $2n = 2x = 14$), and achieved an infertile *Triticale*². Similar attempts to create *Raphanobrassica* by hybridizing radish (*Raphanus sativus*) with cabbage (*Brassica oleracea*) (both of Brassicaceae) failed. Undeterred by these vain trials, TSV attempted intergeneric and interspecific hybridizations and succeeded in crossing *Saccharum officinarum* × *S. spontaneum* and obtaining hybrids bearing 'difficult-to-achieve' traits and with greater levels of sugar, and were amenable to propagation with stem-cutting. His work showed the potential of improving sugar yield further by wide crosses, contrary to the general perception of failure of wide crosses.

The present note aims to reconstruct details of TSV's work, based in part on the available biography by Thuljaram Rao³. Rao was TSV's only M Sc student, who in 1961–1970 and 1976–1979 officiated as the Director of the Sugarcane Breeding Institute, Coimbatore.

Whereas substitute crops are available for carbohydrate (e.g. rice) and protein (e.g. wheat and pulses) and lipid (e.g. mustard and groundnut) requirements of humans, as much as we know, sugarcane is the only plant which is a source of a sweetener and energy in tropical countries. Photosynthetically, sugarcane is the



Figure 1. T. S. Venkatraman.

most efficient plant in terms of the quantity of extractable sugar. Today, nearly 80% of sugar (sucrose: C₁₂H₂₂O₁₁) consumed in the world is from sugarcane, whereas the remainder is from sugar beet (*Beta vulgaris*, Chenopodiaceae) in temperate countries.

In the footsteps of Mendel

Similar to Mendel (1882–1884), who grew garden pea (*Pisum sativum*) as the study material in his monastery, TSV planted *Solanum melongena* (Solanaceae, brinjal, eggplant, aubergine) in a block of land behind his house and was engaged in hybridization trials. Like Mendel, TSV either did not publish his findings or published them in a local journal. According to Thuljaram Rao, TSV was inspired by Jonathan Swift's words in *Gulliver's Travels*:

'Whoever could make two ears of corn, or two blades of grass, to grow upon a spot of ground where only one grew before, would deserve better of mankind, and do more essential service to his country, than the whole race of politicians put together.'

Professional development

After a postgraduate degree, possibly through a thesis from the University of Madras, TSV obtained his D Sc from Andhra University, Waltair. While being in the Indian Agricultural Service, he worked as a Government Sugarcane Expert in the Sugarcane Breeding Station, Coimbatore. This station was established by the British Government with the objective of collecting indigenous and exotic varieties of canes for generating hybrids (Figure 2). Charles A. Barber (a South African botanist – plant breeder) was the first superintendent of the station. He was succeeded by TSV. Venkatraman desired that India becomes self-sufficient in sugar production. He must have noticed that some cane varieties that did not flower in the Indo-Gangetic Plain, did so in Coimbatore. This should have prompted him to think of the differential responses of plants to climate in the context of flowering, pollination, fertilization and seed set. Hoping for sugarcane varieties as tall as bamboos for a greater yield of sugar, TSV undertook trials of intergeneric

crosses between sugarcane and bamboo. This effort impresses us as a work of courage and novelty, when viewed against the background that until that time attempts at intergeneric hybridization had failed. TSV succeeded in raising a few hybrid seedlings (*S. officinarum* × *S. spontaneum*) under field conditions, some of which appeared weak, although in due course they flowered and produced seeds in Coimbatore. This finding indicated that species delimitation in the genus group *Saccharum* may not be as rigid as in other plants. The development of hybrid cane varieties has indeed paved the way for future biotechnological possibility of creating tall varieties by crossing *Saccharum officinarum* and *Bambusa* sp. (ref. 3).

Research and evaluation

To meet the sugar demand in colonial India and in Britain, the British established the Sugarcane Breeding Station at Coimbatore in 1912 with Barber, as its first superintendent, who recruited TSV as his deputy. TSV must have noted that in the warm climate some close relatives of sugarcane would flower, enabling the production of hybrid canes by crossing, a physical process by which the pollen (male reproductive cell) is transferred to the receptive surface of the female reproductive organ. TSV collected all plants with cane phenotype that suited the prevailing hot (summer, April–June) and cold (winter, November–January) conditions in the Indo-Gangetic Plain.



Figure 2. *Saccharum* cane (red).

Several varieties which did not flower in the northern states because of large variations in temperature, and/or diurnal variations in the photoperiod, flowered in Coimbatore.

Coimbatore as the world capital of sugarcane research

The climate and geographical location of Coimbatore (11°N; 77°E) enabled several varieties of sugarcane to flower and set seeds. TSV succeeded in generating interspecific hybrids by crossing selected parents (Figure 3) and developed high-yielding varieties (e.g. Co 205, Co 255, Co 299, Co 312, Co 313, Co 513, Co 527), as a result of which India changed from the status of holding a 'begging bowl' for sugar to that of being a sugar exporter. It is to the credit of TSV, who had known that pollen viability, stigma receptivity and the time of the day for cross-pollination were critical for fertilization and fertile seed formation. These varieties are, used even now as stocks for breeding in Australia, Bangladesh, Indonesia and Pakistan. Today, sugarcane is even more valuable. It is a fuel crop, being the source of fibrous cellulosic and hemicellulosic biomass for its conversion into commercial alcohol via the conversion of its glucose contents using fungus-derived cellulase and subsequent anaerobic conversion into alcohol by yeast fermentation as a transport fuel.

