Vision 2050

Central Rice Research Institute
Indian Council of Agricultural Research
Cuttack (Odisha) 753006

www.crri.nic.in

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शरद पवार
SHARAD PAWAR

कृषि एवं खाद्य प्रसंस्करण उद्योग मंत्री
भारत सरकार
MINISTER OF AGRICULTURE &
FOOD PROCESSING INDUSTRIES
GOVERNMENT OF INDIA

MESSAGE

The scientific and technological inputs have been major drivers of growth and development in agriculture and allied sectors that have enabled us to achieve self reliant food security with a reasonable degree of resilience even in times of natural calamities, in recent years. In the present times, agricultural development is faced with several challenges relating to state of natural resources, climate change, fragmentation and diversion of agricultural land to non-agricultural uses, factor productivity, global trade and IPR regime. Some of these developments are taking place at much faster pace than ever before. In order to address these changes impacting agriculture and to remain globally competent, it is essential that our R&D institutions are able to foresee the challenges and formulate prioritised research programmes so that our agriculture is not constrained for want of technological interventions.

It is a pleasure to see that Central Rice Research Institute (CRRI), Cuttack, a constituent institution of the Indian Council of Agricultural Research (ICAR) has prepared Vision-2050 document. The document embodies a pragmatic assessment of the agricultural production and food demand scenario by the year 2050. Taking due cognizance of the rapidly evolving national and international agriculture, the institute has drawn up its Strategic Framework, clearly identifying Goals and Approaches.

I wish CRRI all success in realisation of the Vision-2050.

(SHARAD PAWAR)

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Dr. S. AYYAPPAN
SECRETARY & DIRECTOR GENERAL

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FOREWORD

The Indian Council of Agricultural Research, since inception in the year 1929, is spearheading science and technology led development in agriculture in the country. This is being accomplished through agricultural research, higher education and frontline extension undertaken by a network of research institutes, agricultural universities and Krishi Vigyan Kendras. Besides developing and disseminating new technologies, ICAR has also been developing competent human resources to address the present and future requirements of agriculture in the country. Committed and dedicated efforts of ICAR have led to appreciable enhancement in productivity and production of different crops and commodities, which has enabled the country to raise food production at a faster rate than the growth in demand. This has enabled the country to become self-sufficient in food and emerge as a net food exporter. However, agriculture is now facing several challenges that are expected to become even more diverse and stiffer. Natural resources (both physical and biological) are deteriorating and getting depleted; risks associated with climate change are rising, new forms of biotic and abiotic stress are emerging, production is becoming more energy intensive, and biosafety concerns are growing. Intellectual property rights and trade regulations impacting technology acquisition and transfer, declining preference for farm work, shrinking farm size and changes in dietary preferences are formidable challenges.

These challenges call for a paradigm shift in our research approach to harness the potential of modern science, innovations in technology generation and delivery, and enabling policy and investment support. Some of the critical areas a genomics, molecular breeding, diagnostics and vaccines, nanotechnology, secondary agriculture, farm mechanization, energy efficiency, agri-incubators and technology dissemination need to be given priority. Multi-disciplinary and multi-institutional research will be of paramount importance given the fact that technology generation is increasingly getting knowledge and capital intensive.

It is an opportune time that the formulation of 'Vision-2050' by ICAR institutions coincides with the launch of the national 12^{th} Five Year Plan. In this Plan period, the ICAR has proposed to take several new initiatives in research, education and frontline extension. These include creation of consortia research platforms in key areas, wherein besides the ICAR institutions, other science and development organizations would be participating; short term and focused research project through scheme of extramural grants; Agri-innovation fund; Agri-incubation fund and Agri-tech Foresight Centres (ATFC) for research and technology generation. The innovative programme of the Council, 'Farmer FIRST' (Farmer's farm, Innovations, Resources, Science and Technology) will focus on enriching knowledge and integrating technologies in the farmer's conditions through enhanced farmer-scientist interface. The 'Student READY' (Rural Entrepreneurship and Awareness Development Yojana) and 'ARYA' (Attracting and Retaining Youth in Agriculture) are aimed to make agricultural education comprehensive for enhanced entrepreneurial skills of the agricultural graduates.

I am happy to note that the Vision-2050 document of **Central Rice Research Institute, Cuttack** has been prepared, based on the assessment of present situation, trends in various factors and changes in operating environment around agriculture to visualize the agricultural scenario about 40 years hence and chalk out a demand-driven research agenda for science-led development of agriculture for food, nutrition, livelihood and environmental security, with a human touch.

