# Century of Rice farmers' innovation in farm based approaches, experiences and lessons with SRI and way forward for future rice production and quality within the context of climate change

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## 1. Rice and India

Rice is not every thing in India, but every thing in most parts of India starts and ends with rice. It is more an integral part of Indian culture. It is life line; this life line has extended in more than 540 districts of 604 districts in India. It is a versatile crop grown in all most all agro-climatic zones except on the very high altitudes, glaciers.

The name of the global grain rice probably has its roots in India. According to the Microsoft Encarta Dictionary (2004) and the Chambers Dictionary of Etymology (1988), the word rice has an Indo-Iranian origin. It came to English from Greek *óryza*, via Latin *oriza*, Italian riso and finally Old French *ris*. It has been speculated that the Indo-Iranian *vrihi* itself is borrowed from a Dravidian *vari* or even a Munda language term for rice, or the Tamil name *arisi* which the Arabic *ar-r*uzz, from which the Portuguese and Spanish word *arroz* originated (http://en.wikipedia.org/wiki/Rice).

In India, rice cultivation probably began in the upper and middle Ganges between 2000 and 1500 B.C. It expanded quickly after irrigation works spread from Orissa State to the adjoining areas of Andhra Pradesh and Tamil Nadu in the Iron Age around 300 B.C. ( http://www.cambridge.org/us/books/kiple/rice.htm).

Rice is first mentioned in the Yajur Veda (c. 1500-800 BC) and then is frequently referred to in Sanskrit texts, which distinguished summer varieties from rainy season and winter varieties. *Shali* or winter varieties were most highly regarded. About 2000 years ago, rice was well-established as the main cereal of the sub-continent, with barley second and wheat a barely mentioned winter food. Greek visitors noted the popularity of rice amongst Indians. The Greek emissary Megasthenes, visiting Pataliputra (modern Patna) in 315 BC, wrote that they ate it ceremonially, boiled, placed in a bowl and then various other dishes added to it. Hundreds of years later, the Portuguese in the 15th century observed cooked rice being eaten in much the same way. The 17th century traveller Francois Bernier described fields of rice in Kashmir and Bengal, irrigated by endless channels. The Muslim rulers of India created famous rice and meat dishes such as pilafs and biriyanis. The number of dishes made with rice was by this time legion. Annapurna is the Hindu god of rice. Her name comes from the Sanskrit word for rice, anna. She is often depicted with a rice spoon in her hand. In peninsular India, there are numerous festivals connected with the sowing, planting and harvesting of rice. Major harvest festivals include Pongal in Tamil Nadu, Onam in Kerala, Huthri in Coorg (Kodagu). Rice, tinted with the auspicious yellow colour of turmeric, is showered onto newly-married couples, and is part of numerous rites and celebrations. It is offered to the deities and used as an oblation in the sacred fire of Hindu ritual. Rice is used in many Indian celebrations, including weddings.

Rice features in many legends about the Buddha's life. In a famous tale, he was offered a bowl of milk and rice by a young woman named Sujata, which gave him, renewed strength during his austerities in pursuit of Enlightenment. Sweetened rice thus forms part of offerings to the Buddha in Buddhist ceremonies. ( http://www.plantcultures.org/plants/rice_history.html)

India is one of the richest countries in the world in terms of possessing tremendous diversity in rice varieties. There are different varieties of rice-depending on the weather, soil, structure, characteristics and purposes. According to Dr. Richaria, one of the most eminent rice scientists of the world, 4,00,000 varieties of rice existed in India during the Vedic period. He estimated that, even today 2,00,000 varieties of rice exist in India, which is indeed an exceptionally high number. This means that even if a person eats a new rice variety every day of the year he has to live for over hundred years without reusing a variety. Every variety has a specific purpose and utility. (http://www.rice-trade.com/)

## 2. Rice Production in India

India has the world's largest area devoted to rice cultivation, and it is the second largest producer of rice after China. Over half of its rice area is irrigated, contributing 75% of the total production, but also consuming 50-60% of the nation's finite freshwater resources. Of the country's 1.15 billion inhabitants, 70% rely on rice for at least a third of their energy requirements. India's population is projected to grow to 1.6 billion in 2050, putting tremendous strain on its land and water resources.

India shares around 21 % of global rice production from about 28 % of rice area (Figure 2). Rice area in India fluctuates around 43 million hectares during the last two decades and was at a maximum of 45.5 million hectares in 2008-09 (Figure 2). Total rice production was also the maximum (99.2 million tonnes) during this year. Rough rice productivity which was at 1002 kg/ha in 1950-51 had reached a maximum of 3303 kg/ha in 2007-08. Interestingly the rough rice productivity during the early 20$^{th}$ century was around 1600 kg/ha, which declined to 1139 kg/ha during 1940-41 (Figure 3).

