Dr. SVS Shastry Memorial Lecture

Designing future rice for enhanced profitability and nutritional security

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At the outset I wish to express my heartfelt gratitude to the Organizing Committee, ICAR-Indian Institute of Rice Research (ICAR-IIRR) and Society for Advancement of Rice Research (SARR), Hyderabad for giving me an opportunity to deliver the first Dr. S.V.S. Shastry Memorial Lecture 2019. It is indeed a great honour and am humbled with this noble association with Dr. Sishta Venkata Seetharama Shastry, with whom my association dates back to *Kharif* 1969 when he himself came to monitor the AICRIP trials. The trials were conducted at IARI Regional Station, Karnal. We travelled together and he knew the details of each and every trial being conducted at Karnal. Thus, through his exceptional vision and meticulous planning as the Project Coordinator, he spearheaded the All India Coordinated Rice Improvement Project (AICRIP), the first of its kind in the world for rice varietal evaluation and release.

The vision of Dr. Shastry was farfetched with respect to crop improvement in India, especially rice improvement. As a rice cytogeneticist, he published the seminal report on the pachytene analysis in rice for the first time (Shastry *et al.*, 1960). As an evolutionary biologist, his extensive research on biosystematics of *Oryza* complex helped in delineating the taxonomic identity of two new species of *Oryza* namely, *Oryza nivara* and *O. collina*. Based on their studies, they proposed that *O. nivara* is the progenitor of cultivated rice (Shastry and Sharma, 1973). One of the collections of *O. nivara* was found to be resistant to grassy stunt virus disease of rice at International Rice Research Institute (IRRI), Philippines which helped the development of grassy stunt virus resistant rice varieties. As a pioneer in rice varietal evaluation system in the country, he extended his interest on crop adaptation traits, extensively searching the gene pool for resistance to pests and diseases, tolerance to nutrient deficiency over and above the major focus of his research on yield improvement. Dr. Shastry was an ardent fighter for poverty alleviation worldwide, particularly in India, and he was one of the early researchers to realise the importance of improving rice yield in alleviating hunger in the country. He was conscious of rice grain quality and with his futuristic vision was instrumental in constituting the first slender grain varietal trial in 1969, which was later renamed as Basmati derivative trial. This trial later on evolved as National Basmati Trials. He has developed the premium quality slender grain rice variety, “Sona”, which was widely used as one of the parents for developing fine grain rice varieties such as Haryana Basmati 1 (Sona/ Basmati 370).

Dr. Shastry recorded his futuristic views on rice breeding in India in an article published in the journal Crop Science, which I quote “This shift in priority from production to productivity, and then on to profitability is an index of progress with technology. It is also the continuing challenge for the future” (Shastry 2006). He was referring to the transformation of rice varietal evaluation system from production improvement as happened in the early green revolution period, to improved productivity as a function of grain output per unit land area, as it was realized later towards the end of last millennia. The transformation from the days of ‘hands to mouth’ to the ‘enough in hands’ has been a reality mainly because of the continuous crop improvement that has happened during the active period of Dr. Shastry as the founder leader of AICRIP system in India. Now, in order to metamorphose from the ‘handful’, I believe that there is a need to change the paradigm from “productivity” to “profitability” which needs to be addressed by the rice improvement programmes across the country. This has prompted me to address this important issue of “continuing challenge for the future of rice” in this maiden lecture commemorating Dr. Shastry titled “Designing future rice for enhanced profitability and nutritional security”.

Present Status of Rice in India

India produced 112 million tonnes of rice from an area of 43 mha at an average productivity of 2.6 t/ ha. Out of the total area, 24 mha of rice area in Punjab, Haryana, Uttar Pradesh, West Bengal, Bihar, Odisha, and parts of Andhra

Pradesh, Tamil Nadu is irrigated. About 17.2 mha is under rainfed area, out of which more than 70% of which is in eastern India. Around 85% of the total rice production is contributed by the favourable ecologies of irrigated and shallow lowland. Rice is the most resource intensive crop among all the agricultural crops in India and annually it uses about 200 km3 of irrigation water, 6.5 mt of fertilizers, 17% pesticides used in Indian agriculture and emits 3.5 mt of methane (Pathak *et al.,* 2019).