I am sure that the **'Vision-2050'** would be valuable in guiding our efforts in agricultural R&D to provide food and nutritional security to the billion plus population of the country for all times to come.

(S. Ayyappan)

Dated the 19th June, 2013
New Delhi

PREFACE

Global demand for food is rising because of population growth, increasing affluence and changing dietary habits. To meet this demand, the global food production needs to increase by over 40% by 2030 and 70% by 2050 (FAO, 2009). Out of the total 44 million ha of rice area in the country, 18.8 million ha is under rainfed condition, of which 67% lies in the eastern India. The challenges before us are: decline in area and water allocation for rice, shifting of labour to other sectors, increasing cost of cultivation and declining profit margin, distress sale, problem of ensuring food and nutritional security to the people below poverty line, intellectual property regime, post harvest losses, lack of adequate storage facilities and environmental concerns in areas of intensive agriculture. In order to meet the future demand in the face of above limitations, the rice productivity has to be brought to 3.3 tonnes per ha from the current level of 2.4 tonnes per ha. The present (2007-08 to 2011-12) rate of production growth (0.36%) is far below the population growth rate of 1.63 per cent. Therefore, the present deceleration trend in production and yield is a cause of concern and has to be reversed to meet the growing demand and also to meet the need of export markets. Moreover, the profit margin in rice cultivation has eroded making rice cultivation unattractive. Hence, scope of enhancing the production and productivity requires ingenuity of science blended with developmental policies. A real-time analysis of this scenario provides sufficient justification for developing and introducing cutting edge technologies for increasing rice productivity in India. To address the emerging challenges, intensification, strengthening and modernization of basic, strategic and applied rice research in areas of crop improvement, production, protection and environmental research along with related social science disciplines are essential. Indian Council of Agricultural Research in its own wisdom made a systematic effort to envision the challenges and opportunities and chart the strategy to take forward agriculture in the 21st century through the preparation of 'Vision 2050'. The present document lists the strategies to overcome the challenges and harness the power of science and technology to address issues on factor productivity increase, effective natural resource management, abiotic and biotic stress management, farmer-friendly farm mechanization, besides promoting environment quality with focus on rainfed rice production.

I am highly grateful to Dr. S. Ayyappan, Secretary (DARE) and DG (ICAR) for the invaluable guidance and encouragement in preparing this document. His personal intervention in charting the progress through several meetings has been of great support. I would also like to personally thank Prof. (Dr.) Swapan Datta,

DDG (Crop Sciences) for critically going through the draft document and introducing new ideas from his huge repertoire of rice knowledge. The valuable guidance received from Dr. R. P. Dua, ADG (FFC) is gratefully acknowledged. I appreciate the efforts of my colleagues including Drs. S.G. Sharma, K.S. Rao, O.N. Singh, A. Prakash, B.N. Sadangi, P. Samal, M. Variar, K.B. Pun, A.K. Nayak, R. Raja, Mohammad Shahid and others in preparation of this document. I am thankful to all my scientist colleagues who expressed their views openly and candidly through the brainstorming session organized for this purpose. I strongly believe that 'CRRI Vision 2050' will serve as a strategy document for promoting innovation in rice research and development in the country.

(T. Mohapatra)
Director
Central Rice Research Institute (ICAR)
Cuttack (Odisha) 753 006

Dated the 27th June, 2013
Cuttack

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CONTEXT

An outbreak of devastating brown spot disease in epiphytotic form coupled with wide abiotic stresses, in the then Bengal province resulted in a serious shortage of rice production in the year 1942 and the Great Bengal Famine in 1943. Against this background, the Central Government decided to intensify research on all aspects of rice crop in the year 1944 and considered setting up a Central Rice Committee to be financed by a cess levied on the crop. However, in 1945, the Government of India decided to establish a central institute for rice research from its own funds. As a result, the Central Rice Research Institute was established in 1946 at Cuttack. The administrative control of the Institute was subsequently transferred to the Indian Council of Agricultural Research (ICAR) in 1966.

The Central Rice Research Institute has been charged with the responsibility of conducting research on all aspects of rice and transfer of technology. The Institute has a Management Committee for deciding the policies and administrative matters. The Institute is headed by the Director who is also the Chairman of the Management Committee. The Director executes the mandate of the Institute through a full-fledged administrative setup and 12 divisions/sections viz., Genetic Resources, Plant Breeding and Genetics, Agronomy, Physiology, Biochemistry, Soil Science and Microbiology, Plant Pathology, Entomology, Agricultural Engineering, Extension, Communication and Training, Agricultural Economics and Statistics. The divisions/sections were subsequently reorganized into 5 new major divisions viz., (i) Crop Improvement, (ii) Crop Production, (iii) Crop Protection, (iv) Biochemistry, Physiology and Environmental Science, and (v) Social Sciences.