Grain production in India, following the Green Revolution in 1969-70, yielded 99.5 million tonnes and nearly doubled by the end of the last century. The highest average annual increase of 6.1% in grain production was recorded during the 1980s: from 110 million t in 1979-80 to 171 million t in 1989-90; but the annual increase in grain production during the 1990s dropped to 1.5%.

India produced about 40 per cent of the world's exportable surplus of rice during 1913-14. This scenario changed subsequently and the country faced a severe famine in 1943. Export of milled rice was a mere 0.5 million tonnes in 1989 but reached a maximum of 6.7 million tonnes during 2001.

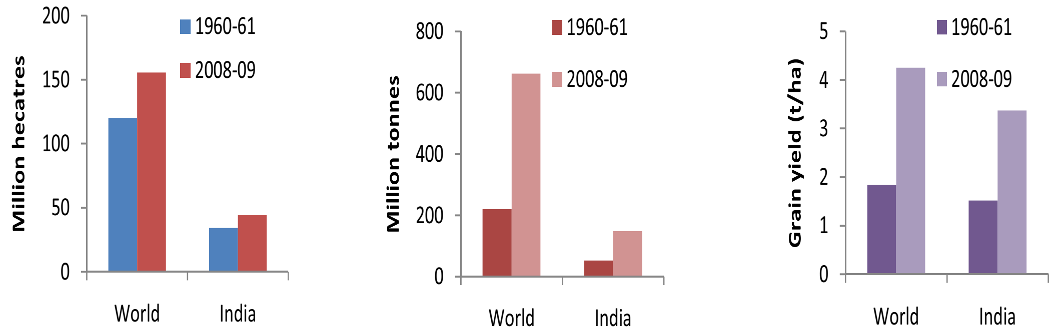


Figure 1. Rice area, rough rice production and productivity in the world and India during 1960-61 and 2008-09.

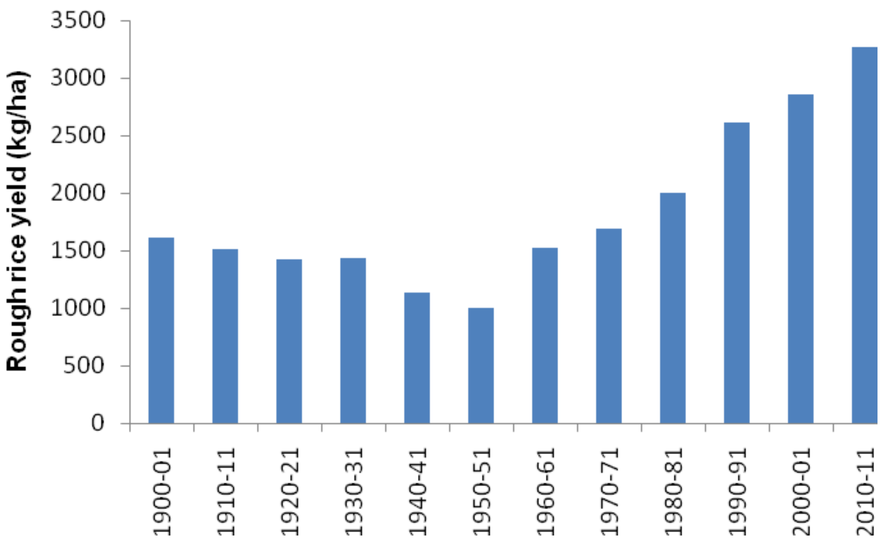


Figure 2. Rough rice yield in India since the beginning of 20th century. The data for 1900-01, 1910-11, 1920-21 and 1930-31 are averages for 1900-01 to 1904-05, 1910-11 to 1914-15, 1920-21 to 1924-25 and 1930-31 to 1934-35 respectively *(Source: Baljit Singh. 1945. Whither Agriculture in India. N.R. Agarwal & Co, Agra)*. The data for 2010-11 are estimates *(Source: Directorate of Economics and Statistics, Agricultural Statistics at a glance 2010. Department of Agriculture and Cooperation, Ministry of Agriculture, Govt. of India, New Delhi.*

