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Rice production in India — Relevance of hybrid and transgenic technologies[1]

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Rice occupies the enviable prime place among the food crops cultivated around the world. It is grown in 152 million hectares with a production of 585.6 million tonnes. India has the largest area among the rice growing countries and enjoys the second rank in rice production. India produces 90 million tonnes of rice in an area of 44 million hectares with a productivity of over two tonnes per hectare. Since land is a shrinking resource, increasing food production by expanding the area under cultivation is impossible. So the only way out is to enhance marginal land productivity. On the other hand, population progression demands maximizing production per unit land. By increasing productivity, part of rice area can be made available to other crops as China has demonstrated successfully using hybrid rice technology. Therefore, efforts to enhance rice productivity must receive top priority. Also, in view of the rampant malnutrition in the developing countries, improvement in nutrition status in rice through use of biotechnology as well as role of these technologies in solving the social problems like river water disputes are covered in this article, though not in exhaustive manner.

A. Exploiting potential of hybrid rice

Introduction of semi dwarf varieties possessing improved harvest index, non-lodging, erect plant type with high responsiveness to fertilizers in mid-sixties boosted the rice production of India substantially. However, the productivity has come to stagnation since the last two decades and all efforts have failed to give tangible results to break the present genetic yield barrier in rice. Successful demonstration of substantial yield increase through exploitation of hybrid rice technology in has encouraged scientists in other rice growing countries including India to adopt hybrid technology as a practical option to enhance the productivity of rice. China started its hybrid rice research in 1964 with the identification of wild abortive cytoplasm. CMS lines with WA cytoplasm were developed in 1974 and the first hybrid was developed in the year 1976 under the guidance of Prof. Yuan Long Ping. The area under hybrid rice in 1976-79, which was 4.74 m.ha with a productivity of 4.7 t/ha, was enhanced to 18 m.ha in 1992 with a productivity of 6.78 t/ha. Today, China has developed 'super hybrids' with an yield potential of 17 t/ha.

Even though the hybrid rice research activities were initiated in India during early seventies, which were confined to studies of basic research and there was no serious effort towards commercial exploitation mainly because of anticipated seed production difficulties. Convinced by the potential of hybrid rice technology, the Indian Council of Agricultural Research (ICAR) identified this as a top priority area and initiated net work project on hybrid rice from December 1989 in collaboration with the International Rice Research Institute (IRRI) Philippines. This project was further strengthened with the assistance from UNDP/FAO from September 1991. The Mahyco Research Foundation (MRF) also financed to augment the gaps in the program. A network approach of 12 centers across the country in the targeted states with the Directorate of Rice Research (DRR) Hyderabad as the coordinating center was established with the major objectives of: i) Development of Hybrids with 15-20% yield advantage over the highest yielding check variety. ii) Optimization of seed production package for cultivation of hybrids and iii) Conducting basic research relevant to the project.

As a result of concerted and coordinated efforts, for the first time in the country the states released four rice hybrids for commercial cultivation during 1994. Since then a total of 20 rice hybrids have been released both from public and private sectors. The trial of commercial hybrids tested during *kharif* of 1999 and 2000 in 64 and 46 locations in different rice growing locations of 14 states of the country revealed KRH-2 as the best performer besides being highly stable. Among the public bred ones, PHB-71 and Sahyadri are the other promising hybrids. These trials convincingly showed that rice hybrids were definitely superior to semi dwarf varieties across all the locations. Another salient feature of the Indian hybrid rice program is the successful development of Pusa RH-10, a scented hybrid that has all the qualities of the scented varieties yielding 39.9% more than the check variety Pusa Basmathi-1.

Development of Parental Lines: Identification of restorers and maintainers and evaluation of parental lines and conversion of promising maintainer lines into CMS lines forms all integral part of the hybrid rice breeding. Therefore, promising maintainers and restorers

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have been identified from the existing germplasm at various network centers. Promising hybrids were developed and forwarded for evaluation. Genotypes with reasonable resistance to frequently occurring disease and insect pests with desirable grain type form an integral part of the programme.