In order to address the issues related to location specific research on rainfed rice, two sub-stations, were established: Central Rainfed Upland Rice Research Station at Hazaribag, Jharkhand and Regional Rainfed Lowland Rice Research Station at Gerua, Assam. Further, for propelling the technology transfer, two Krishi Vigyan Kendras, one at Santhapur, Cuttack (Odisha) and another at Jainagar, Koderma (Jharkhand) are in operation.

The Central Rice Research Institute along with its sub-stations has played a pivotal role in rice research and development in the country by initiating, strengthening and intensifying research in the sector, lifting the country from near famine situation to the second largest producer of rice in the world. During the last 67 years of its existence, the Institute has released more than 100 high-yielding rice varieties, including three hybrids, and developed viable crop production and protection technologies for different rice ecologies, with major emphasis on handicapped rainfed ecologies that constitute major chunk of the rice-growing area and encounter immense challenges of multiple abiotic and biotic stresses. The Institute has been identified as the nodal agency for planning, implementation and monitoring of the 'Bringing Green Revolution in Eastern India' programme supported by the Government of India. These efforts of the Institute have immensely contributed towards increasing rice production from 20.3 million tons in 1950-51 to an all time high of more than 105 million tons in 2011-12 and helped ensuring food security. Many rice varieties released by this Institute have also been adopted in countries like Afghanistan, Bangladesh, Nepal, Pakistan, Srilanka, Malaysia, Vietnam, Sierra Leone, Burkina Faso, Burundi, Malawi, Mali, Tanzania and Paraguay contributing to the global food production as well. The Institute has collected and conserved around 30,000 rice germplasm. It has characterized a large number of germplasm for tolerance to different abiotic and biotic stresses and is sharing them with different national and international centers for their utilization in rice improvement programmes. CRRI has played a leading role in preparing green house gas emission inventories from rice fields of India, which helped the country in climate change negotiations at international level.

Global demand for food is rising because of population growth, increasing affluence and changing dietary habits. The UN/FAO forecasts that global food production will need to increase by over 40% by 2030 and 70% by 2050 (FAO, 2009). Yet globally, water is anticipated to become scarce and there is increasing competition for land, putting added pressure on agricultural production. In addition, climate change will reduce the reliability of food supply through altered weather patterns and increased pressure from pests and diseases. Rice along with wheat forms the bedrock of Indian food security and to meet the country's stated goal of ensuring food for all, farmers will have to produce more rice from lesser land, using less water, energy and other inputs in harmony with the fragile environment.

The Institute's future research endeavor would focus on developing rice varieties for different ecologies with higher yield potential and improved tolerance to abiotic stresses such as drought, submergence, stagnant and flash flooding, salinity and high temperature, and major biotic stresses in the context of climate change by integrating conventional and innovative approaches such as marker-assisted breeding, heterosis breeding and doubled haploid breeding, functional genomics and transgenics. Development of super rice, improvement of photosynthetic efficiency through C_4 mechanism, development of nutrient-rich rice varieties and improvement of grain quality parameters will also receive high priority. For, trait-specific germplasm evaluation, identification of promising donors for target traits, identification, fine mapping and introgression of new genes/QTLs, state of the art high throughput phenomics and genomics facilities are essential.

Research on crop production would focus on factor productivity improvement leading to efficient utilization of water, fertilizers, pesticides and other agricultural inputs, which will decrease the cost of cultivation, maximize profit and yet secure cleaner environment. Research on rice-based cropping/farming systems and crop diversification, *boro* rice, flood-prone rice, organic scented rice, aerobic rice, climate resilient production technologies, soil resilience, integrated nutrient management, integrated crop management etc. will be strengthened. Post-harvest technology and value addition keeping the requirements of consumption, internal trade and exports will also form an integral part of our research. The quality of rice soil and its produce along with ecosystem carrying capacity are becoming more important in the context of growing concerns of food safety, international trade and climate change. For this, a state of art modern quality laboratory (rice soil and grain quality) is highly essential.

VISION

Our vision is sustainable food, nutritional and livelihood security and equitable prosperity through rice science.

GOAL

Our goal is to ensure food and nutritional security of the present and future generations of the rice producers and consumers.

MISSION

Our mission is to develop and disseminate eco-friendly technologies to enhance productivity, profitability and sustainability of rice cultivation.