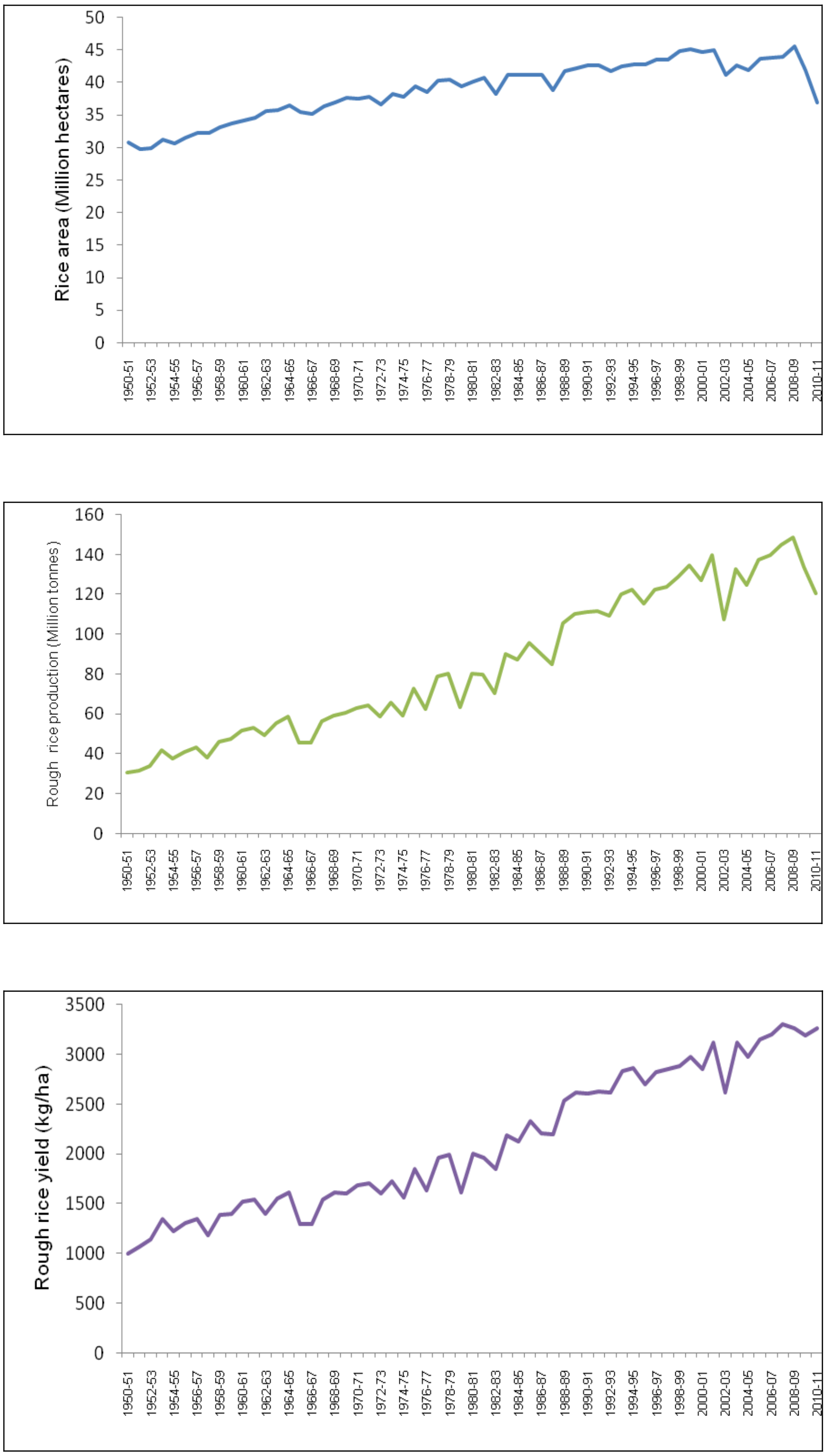


Figure 3. Rice area, rough rice production and productivity during 1950-51 to 2010-11 (Data for 2009-10 and 2010-11 are estimates)

*Source: Directorate of Economics and Statistics, 2008. Agricultural Statistics at a glance 2010. Department of Agriculture and Cooperation, Ministry of Agriculture, Govt.of India, New Delhi.*

## 3. Quest for improving the yields

Indian farmers and rulers always focus on improving the yields as effective way of improving the food security. While investments have gone in expanding the area by the rulers, the efforts and innovation by largely farmers continued in improving the yields of per unit of area. Until last five decades or so, these efforts are largely or even exclusively farm based, selecting the suitable varieties for different agro-climatic zones with improving the soil, water and organic input management to achieve the maximum yields.

Most striking and ingenious attempt which has come to limelight is the *gaja planting* - with its own name and the specifications. When we were examining why in a country with long experience of rice cultivation, no innovative method was tried to increase the yield with reduced inputs. A simple thought and a bit of luck has led to a major breakthrough in documenting an approach known to Tamil farmers a century ago. Today System of Rice Intensification (SRI) is known to many rice farmers of Tamil Nadu as '*Ottrai Natru Nadavu'* (single seedling planting). This recognition has come through SRI. But, to our surprise, we find that single seedling planting was known 100 years ago in Tamil Nadu.