Enhancement of heterosis level: The magnitude of heterosis of released hybrids ranges between 15-20%. To make the rice hybrids more attractive and economically more beneficial, it is essential to increase the magnitude of heterosis to 20-30%.. Development of new parental lines: Combining desirable traits and increasing the heterosis is the major objective of the parental breeding. For this purpose maintainer × maintainer, and restorer × restorer crosses are being effected and the new useful new recombinants are selected. In addition to this approach genic male sterility facilitated recurrent selection program is undertaken. The maintainer and restorer populations received from IRRI are being used as basic population. IARI has developed isocytoplasmic restorer lines with unique basmati quality using CMS × partial restorer crosses followed by selective intermating. A few of them have been released for commercial cultivation as variety. Besides, inter-project linkages have been established with the National Seed Project (NSP) to investigate on some of the crucial aspects. These combined efforts have helped to optimize a seed production package by which seed yields of 1.0 to 2.5 t/ha. Many seed growers are following this package and seed yields of 1.0 to 2.0 t/ha is being obtained. Experiments are underway to further,refine the seed production technology to economize the seed cost and to expedite the spread of hybrid rice in the country. A major expense in hybrid rice seed production is on Gibberellic acid spray. Search for alternate chemical has culminated in identification of Naphthalene Acetic Acid (NAA) 200 gm/ha which has the same influence as that of GA3. Two hundred gm of NAA costs only Rs.400 as against Rs. 1880 for 45 gm of GA3.

Economics: The hybrid rice, farmers and seed growers were surveyed and the economics were calculated in different seasons. The results of one such a survey in Karnataka are given in Tables 1 and 2.

Table 1. Economics of hybrid seed production

Details of income/Rs/ha		Details of expenditure/Rs/ha	
Hybrid seed	1375	Labor	14785
Cost per kg	55	Fertilizers & Chem.	7300
Gross income	75625	GA3	3000
Expenditure	28360	Seeds	1875
Net income	47265	Transport	300
		Others	1100
		Total expenditure	28360

Source: Honnaiah, (E.E.U, A.R.S. Nagenhally, Karnataka)

Table 2. Economics of hybrid cultivation

Summer 2000 (mean of 49.0 ha.)				
Variety/ hybrid	Yield (Kg/ha)	Gross income (Rs.)	Cost of cultivation (Rs.)	Net income
KRH-2	7694	46239	15830	30409
Check	5948	37327	14411	22916
Difference	1746	8912	1419	7493
KRH-2	7463	43963	16243	27720
Check	5295	32153	14311	17842
Difference	2168	11810	1932	9878

Source: Honnaiah (E.E.U, A.R.S. Nagenhally, Karnataka)

Extension: To popularize the hybrids, large-scale front line demonstrations were laid out in the targeted states. Demonstrations of seed production were also laid out. Field days were organized. Training of various agencies was undertaken on hybrid rice production as well as on hybrid rice seed production in all the net work centers. This has helped in the spread of the hybrids. Some states like Karnataka, Maharastra have subsidized the hybrid rice seed to encourage the farmers to grow the rice hybrids. Now the states of Maharashtra, U. P. and Karnataka have drawn action programmes to popularize hybrid rice.

B. Towards finding a solution to inter-state river water dispute

River water Disputes are not peculiar to any one part of the globe. Increased pressure of both human (400 percent) and livestock (127 percent) populations during the previous century has imposed tremendous pressure on natural resources. Consequently, demand for drinking and irrigation water is rapidly increasing. India is facing complex situations in this respect. Arid zones in India face drought situations once in alternate or three years, and prolonged droughts, about five times in a century, leading to severe scarcity of food, fodder, fuel, fruits, flowers and fiber. In view of the above situations, the British Government, as recommended by the first Famine Commission (1880), established five dry farming research centers during 1933 and many research centers for research on use of irrigation water. Subsequently, ICAR established many training and research centers during 1954 to conserve precious soil and water resources, 23 AICRP locations and 47 macro watersheds for drought mitigation in 1970. Many states too had their own engineering research stations. It is of interest to note that, even though our rainfall is low and unevenly distributed, it is certainly not as low as in Israel, which receives between 400 mm and 800 annually. Israel has been a pioneer in developing efficient ground water conservation and water utilization technologies, rather than in ground water extraction technologies. India has some thing to learn from both China and Israel.