MANDATE

- Conduct basic, applied and adaptive research on crop improvement and resource management for increasing and stabilizing rice productivity in different rice ecosystems with special emphasis on rainfed ecosystems.
- Generation of appropriate technology through applied research for increasing and sustaining productivity and income from rice and rice-based cropping/ farming systems in all the ecosystems in view of decline in per capita availability of land.
- Collection, evaluation, conservation and exchange of rice germplasm and

distribution of improved plant materials to different national and regional research centres.

- Development of technology for integrated pest, disease and nutrient management for various farming situations.
- Characterization of rice environment in the country and evaluation of physical, biological, socioeconomic and institutional constraints to rice production under different agro-ecological conditions and in farmers' situations and develop remedial measures for their amelioration.
- Maintain database on rice ecosystems, farming situations and comprehensive rice statistics for the country as a whole in relation to productivity and profitability.
- Impart training to rice research workers, trainers and subject matter/extension specialists on improved rice production technologies and rice-based cropping and farming systems.

THRUST AREAS

- Harnessing the modern science of genomics, nanotechnology, imaging and sensors for improving the efficiency of rice crop
- Trait specific germplasm evaluation and their utilization for gene discovery, allele mining and genetic improvement
- Designing, developing and testing of new plant types, next generation rice and hybrid rice with enhanced yield potential.
- Identification and deployment of genes for input use efficiency, tolerance to multiple abiotic/biotic stresses and productivity traits.
- Intensification of research on molecular host parasite/pathogen interaction and understanding the pest genomes for biotype evolution, off-season survival and ontogeny for devising suitable control strategy.
- Developing nutritionally enhanced rice varieties with increased content of pro-vitamin A, vitamin E, iron, zinc and protein.
- Development of climate resilient production technologies for different rice ecologies.
- Development of cost effective and environmentally sustainable rice-based cropping/farming systems for raising farm productivity and farmers' income.
- Catalyzing technology transfer through interfacing and collaboration in participatory mode involving all stake holders.

RICE PRODUCTION SCENARIO

Area, Production and Yield

The productivity of rice has increased from 668 kg per hectare in 1950-51 to 2395 kg per hectare in 2011-12. The production of rice has shown an upward trend and reached a record level of 105.31 million tonnes in 2011-12 (Fig 1). The increase in productivity is about 258% and this increase is due to introduction of high yielding varieties responsive to high dose of fertilizers coupled with improved package of management practices evolved by agricultural scientists for various regions.

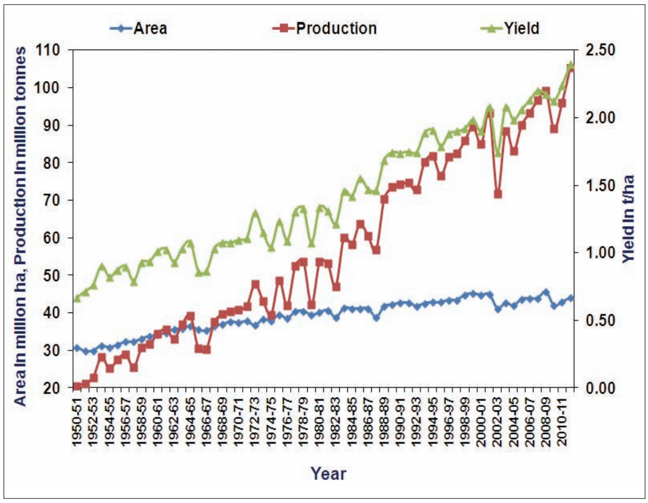

Fig 1. Area, production and yield of rice in India (1950-51 to 2011-12)

Trends in Rice Area, Production and Yield

The growth experience of rice over the last 30 years (1980-81 to 2010-11) at all India level shows that maximum yield growth of 3.14% was obtained during 1980s (Fig. 2). Subsequently, the yield growth has reduced to 1.26% during 1990s and 1.49% during 2000s. After 1980s, especially during 1990s and 2000s, gradual decrease in area growth and yield growth negatively impacted production (Table 1). The additional yield has also got reduced from 387 kg/ha to 200 kg/ha during the above said period. Considering the fact that area growth is almost exhausted, shrinkage in production growth is a cause of real concern (Table 1).