A century ago, an innovative farmer in Tamil Nadu, had the idea of modifying existing agronomic practices in rice cultivation with single seedlings, wider spacing, and some intercultivation operation and reported a yield of 6,004 kg $ha^{-1}$. This *gaja* method employed inter-row spacing of 1 1/2 feet (45 cm) and within-row spacing of 1 foot (30 cm) between single plants, resulting in a plant population of only 7–8 plants $m^{-2}$. Further research into the history of rice cultivation in Tamil Nadu has revealed that in 1,911 several farmers published articles in Tamil language on single-seedling planting (Kulandai Veludaiyar 1911, Anonymous 1911). The scanned copies of these articles in Tamil and their English versions have been published separately (Thiyagarajan and Gujja 2009). It was also found that this single-seedling planting was popularized by the then British Government in the Madras Presidency. By 1914, single-seedling planting was being adopted in 40,468 ha (Chadwick 1914).

Vaidyalingam Pillai's reported yield of 6,004 kg grain $ha^{-1}$ with *gaja* planting methods in Thanjavur District was 2.7 times more than that obtained from the same field the previous year when using bunch planting. Yanagisawa (1996) has estimated that the average rice yield in Thanjavur District during 1911 was 1,693 kg paddy $ha^{-1}$, while the average yield in this district for the period 1911-1915 was 1,492 kg $ha^{-1}$ (Sivasubramanian 1961).

It is fascinating that such high yields were being obtained by farmers with their own innovations a century ago, when no chemical fertilizers were applied. Unfortunately, such farmer innovations have disappeared after scientific recommendations have taken over by Green Revolution.

### *Rice Breeding*

Developing improved varieties has been one of the major thrust areas since the beginning of rice research. Rice breeding programme in India was started by Dr. G. P. Hector, the then Economic Botanist during 1911 in undivided Bengal with headquarters at Dacca (now in Bangladesh). Subsequently, in 1912, a crop specialist was appointed exclusively for rice in Madras Province. Prior to the establishment of the Indian Council of Agricultural Research (ICAR) in 1929, Bengal and Madras were the only provinces, which had specialist exclusively for rice crop. After the establishment of ICAR, it has initiated the rice research projects in various states of the country and by 1950, 82 research stations in 14 states of the country were established, fully devoted for rice research projects.

Major chronological events in rice breeding were:

| | |
|---|---|
| 1911-1949: | Pure line selections and very few hybridizations |
| 1950-1964: | Inter-racial hybridization between japonicas and indicas |
| 1965 - : | Inter-racial hybridization with semi dwarfs |
| 1970 - : | Development of hybrid rice |

*(http://dacnet.nic.in/rice/Rice%20Varieties%20in%20India.htm)*

More than 700 varieties have so far been released in the country by national and state research establishments.

***Soil and Crop Management***

Besides introducing high yielding variety, management practices towards better nutrient supply, soil and water management, protecting the crop from pest and diseases and exploiting the genetic potential of the crop, have been developed and is being continued now. These practices are recommended to farmers for adoption. The major implications of these recommendations were on increased use of chemical fertilizers and plant protection chemicals.

***Green Revolution***

The Green Revolution took place between 1967 and 1978, which involved improvements in agricultural practices that dramatically increased food production, especially wheat and rice. The government began to develop more farmland and introduced modern irrigation systems, making it possible for farmers to plant two crops a year instead of one. Indian farmers also planted genetically improved seeds that greatly increased crop yields. Within a decade, India had become one of the world's largest producers of farm products. In some years, farmers produced more food grains than the Indian people needed, so they sold the excess to other countries. Famine in India, once accepted as inevitable, has not returned since the introduction of Green Revolution crops (http://www.bigsiteofamazingfacts.com).

In wheat, for example, production increased by a third from 12.3 million tons in 1964-1965 to 16.6 million tons in 1967-68 and 20 million tons in 1969-1970. Rice production increased more slowly (due to the later introduction of IR-8), growing from 30.5 million tons in 1964-65 to 40 million tons in 1969-1970. More importantly, these gains in yield were resilient to fluctuations in the monsoon, the primary natural driver of Indian macro-level food shortages. An early example of this was in the poor weather of 1968-1969, which caused a decrease of only two percent against the previous year's record yield. By 1977, India no longer required structural cereal imports, and in later years became an intermittent exporter. Clearly, these statistics show that India achieved the primary goal of the Green Revolution, the restoration of agricultural self-sufficiency on the national level (Arena, 2005).

The achievements through Green Revolution has come with a price- ignoring traditional varieties and higher use of chemical fertilizers forgetting organic sources obtained through animals and plants and most importantly total dependence of farmers not only for seeds, fertilizers, pesticides but even for the knowledge and cultivation method etc. By the end of green revolution, with erosion of local varieties, replacement of organic fertilizers, total dependence of farmers on scientific institutions for guidance and advise has resulted in agriculture being driven by factors other than farmers in every sphere.