Rice in India is at a critical juncture. The monopolistic development in rice area and production has almost stalled and the climb in the graph that has been witnessed since mid-sixty's has reached a plateau. The primary reason for this is the increase in human population which always outperformed the rate of agrarian development. This trend could be worrisome, because, if this level continues without significant improvement in food availability, we might be returning back to the dreaded olden days where hunger dominated our society. However, future is still bright, thanks to the explosive development in science especially genetics, that has already proven its role in securing food security by the way of green revolution. If one or few genes such as the dwarfing gene could produce a green revolution there are about 55,986 genes on rice genome that can be relied upon.

Achievement in Rice Improvement

Since 1950s, India has witnessed release of more than 1500 rice varieties, suitable for different agro-ecological zones. Comparing the yield levels of these varieties, one cannot witness any perceptible yield increase in the varieties that were released later than from the earlier ones. For instance, the popular variety, "Jaya" bred by Dr Shastry released in 1969 has an estimated yield level about 55-60 q/ha. Still, yield of Jaya can be regarded comparable to that of a variety released in 2000's. This implies that we are lacking somewhere in our assessment especially the yardstick for promoting a variety, which needs introspection. There have been a large number of landmark varieties evolved and released over time in India, which have ruled the rice production scenario in India and other rice growing countries during last few decades. The mega-varieties of rice such as Jaya, Swarna (MTU7029), Savithri (CR1009), Samba Mahsuri (BPT5204), IR36, IR64, Pusa Basmati 1, Cotton Dora Sannalu (MTU1010), Pusa Basmati 1121 and some new ones like Pusa Basmati 1509 slowly catching up with its popularity.

The green revolution could help in bringing a major leap in rice production with the milled grain production of 34.6 million tonnes in 1960 increasing to 115.0 million tonnes in 2019. The growth has been almost steady although few falls in the trend has been witnessed in some of the years. Furthermore, the overall rice production trend in India still pointed upwards trend in spite of a reduction in total area. The modern Indian rice varieties have been made smart, from the high resource hungriness to resource efficient. Thanks to the use of streamlined breeding efforts using precise tools of genomics, the modern-day rice varieties are tolerant to drought making it more water use efficient, resistant to disease and pest, and other abiotic stresses such as submergence, salinity and sodicity and as I understand efforts to develop rice varieties with improved nutrient use efficiencies and enhanced tolerance to low nutrient are at advanced stages especially for phosphorus (P) with the introgression of PSTOL locus which provides tolerance to low P. A beginning has been made and it has traverse long to meet the needs of the future. Our hope, lies with more than 55,986 genes on the rice genome and with more than 40,000 rice genotypes, in which these genes are being ingrained in different forms (alleles) together with an additional pool of more than 90,000 related wild and cultivated lines.

Challenges in Rice Research

India currently grows rice in about 43 million ha, almost a million hectare has been lost for rice production during this decade so far, owing to several factors such as shrinking water availability, nutrient depletion, uncertain rains, soil salinization, urbanisation, cropping system changes and poor economic returns. Comparing the global scenario, the loss is significant, because worldwide trend in rice area still remains upwards except China, although the slope has declined. Beginning from the days of green revolution, after the introduction of famous sd1 gene into the breeding lines from the Taiwanese variety, Dee-Geo-Woo-Gen, the average rice yield worldwide has doubled from 2.0 to 4.0 tonnes/ha (www.ricepedia.org). The increase corresponding to this period in India is however not in tune to the world figure, a meagre increase of 2.2 tonnes/ha from 0.7 tonnes/ha. The rice production, although indispensable, has been always a challenge to Indian farmers. Alternatively, the introduction of high yielding varieties has witnessed another dramatic climb in the area under the modern varieties. The area of less than 100 ha under HYVs in 1965, has risen to more than 40 million ha by the late 2010. The corresponding increase in total rice area was from 30 million ha to 40 million ha. Therefore, it is a fact that during green revolution, modern varieties not only replaced most of the 30 million ha occupied by traditional cultivars, but also brought in another 10 million ha under rice cultivation. Most of these areas came from non-traditional regions such as Punjab, Haryana and western Uttar Pradesh, where once the cultivation of rice was very limited. Long term consequence of this shift in cultivation aimed at higher earnings from farm holdings with support in the form of minimum support price (MSP) has led to significant damages to the environment and depletion of groundwater. The dwindling water resources has forced the ban on rice planting until mid-June, in states like Punjab and Haryana. The repercussions of pushing rice towards the fringes of wheat cultivation window, is now seen as air pollution by indiscriminate burning of stubbles with the aim to clear the lands in short period of time.