Nobilization

Sugarcane is grown in more than 90 countries. It is an ideal example of crop improvement by multiple hybridization (backcrossing) with a 'noble' cane, *Saccharum officinarum*, which became popular in India. The variety Co 281 became popular in Louisiana (USA), whereas varieties Co 281 and Co 290 became popular in South Africa. Co 281 became popular in Cuba. TSV's work impacted on sugarcane production in almost all tropical sugar-producing countries. According to Thuljaram Rao³, Co 419 was hailed as 'the wonder variety for the tropics and served for four decades in states below the Vindhyas'.

The yellow or the greenish-purple stem of the cane varieties include about 18% sucrose in the expressed juice⁴ (Table 1).

HISTORICAL NOTES

Table 1. Characters of select commercial sugarcane varieties, species involved in crossings and sucrose content*

Variety	Botanical characters	Species involved in crosses	Varieties (named after locations) involved in crosses	Sucrose in juice (%)
Co 1148 (variety is a derivative of the wonder cane of India, Co 419)	Yellowish-green with purple tinge	<i>Saccharum officinarum</i> <i>Saccharum barberi</i> <i>Saccharum spontaneum</i>	Banjarmasin Hitam, Black Cheribon, Fidji, Chuneer, Kaludai Boothan Lahaina, Loethers Coimbatore Java	17.1
Co 6304	Thick, green	<i>Saccharum officinarum</i> <i>Saccharum barberi</i> <i>Saccharum spontaneum</i>	Banjarmassin Hitam Chuneer Coimbatore	10.9
Co 62198	Light green	<i>Saccharum officinarum</i> <i>Saccharum barberi</i> <i>Saccharum spontaneum</i>	Mauritius Chuneer Saretha Coimbatore Java	18.3

*From Sankaranarayanan *et al.*⁴.

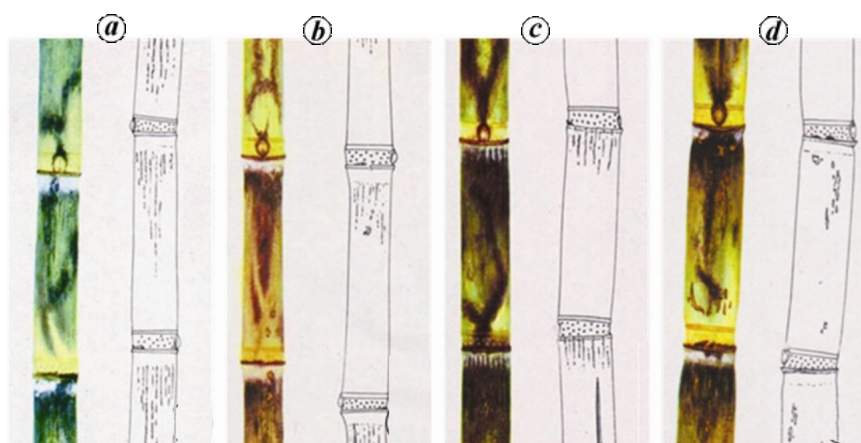


Figure 3. High-yielding sugarcane varieties. (a) Co 853, (b) Co 1148, (c) Co 6304 and (d) Co 62175.

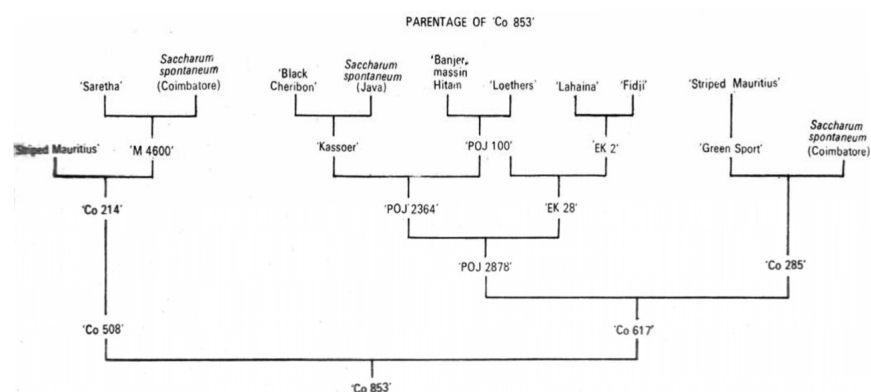


Figure 4. Synthesis of Co 853. The variety Co 853 illustrates the intergeneric and interspecies hybridization protocol that Venkatraman used to create noble sugarcane. According to Sankarnarayanan *et al.*⁴, the variety was derived by crossing Co 508 with Co 617 and the seed parent Co 508 was bagged. The variety has in its genome complement *S. officinarum* from 'Banjermassin Hitam', 'Black Chribon', 'Fidji', 'Lahaina', 'Loethers' and 'Striped Mauritius', *S. barberi* from 'Saretha', and *S. spontaneum* from Coimbatore and Java forms. The variety was cultivated mainly in Tamil Nadu and Pondicherry. Reportedly a good ratooner gives light yellow jaggery⁷.