*Significant impact events on rice in India*

| | |
|---|---|
| 1906 | Introduction of *Single Seedling Planting* in Madras Presidency |
| 1911 | Introduction of *Gaja Planting* in Madras Presidency |
| 1914 | Beginning of systematic study on rice in Coimbatore |
| 1946 | Establishment of Central Rice Research Institute at Cuttack |
| 1951 | Introduction of Japanese method of rice cultivation |
| 1965 | Launching of All India Coordinated Rice Improvement Project (ICAR) |
| 1969 | Introduction of IR8 variety, Surge in expansion of rice area in Punjab |
| 2000 | Introduction of SRI |

***Concerns in rice production***

Much of the green revolution's gains have been achieved through highly intensive agriculture that depends heavily on fossil fuels for inputs and energy. Whether more food can be produced without damaging the soils and fresh water and crop diversity is questionable as these food producing bases are being degraded in many places.

Rough rice production has increased in India 4.68 times in the last 57 years – from 30.9 million tonnes (1950-51) to 148.4 million tonnes (2008-09). Enhancement in rice production is mainly credited to a productivity-led increase since harvested rice area for the corresponding period has expanded from 31 m ha to about 44 m ha, accounting for only 42 per cent increase.

Grain demand in India is estimated to be about 300 million t per annum by 2020, necessitating an increase of about 91 million t from the estimated 209 million t production for 2005-06. Since there is no probability of any further increase in the area under cultivation over the present 142 million ha, much of the desired increase in grain production has to be attained by enhancing the productivity per unit area. The productivity of milled rice has to be increased from the present 2,077 kg $ha^{-1}$ to 2,895 kg $ha^{-1}$ by 2020 with an average increase of about 5% per annum (NAAS, 2006).

A historical analysis by Barah (2005) shows that over the decades, the phenomenal pace in increase in rice production has been uneven and the regional disparity highly pervasive among the States as well as across the diverse ecosystems. Clearly, the gain due to modern rice technology has been discriminatory against the resource poor areas, which is also dominated by small and marginal farmers. The analysis also brings out a distinct production divide between irrigated tracts and rainfed areas, which substantiated the interregional disparity in production and productivity in rice. About 36 percent of the districts covering 44 per cent total rice area in the country achieved productivity level of more than 2tonnes/ha (approx 3 tonnes/ha of rough paddy). The average rice yield was in the range l-2tonnes/ha in 90 percent of the rice area of eastern India during 1970-79. But during 1990-97, this has changed substantially, whereby only 47 percent of the rice area was in this yield range, and 51 percent of the area increased yield levels higher than 2tonnes/ha.

The rice production data for 2006-07 shows the rough rice productivity is below 2 t $ha^{-1}$ in about 18.7 % (8 million ha) of total paddy area spread over 150 districts and contributing only 9.0 % of total production (Table 1). This situation after four decades of green revolution and huge investments speaks of the rice production conditions of these areas.

Table 1. Rough rice productivity range in India, 2006-07

| Yield (t/ha) | No. of Districts | Area (000'ha) | Production (000'tonnes) |
|---|---|---|---|
| < 1 | 33 | 444 | 369 |
| 1 – 1.5 | 56 | 3139 | 3957 |
| 1.5 - 2 | 61 | 4626 | 8198 |
| 2 – 2.5 | 106 | 8646 | 19343 |
| 2.5 - 3 | 68 | 4559 | 12528 |
| 3 – 3.5 | 58 | 5294 | 17038 |
| 3.5 - 4 | 65 | 5944 | 22516 |
| > 4 | 106 | 11235 | 55257 |
| **Total** | **553** | **43,887** | **139,206** |

The growth rates of rice area, production and productivity during 1994-95 to 2009-10 were (-) 0.04, 1.15 and 1.04 respectively. The growth rate of area went down by (-) 8.30 in 2002-03 and reached a maximum of 4.18 during 2005-06. The negative growth rates of production and yield were highest during 2002-03 (Figure 4). The impact of the delayed and sub-normal monsoon was reflected in reduced area under rice cultivation during 2009-10 over 2008-09 by 14.3 per cent. (Annual Report 2009-10, NABARD).