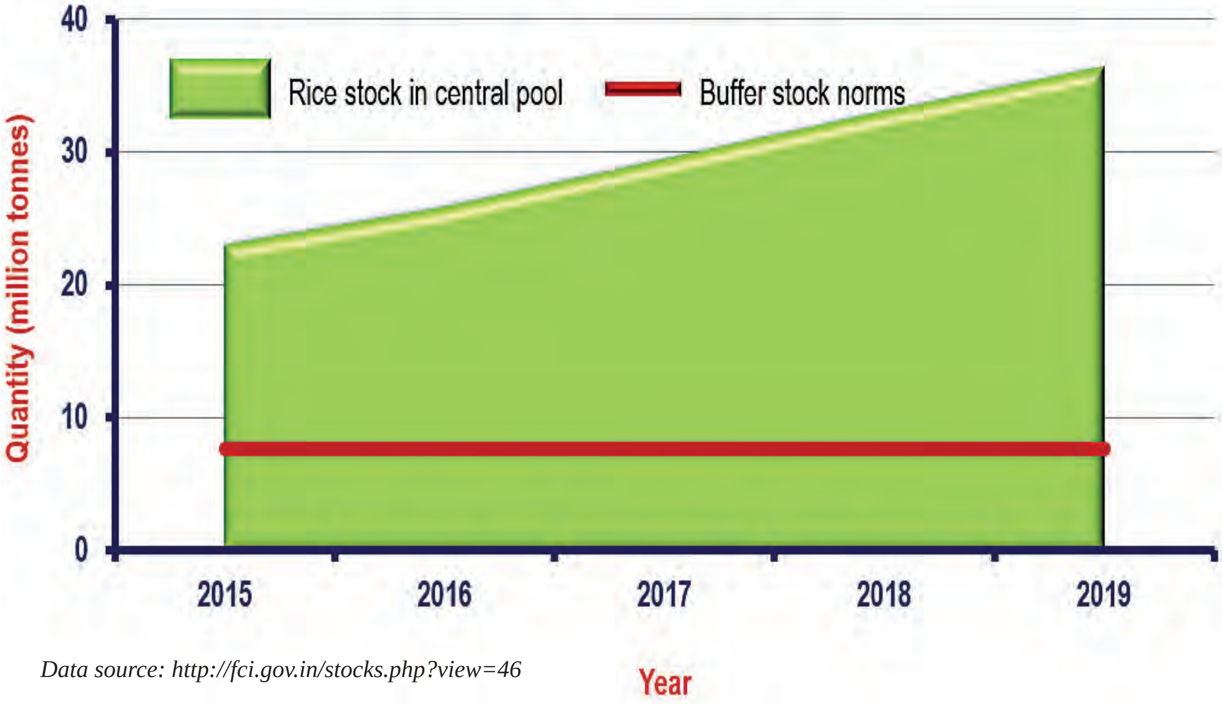
There was a concern raised by the critics that due to introduction of high yielding varieties there has been a severe loss of the wealth of traditional rice varieties in India. Taking a critical look, it is not hard to realise that most of these traditional cultivars are conserved in our National Gene Bank and valuable alleles, if any can be brought back into the modern-day cultivars using precision tools available to modern day breeders. In contrary, the high yielding modern varieties have in fact amassed a great proportion of alleles for yield and resource efficiency. Later, emphasis on quality was introduced, especially in the 1980s, which had brought out several commercially important varieties particularly known for grain quality. However, in spite of the boom in high yielding varieties, there has been several traditional cultivars conserved in the farm holds for special purposes that are even grown today. These landraces could be treasure trove for alleles governing specialty traits in rice.