Wide hybridization

With the idea of shortening the flowering time of the cultivated cane, yet maintain its juiciness, TSV pollinated *S. officinarum* using the pollen of *S. spontaneum* and obtained the hybrids Co 205 and Co 285, which yielded 50% more in Punjab. TSV also tried three or four interspecific hybrids combining the genomes of *S. officinarum*, *S. spontaneum*, *S. barberi*, and *S. robustum* for sugar production in Uttar Pradesh. According to Thuljaram Rao:

'The technique consisted in isolation of sugarcane stalks through aerial rooting at the nodes using inexpensive tile pots and removing the rooted stalks for controlled hybridization away from the foreign pollen ... This novel method of rooting and isolation later led to the development of techniques in other countries for controlled crossing.'

To illustrate TSV's hybridization protocol, we take the example of Co 853 (Figure 4) that was derived⁴ by crossing Co 508 with Co 617. The seed parent was bagged (covered with an envelope to prevent self-pollination). Co 853 has unidentified genes of *S. officinarum* from 'Banjermassin Hitam', 'Black Chribon', 'Fidji', 'Lahaina', 'Loethers' and 'Striped Mauritius', presumably from the West Indies, *S. barberi* from 'Saretha', and *S. spontaneum* from Coimbatore, and a few anonymous Java forms. Co 853 withstood waterlogging and drought

conditions. The variety was resistant to rust, and smut disease caused respectively, by pathogenic fungi *Puccinia melanocephala* and *Ustilago scitaminea*. It was suitable for medium and heavy soils. It was a good ratooner and yielded good-quality unbleached sugar, light yellow in colour, hard and crystalline⁴.

TSV spent his working life at the Sugarcane Breeding Institute. On the occasion of its centenary, Nair⁵ mentioned that the first variety Co 205 released from the Institute in 1918 recorded more than 50% improvement in cane yield over the native varieties and replaced them within a short span of 6–8 years, thus marking the green revolution in sugarcane; several wide crosses involving bamboo were made by TSV and his colleagues, but perhaps because the work was done towards his retirement, the data are incomplete and not well-documented.

Honours and awards

Thuljaram Rao proudly refers to TSV as the 'sugarcane wizard', obviously referring to his ability to discriminate varieties from their thickness, colour, joint shape markings, length of the internode and the shape and position of bud. TSV was a Foundation Fellow of the Indian National Science Academy. He was a member of the International Genetics Congress Association, President of the Indian Society of Genetics and Plant Breeding, and member of the International Society of Sugarcane Technologists. TSV was conferred the titles Rao Sahib (1920), Rao Bahadur (1928), and Commander of the Indian Empire (1937). He was knighted in 1942, and independent India bestowed Padma Bhushan in 1956. He was President, Agricultural Section (1928) and General President (1935), Indian Science Congress Association.

An agenda for novel sugarcane breeding

As sugarcane is a polyploid ($2n = 82-124$)⁶, obtaining fertile hybrids must have been formidable; the overwhelming majority of seedlings in the population are worthless⁶. It is gratifying that high-yielding sugarcane varieties, wherever they are grown in the world, have genomes contributed by varieties developed by TSV at Coimbatore and these countries also have a programme of wide-hybridization with plants belonging to Gramineae (*Bambusa*, *Erianthus*, *Miscanthus*, *Sorghum* and *Tripsacum*) to 'widen the genetic basis for use of sugarcane for the production of sugar, ethanol, fibre, and electricity'⁷.

Glossary

Allopolyploid – Possessing two or more unlike sets of chromosomes.

Autopolyploid – More than two sets of homologous chromosomes derived from a single species

Introgression – The introduction of genes from one species into the gene pool of another species through artificial mating to produce fertile hybrids.

Noble cane is a juicy variety of *S. officinarum*.

Nobilization – The process of recurrent backcrosses of a hybrid sugarcane variety to a noble cane. As an example experimental F₁ hybrids between *S. officinarum* and *S. spontaneum* were called the 'first nobilization' of *S. spontaneum*; the first back cross with *S. officinarum* obtained the name of 'second nobilization' and the second back cross the 'third nobilization' of *S. spontaneum* to improve its sugar content and resistance to pests and pathogens.

POJ, Profestation oost Java – A variety of *S. officinarum* from Java used in backcrosses for constructing Co (Coimbatore) canes.

Saccharum spontaneum – A wild cane typically forming stolons with little juice; $2n = 40$ or more chromosomes.

Saccharum officinarum – A cultivated variety of cane with thick and juicy stem; $2n = 80-126$.

Saccharum robustum – Wild cane typically forming long subterranean runners, but with low sugar content; $2n = 60$ or 80 .

Wide cross – To form a hybrid by crossing two unrelated species or genera.

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