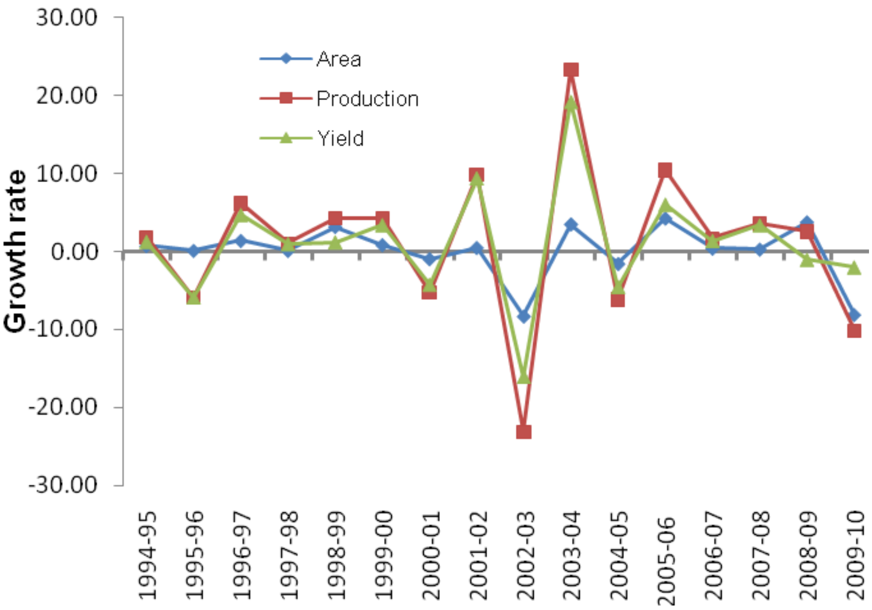


Figure 4. Growth rates in rice area, production and yield during 1994-95 to 2009-2010 (Data for 2009-10 and 2010-11 are estimates)

*Source : Directorate of Economics and Statistics, 2008. Agricultural Statistics at a glance 2010. Department of Agriculture and Cooperation, Ministry of Agriculture, Govt.of India, New Delhi.*

The per capita net availability of rice which was at 159 grams/day during 1950-51 increased to 200 – 2008 grams/day during 1990 to 2002 but has been below 200 grams/day after that.

India’s post-independence agricultural growth involved huge investments in irrigation projects that resulted in more than a tripling in the gross irrigated area from 22.6 million hectares (1950-51) to 76.3 million hectares (1999-00). This has contributed to a drastic reduction in per capita fresh water availability, from 5,410 cubic meters to 1900 cubic metres during that period. The greatest growth of irrigation has been through the installation of wells. In some regions, over- exploitation of ground water supplies through pump extraction is leading to serious declines in ground water levels. India is the largest user of groundwater in the world (over a quarter of the global total); 60% of irrigated agriculture and 85% of drinking water supplies are dependent on groundwater. According to the World Bank, if current trends continue, in 20 years about 60% of all aquifers in India will be in a critical condition. This will have serious implications for the sustainability of agriculture, long-term food security, livelihoods, and economic growth. It is estimated that over a quarter of the country’s harvest will be at risk. There is an urgent need to change the status quo.

Rice cultivation is in crisis world over and India is no exception with shrinking area of rice cultivation, fluctuating annul productions, stagnant yields, water scarcity and escalating input costs. The cost of cultivation of paddy has consistently been increasing owing to escalating costs of labour and inputs. With increasing labour scarcity due to urbanization, sustaining the interest of the farmers in rice cultivation itself has become a challenge.

The current productivity is much lower than many other rice producing countries and need to be enhanced under the circumstances of less hope for increase in area and irrigation potential. During the last decade the percent irrigated rice area has been fluctuating around 53 % showing no appreciable increase.

The future of country’s rice production will depend heavily on developing and adopting strategies and practices that will use irrigation water efficiently at farm level. The country needs its increase its paddy production at the rate of 3.75 million tonnes per year until 2050 to meet its food security. The paddy productivity in many states requires to be enhanced from the current level.

Rice production today faces a number of problems that threaten many rice producing Asian countries’ ability to support the food needs of their rapidly growing populations. These constraints include pest outbreaks, diseases, soil degradation, scarcity of water, conversion of rice lands for industrial use, soil salinisation and adverse soil conditions. Contrary to the claims of genetic engineering proponents, the real cutting edge solutions to the problems of rice production lie not in developing GE rice but rather in developing and/or adopting strategies that take advantage of ecological principles within agricultural systems, and integrating traditional farming practices with modern scientific knowledge. Existing biodiversity of rice varieties and their nutritional composition needs to be explored before engaging in transgenics (Borromeo and Deb, 2006).

## 4. SRI in India

An exciting approach has recently been developed, the System of Rice Intensification (SRI), which not only reduces the use of irrigation water, but also increases yields significantly and enhances the livelihood of rice farmers (WWF 2007). SRI is environmentally-friendly. The plants are usually healthier and do not require pesticide application. In addition, unflooded soil has greater biodiversity and does not produce methane (http://ciifad.cornell.edu/sri/advant.html).

### *Introduction of SRI*

Introduction of SRI in India happened in 2000 in Tamil Nadu, Puduchery and Tripura. In Tamil Nadu, Tamil Nadu Agricultural University (TNAU) initiated experiments involving SRI principles and one farmer tried SRI under organic farming. The source of information on SRI was from Dr.Uphoff for TNAU and the farmer had learnt from LEISA. In Tripura some preliminary evaluation of SRI principles was initiated by the Department of Agriculture and demonstrations were organized from 2003. In Puduchery, SRI was tried from 2000 by Auroville Farm. When the Acharya N.G. Ranga Agricultural University (ANGRAU) introduced SRI in farmers' fields during *kharif* 2003, directly from the knowledge gained from Sri Lanka, the experience generated nationwide interest and today.