Rice is consumed by 0.8 billion people across the country. In order to meet our commitments of the Sustainable Development Goals especially goal 2 (Zero hunger), we need to produce safe nutritious and sufficient food, which would be around 135 mt of rice by 2030. All along, we need to ensure doubling both agricultural productivity and incomes of small farmers. Add to this the limitations imposed by climate change and our commitment to maintain ecosystems and the genetic diversity of seeds, there is a need for introspection and act accordingly.

The severity in incidence of the major biotic and abiotic stresses, changing scenario of hitherto minor diseases, insect-pests and weeds causing major economic losses due to climate change are new challenges for rice improvement. For example, the increase in incidence of bakanae disease in Basmati rice, panicle blight in rice across northern India, false smut across rice growing regions of India especially in eastern India, brown plant hopper in rice, flash floods due to skewed rainfall distribution in eastern India and salt accumulation in coastal regions due to ingression of sea water needs to be addressed through strategies involving transdisciplinary research.

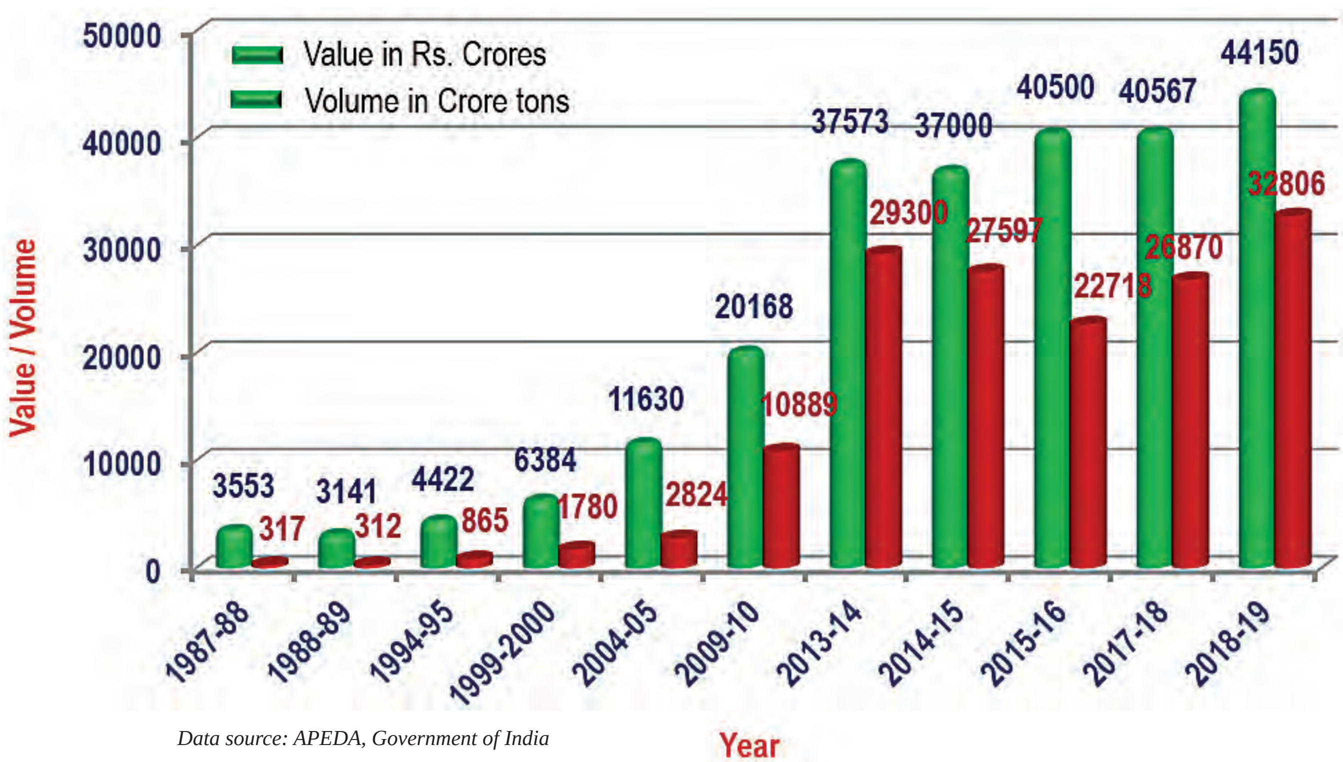
About 4.5 mha of the irrigated rice is cultivated in Punjab and Haryana, out of which about 3.3 mha is under non-Basmati rice which is primarily meant for the public distribution system (PDS). A cursory glance at the buffers stock norms and the actual stocks of rice in the central pool during the last five years (Fig. 1) indicates that there is around 4 times more rice stock in the central pool on an average over this period, which goes unattended in open storage resulting in huge losses if there is untimely rains after procurement.