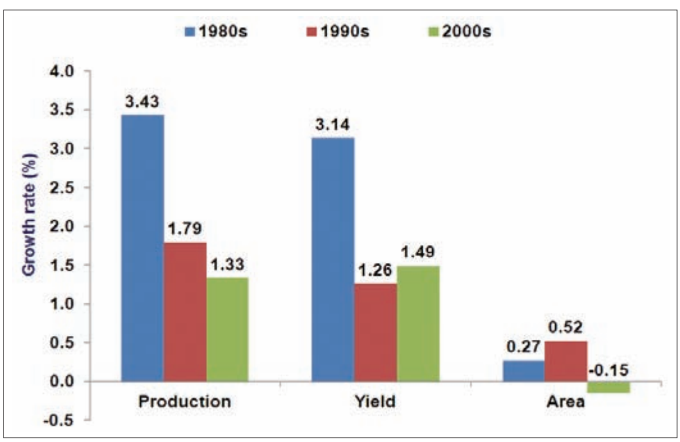

Fig.2 Trends in all India growth rates of area,production and yield during different decades (1980-81 to 2009-10)

Table 1. Trends in average area, production and yield of rice at all India level for the last three decades (1980-81 to 2009-10)

Particulars	1980s	1990s	2000s
Production (million tonnes)	59.74	80.04 (20.30)	89.19 (9.15)
Yield (tonnes/ha)	1468	1852 (384)	2052 (200)
Area (million ha)	40.69	43.19 (2.50)	43.41 (0.22)

Figures in parentheses indicate incremental values over the previous period

Rice is grown in two major seasons in India *i.e.* during *kharif* and *rabi*/summer. Presently, *kharif* and *rabi*/summer rice accounts for 89% and 11% of total rice area and 85% and 15% of total rice production, respectively at all India level. The growth rate in area during 1990s was more in comparison to 1980s because of increase in area, both in *kharif* and *rabi*/summer season. However, during 2000s, the area growth rate became negative and decreased at the rate of 0.15% per year due to decrease in *kharif* season area (Fig. 2). The growth in production during 2000s was 1.33% per year mainly due to yield growth (1.49%). Disaggregated by season, the production growth was impressive for *rabi*/summer rice than kharif rice due to maximum growth in area under *rabi*/summer rice (Fig. 3 and 5). The area expansion of *kharif* season rice has been up to 1990s and thereafter the area

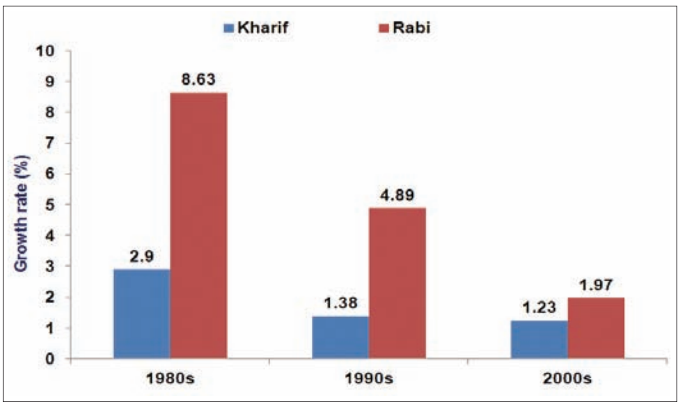

Fig.3 Season wise comparison of production growth rates during last three decades

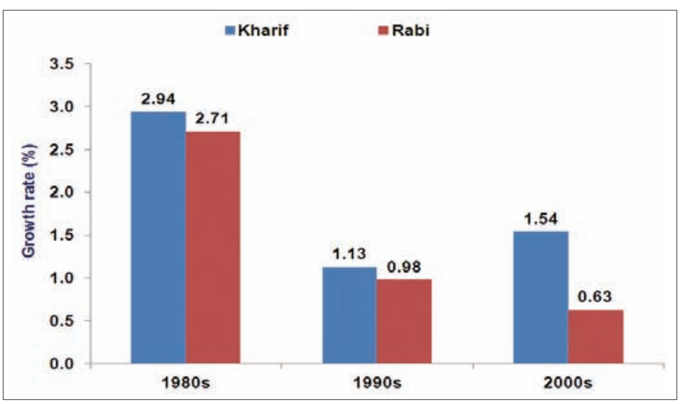

Fig.4 Season wise comparison of yield growth rates during last three decades

has declined at the rate of 0.30% per year in the *kharif* season during the last decade (Fig. 5). However, during *rabi*/summer season, the area has increased at the rate of 1.35% per year during the last decade.