Reduction of area under water intensive crops - Chinese Experience: Regions with shortage of irrigation water can richly benefit from the China's experience. China has been successful in reducing the area under paddy without sacrificing its production and in promoting cultivation of other export earning profitable crops, thereby, improving the agricultural economy of the farmers. Around 1643 liters of water are applied to produce one kg of paddy, since paddy uses around 40 acre inches of water per acre. With this water at least four acres of semi dry crops like ragi, groundnut, jowar, or sunflower can be cultivated. China was cultivating 99 ml acres of paddy during the 1970s, and in the late eighties, this was brought down to 79 ml acres, saving 20 ml acres (20 percent) without affecting the total paddy production. The land and irrigation water so saved was diverted to less water consuming and high value crops. China was able to do this by introducing high yielding varieties and particularly hybrids with improved management practices. China is now further reducing the paddy area to 62 ml acres (saving 37 percent), with the introduction of 'super rice' and 'super hybrids' and the process has already commenced. The Chinese super rice varieties and hybrids have the potential of 69 quintals per acre as against 48 quintals per acre from the conventional HYVs and hybrids grown during the 1980s and 1990s. It is pertinent to mention here that, in India, paddy productivity is below 20 quintals per acre. The hybrid rice in India yields 32.4 quintals to 36.4 quintals per acre as per the data generated by the AICRIP, Hyderabad that indicates the potential of this technology.

Scenario in southern states: This can be a pragmatic solution to our four riparian states of Cauvery Basin *viz.*, Karnataka, Kerala, Tamilnadu and Pondy. According to the evaluation in the National trials, Karnataka Rice Hybrid (KRH-2) of UASB is the best hybrid among the presently recommended rice hybrids and is recommended in UP, Orissa and Himachal Pradesh etc. This technology will also generate employment opportunities for rural youth as seed production activity will have to expand to meet the hybrid seed requirement since the hybrid cultivation needs change of seed for every newly planted crop. Many new hybrids of farmer's choice are already released or are in the pipeline for south Indian states. If all the states of the Cauvery Basin seriously try to emulate China and focus attention with needed support from the respective governments to develop and popularize the appropriate technology, this technology will go a long way towards finding a solution for the long-standing dispute.

State wise analyses: Agriculture in Karnataka largely depends on the distribution of southwest monsoon, the normal rainfall being 1139 mms receivable in 55 normal rainy days. About 71 percent of rainfall is received during southwest monsoon, 17 percent during northeast monsoon and the balance is the pre-monsoon rainfall. With a net sown area of 104 lakh ha, the area irrigated is 24 percent. About 65 percent of the net sown area is in Kharif, 30 percent is sown in Rabi, and 5 percent in summer. About 33 percent of the area is deficit in rainfall during crucial crop growth in Kharif. In the state, an area of 27.2 lakh acres is planted with paddy producing around 35 lakh tonnes. Even if hybrid rice is planted to a modest 25 percent of this area over a period, 7.4 lakh acres can be released for other profitable crops with a saving of water that can irrigate an additional area of at least 24.7 lakh acres for the crops that are profitable in the region. Further, it is crucial to promote Hybrid Rice seed production in Karnataka, as the state has ideal locations for hybrid seed production, for meeting the demand for parental and hybrid seeds for the state as well as for other needy states in the Country.

Tamil Nadu's Agriculture is dependent more on north-east monsoons, and the state which is next to Andhra Pradesh in rice production in South India, but one of the top states in productivity in the country, cultivates rice 3 to 4 seasons in a year depending on the regions suitable for different cropping systems. Of this, Kuruvai rice is grown totally using stored water drawn from the reservoirs that too in dry season. The two Rice Research centers in this state- one at Aduthurai and the other at Coimbatore, have strong research groups ready with rice hybrids with a potential to yield 1-2 tonnes more under the same input conditions as for presently cultivated high yielding varieties. Out of the 55 lakh acres, even 25 % devotion to hybrid rice would save water sufficient for raising 55 lakh acres of light irrigated crops.