Based on the basic principles of availability, accessibility and absorption, the problems of fast depleting ground water, unbalanced fertilizer use, indiscriminate use of agro-chemicals and other issues associated such as paddy straw burning for fast disposal resulting in air pollution, growing non-Basmati rice for PDS in these states are moving towards unsustainability in the long-term. With abundant water and well suited agro-climate the rice cultivation and schemes such as Bringing Green Revolution to Eastern India (BGREI), it will not take long for the sleeping giant in the eastern India to produce rice for not only meeting the needs of the PDS of the entire country but also for the potential export markets. In fact, there is a need to reduce the area under rice to around 35 mha, where there is a potential to increase the productivity to 5.0 t/ha, so that the 8 mha from the currently cultivated area with comparatively less potential for rice cultivation can be diverted for other crops.



Data source: http://fci.gov.in/stocks.php?view=46

Fig. 1: The buffer stock norms and the actual stocks of rice in the central pool during the last five years



Data source: APEDA, Government of India

Fig. 2: Trends in Basmati rice exports and foreign exchange earned.

Need for a Change in Paradigm

There is a need for paradigm shift in rice research, wherein it is time to focus from enhancing productivity to profitability enhancement which needs to take into account several factors including (a) economizing the cost of cultivation through development of rice varieties with resistance to major insect-pests, diseases and weeds thereby minimizing the potential risk of pesticide residues, (b) improving the water productivity by developing varieties suited for aerobic/ limited water environments, (c) making sure the timely availability of quality seeds and other agro-inputs in reasonable price, and (d) enacting policy measures for easy marketing and timely payment for the rice produce.

India is endowed with rich diversity of specialty rice including Anterved, Atmashital, Banspatri, Gangaprsad, Kadamphool, Kapursar, Loktimachhi, Shri Kamal, Tilkasturi, Gandhagasala, Keoni, Dudheswar, Dudda Dhan, Devbhog, Kavuni, Navara, Naa maa lhaa lay, Chakhao and Vishnubhog from different parts of the country. India is renowned across the globe for Basmati rice. Systematic research initiated by none other than the father of green revolution, Prof. M. S. Swaminathan, we have made huge strides in combining exceptional grain quality of Basmati with productivity improvement over the last eight and half decades. Scientific studies and proper follow up has resulted in development of exquisite Basmati rice varieties such as Pusa Basmati 1, Pusa Basmati 1121, Pusa Basmati 6 (Pusa 1401) and Pusa Basmati 1509, which has significantly improved the foreign exchange through the export (Fig. 2) resulting in not only improving the balance of trade for India but also created a Basmati revolution in the country by brining in prosperity to different stake holders including the farmers, seed producers, millers, exporters and consumers.

Noteworthy is the profit realisation by the Basmati growing farmers to more than four times since the release of Basmati 370. There is a need to emulate the Basmati rice model for creating the value chain for other specialty rice. Although there has been efforts made to develop nutritionally rich rice varieties such as low glycemic index rice variety, “Madhuraj 55” from the land race Chapati Gurmatiya, high zinc rice variety, “DRR Dhan 45”, high protein rice variety, “CR Dhan 10”, there is a need to strengthen our efforts towards nutrition rich high quality rice varieties. This can be possible through (a) validation of the medicinal properties of the specialty rice through metabolic profiling, (b) coordinated efforts among the national rice researchers in partnership to strengthen the efforts on improvement and designing appropriate package of practices, (c) more emphasis on the grain quality characters such as high density grain, higher brown rice per cent (> 80%), high head rice recovery, non-chalky grains, better mouthfeel, taste, palatability, faster cooking, longer shelf life and stale-lessness of the rice entries being tested (d) constituting an independent body equipped with modern digital tools for organizing the coordinated trials to ease the burden on the rice researchers across the country, (e) time to time interaction with various stakeholders including farmers, millers, exporters and policy makers, (e) modernizing the rice breeding programmes by equipping them with modern technologies including artificial intelligence and modelling for assessing the rice genotypes, growing environments and testing facilities.