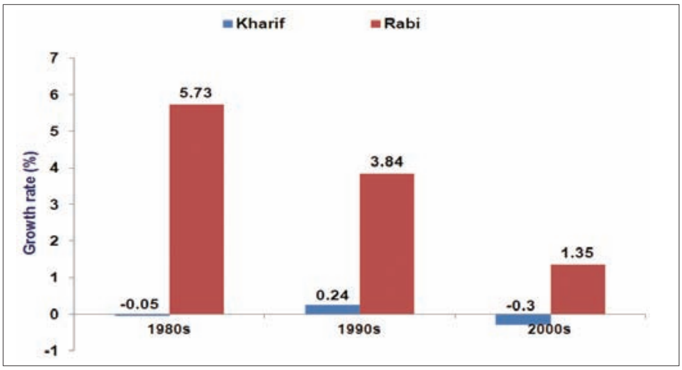

Fig.5 Season wise comparison of area growth rates during last three decades

The production growth during the last decade (2000s) was mainly due to increase in *kharif* season yield growth at the rate of 1.54% per year (Fig. 4). The *rabi*/ summer yield growth was observed to be 0.63% per year only. These observations lead to the conclusion that the area growth in India has exhausted and production growth has decelerated. Therefore, further increase in production has to come from yield increase only.

Trends in Cost of Cultivation and Profit

The growth rates in cost of cultivation have been computed for different states and presented in Table 2. The cost of cultivation per ha has increased in all the states and the growth rates varied from 0.59 % to 3.28 % per year in different states, when data for the period 1980-81 to 2009-10 was considered. The growth rate in cost of cultivation was faster and more than 2% in states like Odisha, Assam, Karnataka, Madhya Pradesh, West Bengal and Haryana. The absolute cost of cultivation varied from Rs 19,386 to Rs 51,749 per ha in different states in the recent past, when average data for the period 2007-08 to 2009-10 was considered. The average profit over cost of cultivation varied from Rs (-77) to Rs 27,489 in different states in the period mentioned above. The profit based on total cost has become negative in some years in states like Assam, Bihar, Madhya Pradesh, Odisha, West Bengal, Uttar Pradesh, Kerala and Tamil Nadu, for which the growth rate could not be computed. The growth in profit over cost of cultivation was positive and significant in irrigated states like Andhra Pradesh, Punjab, and Haryana due to quality rice production and better price realization. Due to declining profit in many states, the policy makers and researchers are concerned about making rice farming profitable, so that the farmers get reasonable profit while the consumers get rice at affordable prices.

Emerging Demand-Supply Imbalances

Growth in population and increase in per capita income are the two driving forces for increasing food demand in India. With increase in income, there has been a shift in diets away from staples and increasing towards vegetables, fruits, livestock products in the country. Therefore, the rate of increase in demand for cereals will be less than other high value crops and livestock products in the future years. According to the projections made by the Population Foundation of India, the country's population will be 1546 million by the end of 2030, 1695 million by the end of 2040 and 1824 million by the end of 2050. It is estimated that the demand for rice will be 121.2 million tonnes by the year 2030, 129.6 million tonnes by the year 2040 and 137.3 million tonnes by the year 2050 (Table 3) for internal consumption. In addition to this, India is currently exporting about 3.5 million tonnes of basmati and 6.9 million tonnes non-basmati rice per year, earning valuable foreign exchange for the country. In order to achieve this target, the productivity of rice has to be brought to the level of 3.3 tonnes per ha, which is 2.4 tonnes presently. The present (2007-08 to 2011-12) rate of production growth (0.36%) is far below the population growth rate of 1.63 per cent. Therefore, the present deceleration trend in production and yield is a cause of

Table 2. Growth trends in cost of cultivation and profit in rice cultivation in different states of India (1980-81 to 2009-10) along with irrigation coverage

Figures in per cent per year

State	CoC (Rs)	Profit (Rs)	IRA (%) (2008-09)
Assam	2.60 (22472)	# (-77)	5.3
Madhya Pradesh	2.51 (21936)	# (4934)	28.3
Bihar	1.07 (19386)	# (2361)	40.8
Odisha	3.28 (28098)	# (2997)	46.8
West Bengal	2.45 (37524)	# (1064)	48.4
Kerala+	0.59 (39620)	# (10769)	72.2
Karnataka	2.57 (41735)	-1.63 (16657)	74.7
Uttar Pradesh	1.41 (30706)	# (7366)	79.1
Tamil Nadu	1.27 (46615)	# (6449)	93.3
Andhra Pradesh	1.83 (51749)	4.91 (10554)	96.8
Punjab	0.82 (49707)	3.68 (24945)	99.5
Haryana	2.37 (49862)	6.42 (27489)	99.9

CoC: Cost of Cultivation; IRA: Irrigated rice area; Figures in parentheses indicate average cost of cultivation and profit for the period 2007-09; # Growth rate could not be computed due to negative profit in some years; + Growth rates for Kerala state has been computed based on data for the period 1999-2000 to 2009-10.

concern and has to be reversed to meet the growing demand and also to meet the need of export markets. Moreover, the profit margin in rice cultivation has eroded making rice cultivation unattractive. Therefore, the two pronged strategy of developing new technologies through more research investments to bring efficiency in production and implementing favourable government policies will help in increasing rice production and productivity in the country to meet the future demand.