Regarding Kerala state, 8.75 lakh acres is gradually coming down particularly due to labor problem. Not much progress in hybrid rice development, but a beginning has been made at the Pattambi Rice research center. The work needs to be speeded up. As for Pondichery, the rice hybrids developed in Tamil Nadu are suitable and similar exercise as suggested for Tamil Nadu holds good.

It is to be made clear that finding a workable solution to this kind of disputes is not that simple. A multipronged approach has to be made. But the strategy suggested here can definitely be a major contributing component of any package that may be thought of as effective and practicable.

Potential for seed production: The southern states have enormous potential for commercial seed production in India, due to existence of irrigation facility, moderate rainfall, balanced day length, moderate humidity, more number of seasons permitting quality seed production of a number of diverse crops, availability of labor at competitive wage rates, and other favorable agro-climatic conditions. This is the reason for so many MNCs to have established their Seed units in South India particularly in Karnataka. Appropriate planning is needed to harness this potential to export seeds to other areas in India and abroad. In the process, a proper mix of public and private sector in seed production and trade and planned support to both sectors by the concerned governments will pave the way for utilizing this potential in Southern states.

C. Transgenics in rice

While the problems relating to the food and environmental safety aspects of genetically modified foods are yet to be fully resolved, there is little doubt that an integrated approach to Mendalian and molecular breeding is likely to make a food-based approach to nutrition, even more effective in the future. The quantity and quality of proteins, carbohydrates, fats vitamins and minerals can all be improved now. The scope for the genetic enhancement of nutritional quality will be evident from the examples given in Table 3.

Table 3. Quality of protein nutritional composition of major cereals

Nutrient	Rice	Wheat	Maize
Protein (%)	7.3	10.6	9.8
Biological value of protein	74.0	50.0	61.0
Net protein utilization	73.8	53.0	58.0
Lysine (g/16g N)	3.8	2.3	2.5
Threonine (g/16gN)	3.6	2.8	3.2
Tryptophane (g/16gN)	1.1	1.0	0.6
Amino acid score (%)	66.0	43.0	-
Vitamin A (mg)	0.0	0.02	0.37
Thiamine (mg)	0.29	0.45	0.32
Riboflavin (mg)	0.04	0.10	0.10
Iron (mg%)	3.0	4.0	3.0
Zinc (mg%)	2.0	3.0	3.0

Source: M. S. Swaminathan, Rio de Janeiro to Johannesburg, 223pp.

Beta-carotene enriched rice: A promising development in the field of genetic engineering is the success in breeding nutritionally enriched 'golden rice'. This contains genes that produce high levels of beta-carotene and related compounds, which are converted in the human body into the crucially needed vitamin-A, the deficiency of which causes more than a million childhood deaths each year, besides being the single most cause of blindness among children.

Dr. Ingo Potrykus and Dr. Peter Beyer of Germany of the Swiss Federal Institute of Technology inserted these genes from a daffodil (*Narcissus pseudonarcissus*) and a bacterium (*Erwinia uvedovora*) into rice plants. If golden rice, currently still in the laboratory stage, becomes a success in the field, it will help to strengthen the food-based approach to nutrition security.

Other transgenics: Transgenic rice cultivars are being developed in a number of ICAR laboratories and other labs in the country. The main focus on the rice transgenics is resistance against yellow stem borer using the *Bt* genes. At National Research Centre on Plant Biotechnology (NRCPB, IARI), *Bt* rice transgenics in agronomically superior cultivars such as IR 64, Karnal local and Pusa Basmati 1 have been developed and are being tested in the limited field resistance against yellow stem borer. At Directorate of Rice Research (DRR, ICAR), Hyderabad also, rice transgenics resistant to *Bt* toxin gene against yellow stem borer and transgenics with chitinase gene for resistance to sheath blight disease are in advanced stage of testing. Bose Institute, Calcutta is also testing *Bt* transgenics of rice for resistance to yellow stem borer.