Conclusion

In conclusion, there is a need for coordinated efforts involving all stakeholders concerned including consumers, millers, farmers, exporters and scientists to realise the slogan “Dhan-Kisan-Vigyan-Udhyog”. As scientific researchers we need to gear up ourselves with modern scientific tools to address the emerging challenges in rice research. Finally, based on my own experience, I would like to emphasise to the young researchers that with all the enablers in place, the motivation to find joy in the testimony by the stakeholders and to work as a team is very important in shaping a better rice for the future.

Dr. Vijai Pal Singh

Born on January 17, 1945, Dr. Vijay Pal Singh received his M.Sc.(Ag) in Agricultural Botany in 1966 and Ph.D. in Agricultural Botany in 1977 from Agra University, Agra. Dr. Singh joined as Seed Production Assistant in the National Seeds Corporation in 1967 and later joined as Research Assistant in the Division of Genetics, Indian Agricultural Research Institute in 1968. Since then, he has been actively engaged in basic and applied aspects of rice research and retired as Project Leader (Rice) in January, 2007. Dr. Singh has served Agricultural and Processed Food Export Development Agency as Advisor in Basmati Development Fund and then a key member in establishing the state of art facilities at the Basmati Export Development Foundation at Modipuram, Meerut, Uttar Pradesh. Dr. Singh has done commendable work in understanding the genetics of quality traits in rice in general and Basmati rice in particular. He has been instrumental in developing the minimum quality standards for Basmati rice, which serves as the benchmark for the rice breeding programs across the world. Apart from application oriented basic research, he has been actively engaged in the development of a large number of high-yielding aromatic and non-aromatic rice varieties including Pusa 2-21 and Pusa 44, which brought the revolution in basmati productivity. Dr. Singh’s significant contribution in Basmati rice improvement began with the development and release of the first high-yielding, semi-dwarf, non-lodging variety with Basmati quality characteristics, Pusa Basmati 1 in 1989, which has brought about Rs. 14,000 crores of foreign exchange earning to India and prosperity to millions of Basmati farmers of north-western India. His landmark contribution came in the form of phenomenal popularity of Pusa Basmati 1121, owing to its overwhelming acceptance in both national and global rice consumers, which led to the new era of prosperity for different stakeholders in Basmati rice supply chain including farmers, traders, millers and exporters. This is considered as one of the best models for improving the profitability and sustaining the rice supply chain across the world. Besides this, he has been instrumental in conceptualization and development of the country’s first product of molecular breeding, Improved Pusa Basmati 1, by introgressing two genes, xa13 and Xa21 governing resistance to bacterial blight and another exquisite Basmati rice cultivar, Pusa Basmati 6 with excellent cooking and eating quality. He has guided four M.Sc. and seven Ph.D. students of which two have been awarded the Jawahar Lal Nehru Outstanding Doctoral Thesis Award by ICAR. He has published more than 30 research papers in reputed national and international journals, written 6 book chapters and has been member of the PG School faculty, IARI, New Delhi, from 1986-2007. Recognising the impact made through his outstanding contribution in Basmati rice improvement, he was honoured by conferred Padma Shri by the President of India in 2012. He has been awarded Hari Om Ashram Trust Award (1974-75), Jawahar Lal Nehru Award for outstanding doctoral thesis (1977), Dr. B.P. Pal Memorial Award (2005), ICAR Team Award for Crop Improvement (2007) and Sh. O.P. Bhasin Award (2012). He is fellow of the National Academy of Agricultural Sciences, New Delhi; Indian Society of Genetics and Plant Breeding, New Delhi and Association of Rice Research Workers, Cuttack.

Society for Advancement of Rice Research congratulates Dr Vijai pal Singh, first recipient of Dr SVS Shastry Award - 2019