SRI is now known to all rice-growing states of the country and a major role has been played by CSOs especially in the northern and eastern states. The role of Donor agencies like WWF-ICRISAT project, SDTT, NABARD has been critical in promoting SRI through CSOs.

As far as research on SRI is concerned, experiments were undertaken in IARI in 2002 itself. The Directorate of Rice Research and Central Rice Research Institute initiated experiments on SRI from 2003 and 2005 respectively. Many other NARs had taken up experiments on SRI after 2005. SRI has also been introduced in the National Food Security Mission as a method to improve rice production.

### *Experiences and lessons of SRI*

SRI is certainly a major breakthrough in the thinking process of rice cultivation. More than its practice, it has contributed to think differently in order to get more production. It also rather challenges the conventional approach of high input oriented agriculture to get more production. It reverses the logic of the current thinking on agriculture.

Large scale initiatives in promoting SRI were taken in Tamil Nadu and Tripura by the respective state Governments. In Tamil Nadu, TNAU is promoting SRI in 63 river sub-basins from 2006 through the World Bank funded IAMWARM project. The state Agricultural Department has planned to cover 1/3$^{rd}$ of rice area under SRI.

SRI has come as a boon to rice farmers. The benefits of SRI were in drastic reduction in seed rate (from 60-75 kg ha$^{-1}$ to 5 to 7.5 kg ha$^{-1}$), considerable reduction in nursery and almost nil seedling pulling costs, reduced water use (30 - 40%) and increased grain and straw yield (20 – 70%). Thus, SRI, which was not an invention of modern scientific experimentation, became a new paradigm to tackle the current problems faced in rice production. Saving seeds, higher net income and lesser irrigation need were the attractive outcome of practicing SRI.

SRI has raised two serious questions- a) the sustainability of the rice cultivation as advocated by the established institutions b) the potential of the innovations from the farmers, civil societies in solving the agricultural issues. The innovation by the farmers was the fundamental to the evolution of agriculture, as mentioned in the beginning of this article. Agriculture evolved much before the science and scientific innovation have helped it to increase the production. But in the process, the farmers have been reduced to mere receivers of knowledge than active contributors of the knowledge system. SRI interestingly brings back that debate. Obviously such debates challenge the established institutions, which is expected. More popular SRI becomes, more the debate becomes polarized and intense

Today, SRI has been accepted by farmers in India. It is spreading from farmer to farmer. Many statement governments have initiated special programmes to promote SRI. For example, the Government of Tamil Nadu had a target of 7.5 lakh hectares for the year 2008-09; this is about 37 % of the area under rice cultivation. Similarly State of Tripura is having major programme to promote SRI. SRI is now part of the National Food security mission (NSFM). SRI is national phenomenon and it is giving good results in improving the productivity and also profits to the farmers while reducing the water input to rice cultivation.

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***Future direction of SRI, Policy and programmatic approach***

There is no single solution to tackle the food security in the country. In fact, it is the one-size-fits-all approach that has been so crippling. Past attempts have failed because they squeezed our diversity or depended too much on chemicals and other inputs that farmers could not afford (Halweil and Neirenberg, 2010).

With climate change, increasing variability of rainfall, and the growing competition for water and land, SRI offers a new opportunity for increasing the production value per drop of water and for reducing agricultural water demand, which, in many parts of the world, accounts for the largest share (World Bank Institute 2008).

In India, the significance of SRI is not limited to rice alone. Its core practices are applicable to other crops such as sugarcane. WWF with ICRISAT recently published a detailed manual, *Sustainable Sugarcane Initiative (SSI): improving sugarcane cultivation in India*. Demonstration sites are in progress in five states. The initial results are excellent. Like SRI, SSI could have significant implications for the way that sugarcane is cultivated in the world. Following the principles of SRI, the System of Wheat Intensification (SWI) is gaining popularity in Himachal Pradesh and Uttrakhand states of India. SRI principles of lower seed rate, limited water use, and intercultivation are being applied to crops like finger millet (*ragi*), mustard, pigeon pea, and other crops in various states of India.

Though SRI came to India in 2000, promoting SRI to farmers in a serious way commenced only in 2003. Real scaling up efforts by official machinery happened only in Tamil Nadu and Tripura. The Government of Tamil Nadu has christened the method as “Rajarajan 1000” in commemoration the Chola King who ruled part of

Tamil Nadu 1000 years ago. In Andhra Pradesh a major step has been taken to form a 'Andhra Pradesh SRI Consortium' to facilitate large scale promotion of SRI. But in other parts of India, it is only the CSOs, which have taken a major lead in popularizing SRI.

Currently about Rs. 48 crores of funds (NFSM: 8 crores; NABARD: 16 crores; SDTT 24 crores) have been allocated by major donor agencies. This is a welcome and appreciable sign towards scaling up of SRI in the country. But this will not be sufficient to carry out the task in a larger scale.