Table 3. Projected demand and supply of rice up to the year 2050

Year	Population (million)	Projected demand (mt)	Projected supply at different growth rates (mt)		Demand-supply gap at different growth rates (mt)	
			1.56%	0.36%	1.56%	0.36%
2015	1292	106.4	103.3	98.4	-3.1	-8.0
2020	1380	111.7	111.6	100.2	-0.1	-11.5
2025	1461	116.6	120.5	102.0	3.9	-14.6
2030	1546	121.2	130.2	103.8	9.0	-17.4
2035	1619	125.5	140.7	105.7	15.2	-19.8
2040	1695	129.6	152.0	107.6	22.4	-22.0
2045	1758	133.5	164.3	109.5	30.8	-24.0
2050	1824	137.3	177.5	111.5	40.2	-25.8

mt: million tonnes; Growth rate for the period 2001-02 to 2010-11 is computed to be 1.56% per year and for the period 2007-08 to 2011-12 to be 0.36% per year; Base period value (average of 2007-08 to 2011-12) is 97.05 million tonnes for supply projections.

CHALLENGES

Land Scenario

Owing to a burgeoning population, it is estimated that per capita total land availability which was 0.32 ha in 2001 against the world average of 2.19 ha will decrease to 0.23 ha in 2025 and 0.19 ha in 2050. Over the years there has been a gradual increase in area put to non-agricultural uses. During the last forty years (1970-71 to 2008-09) the net sown area has remained, by and large, constant at 141 million ha. Area under non-agricultural uses has increased from 16 million ha to 26 million ha, while the area under barren and uncultivable land has come down from 28 million ha in 1970-71 to 17 million ha in 2008-09. However, the gross cropped area has increased from 166 million ha in 1970-71 to 195 million ha in 2008-09. As a normal outcome of urbanization and development, the area under non-agricultural uses is increasing, but due to efforts of the government, land has been reclaimed for cultivation from barren and cultivable waste land category. Fast urbanization, industrialization and the demographic pressure have encouraged farmers to exploit marginal lands for increased rice production to meet their family's demands. Therefore, acid soils, tidal lands, forest lands, etc., have been brought under cultivation, thereby limiting crop yield.

Soil Quality

The quality of Indian soils is gradually deteriorating at the farm and eco-system level. The major threats to soil quality come from loss of organic carbon, erosion, nutrient imbalance, compaction, salinization, water-logging, decline in soil bio-diversity, urbanization, contamination with heavy metals and pesticides and from an adverse impact of climate change. The spread of modern rice also encourages increased utilization of machinery in rice farming, which in turn induces soil compaction. Permanent waterlogging and rice monoculture have commonly caused micro-element deficiencies, especially of zinc and sulphur, and toxicities, notably of iron. Zinc deficiency is the most widespread micro-element disorder of wetland rice. Zinc deficiency is observed in soils having sodicity, high organic matter content, high available P or Si and high Mg/Ca ratio. Continuous soil puddling and drying results in formation of sub-surface hard pans which has high bulk density with less medium and large pores, which in turn reduces the soil permeability, and the root ability to extract nutrients from subsoils. It is apprehended that the soil quality might further decline with injudicious use of chemical inputs, intensified use of underground water for irrigation and contamination with toxic industrial wastes.

Soil Mining

Improved rice varieties exhaust soil fertility more rapidly than traditional varieties. The rice crop removes on an average of 20 kg N, 11 kg P_2O_5, 30 kg K_2O, 3 kg S, 7 kg Ca, 3 kg Mg, 675 g Mn, 150 g Fe, 40 g Zn, 18 g Cu, 15 g B, 2 g Mo and 52 kg Si from soil for production of one tonne of paddy (rough rice). Farmers usually compensate these nutritional losses, especially macro-elements, with chemical fertilizers while neglecting some essential secondary and micro nutrients. In the long run, the micro-elements become deficient and cause an imbalance in soil nutrition affecting the ultimate grain yield. Unless routine test-based replenishment of soil with appropriate nutrients takes place, a significant decline in rice production and productivity is bound to happen.