***Constraints in adoption, scaling up and research***

Constraints in adoption of SRI are location specific but lay on the mindset of the farmer (willingness to change, need for more attention), mindset of labourers (lack of experience in handing young and single seedling and planting in squares, more concentration, etc.), inadequate education on SRI, local soil conditions, water availability, availability and quality of weeders.

Lack of adequate policy and financial support from Governments is one of the major constraints in scaling up SRI adoption.

Research in SRI was limited to TNAU and ANGRAU in the beginning but slowly ICAR institutes (DRR, CRRI and Regional Centres) and other Agricultural Universities have started working on SRI. There is more to be done on research as many questions on the effect of SRI principles on soil and plant system remain unanswered. Also there is no study on the long-term effect of doing SRI on the soil fertility.

SRI is a case of 'land to lab'. New crop production techniques come from research establishments after careful experimentation and evaluation. SRI has not come through that channel but is being followed by several thousand farmers. Still, SRI requires research support not only to explain how it makes the difference from conventional and existing recommended practices but also to understand the effect of the modified agronomic practices on the soil-plant-water system. Though considerable research efforts are there, there is no systematic and organized research to address the issues concerning SRI and more importantly there are no national policies and institutional mechanisms for investment in SRI research.

## 5. Conclusions

High-input agriculture has clearly reached its limit. Even the more complex solutions, which are in the pipeline, require large financial resources; and, if such resources are made available, they require more than 15 years to reach farmers. There is clearly an urgent need to find ways on how to grow more food, but with less water and fewer inputs. Farm-based approaches, which used to be at the centre of agriculture practices for centuries to improve productivity, need to be explored once again. Farm-based approaches are relatively easy and the results are visible in a short period of time. There are some new approaches, which clearly show promising results in farmers' fields. These methods require greater attention not just through investments in the field but also through research, to improve and further refine them.

For the smallholders, the "more with more" approach is the end of the road and even the end of their lives. Unsustainable land and water management practices, including deforestation, have also contributed to losses in soil fertility and productivity and disruptions in food production and economic development, especially in the most fragile and marginal environments, where smallholder farmers are the major custodians of natural resources. Unleashing the full potential of smallholder farming is key to the global food security agenda (FAO 2006).

Under climate change, crops in many regions are prone to environmental stresses that have not been observed before. Many annual crops such as wheat, soybean, and rice have a threshold temperature above which seeds do not form properly. A brief episode of hot temperature (>32–36 °C) can devastate crop yields (University of Reading 2007).

Recognizing that by smart water management and planting practices, farmers in Tamil Nadu have increased rice yields between 30% and 80% and reduced water use by 30%. World Bank President Robert Zoellick has emphasized that SRI not only addresses food security but also water scarcity, which climate change further aggravates (Hindustan Times 2009). However, these methods still have not come into the focus of the mainstream research organizations. These methods are very promising but they require further research and refinement to realize their full potential. The challenge of food security, worsened by the complexity of climate change, could be effectively addressed through farm-based methods, but they need large investments and require immediate attention

It should be realised rice farmers of Tamil Nadu could obtain a yield of 6 t/ha a century ago with existing traditional genotypes but with innovative changes in the cultural practices and without any chemical fertilizers. This yield was obtained when the country's average yield was about 1500 kg/ha (Figure 2). This clearly demonstrates that farm based approaches could enhance the grain yields without high yielding varieties.

Though Green Revolution has helped the country to wriggle out of food insufficiency, it is ironical that 46,26,000 hectares of the rice area are having a productivity of less than 2 t/ha showing that modern technology has either not reached these areas or the high input technology is not suitable for the farmers of the area. SRI and similar farm based approaches offer a ray of hope for these resource poor farmers to produce more with less resources.

Attempts to develop genetically modified rice genotypes have not had much success till now as seen by the limited spread of the 'new plant type' (NPT). Also, the projected breakthrough by modifying the rice plants' photosynthesis to a $C_4$ pathway will take many millions of dollars and at least 10 to 15 years of dedicated work by a global scientific team (Zeigler *et al,* 2008). The same is the case with the attempts for biofortification. We have such an enormous biodiversity with rice, which probably have hidden special properties suitable for the purposes GE research is being undertaken for the last few years. It is time that we wake up to realise our natural potential to discover such genotypes and certainly SRI can very well fit in as the best cultivation practice to follow with such genotypes.

The high profile technologies similar to those of the Green Revolution days, which gave enormous yield enhancements, have ceased to emerge from the research system and farm based approaches like SRI are essential to support the resource poor farmers.

SRI is certainly one of the ways to address the food security of India and efforts are needed to sustain it for the next decade to meet the rice demand. This can happen only when there is a national policy. The Government has to be honest to recognize that SRI actually works and scale it up.

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