Water Related Constraints

Freshwater resources are a critical input for agriculture as well as for many other economic activities. It is estimated that about 3 million ha in the country are covered under ponds, reservoirs, brackish water, lagoons, rivers and canals. Water shortage is going to be a major problem in the coming years due to spatial and temporal variations, high evaporation, continuous droughts and the competing demands of water among different sectors coupled with climate change. Water is the primary factor determining the success of the rice crop. Wetlands have been widely exploited for rice production in many parts of the world. The problems relating to this matter include water availability, water use efficiency and water quality.

Water availability: It is estimated that by 2050, about 22 per cent of the geographic area and 17 per cent of the population will be under absolute water scarcity. The per capita availability of water which was about 1704 cubic metres in 2010 is projected to be 1235 cm in 2050. Of the total annual precipitation of 4000 bcm, the utilizable water is only 1123 bcm (28 per cent), after adjusting for evaporation and runoff. The present water use is 634 bcm and the projected water by 2025 is 784-843 bcm. Owing to increasing demand for industrial and drinking water and for the energy sector, there will be a substantial fall in the availability for agriculture especially for rice cultivation with serious implications for meeting the food production targets.

Under a changed climatic scenario, a number of chain events like the melting of glaciers, sea level rise, submergence of islands and coastal areas, and deviant rainfall patterns are likely to occur. Their possible impacts would include a greater annual variability in the precipitation levels, leading to some parts of India getting wetter while others becoming drought-prone. Sea level rise will increase saline-intrusion of groundwater, rendering it unsuitable for use. All of these will have a direct impact on surface and groundwater resources. Thus, the major water-related future challenges to Indian agriculture will include the growing menace of ground water pollution, soil salinization and gradual decline in productivity especially in those areas, which witnessed the green revolution.

Water use efficiency: Water is the most important factor in rice production. About 55 per cent of the areas cultivated to rice are under irrigation in India. It is known that 2500-3500 litres of water are used to produce 1 kg of rice in many areas. In the states like Punjab and Haryana, even more amount of water is being used to produce same quantity of rice. This has prompted the respective state governments to issue advisory to avoid transplanting rice during the months of May-June. The genetic improvement for higher water use efficiency has remained a challenge that would need strategic interventions.

Water quality: Water quality has been a serious concern in the last two decades. Ground water quality is affected by arsenic, iron, fluoride content, overdraft, fertilizers and pesticides use and saline water intrusion in the coastal regions. Given the rate of industrialization, urbanization and over exploitation of natural resources etc., water quality would further decline in years to come.

Widening Yield Gap and Stagnating Yield

Productivity of rice varies not only between states, but also within the same state depending upon different rice ecologies and production systems used. The gap between the farmers' yields and those obtained by research stations is still large, even though some reduction has been reported recently. This gap exists because of various limiting factors affecting rice productivity and production, ranging from land development, production and marketing. Moreover, in the irrigated area of north-west India with favourable climatic conditions, such as long day-length, high solar radiation and low night temperature, rice productivity has attained almost plateau. There does exist a wide yield gap in Eastern States. In recent years, due to intervention of modern varieties coupled with improved agronomic practices as being promoted under the Bringing Green Revolution in Eastern India (BGREI) programme, there has been some reduction in the yield gap. Despite this moderate success, bridging yield gap would not be easy given the agro-ecological and socio-economic diversity prevailing in the country.

Biotic Stresses

In the humid tropics, introduction of semi-dwarf varieties and increased use of nitrogen fertilizers and insecticides have changed the status of pests from low to high in relation to the economic losses they inflict on the crop. Severe incidence of some insects such as brown plant hoppers, stem borers and leaf folders, etc., and diseases such as blast, bacterial blight and sheath rot has been reported. The short growth duration of modern rice varieties has changed the cropping pattern and intensity from single crop to double or triple crops, thereby introducing favourable environments for insect-pest and pathogen multiplication. In recent years, resurgence of some of these pests and emergence of some pests/diseases such as swarming caterpillar, false smut and sheath rot which were considered minor, at alarming level in some region, has thrown challenges demanding renewed efforts for developing tolerant varieties and sustainable management practices to minimize losses due to these problems. The pest scenario by 2050 could be significantly different from what is prevailing today due to climate change and increased use of chemicals. Continuous monitoring and redefinition of strategies would be the key to success in minimization of losses due to biotic stresses.

Climate Change/Variability

The strong trends in climate change and the increasing scale of potential negative impacts give urgency to address the expected impacts of increased CO_2 and temperature, deficit and excess rainfall and expected sea level rise through developing climate resilient rice varieties and farming practices. Although the current research confirms that, while rice would respond positively to elevated CO_2, the associated events such as rise in temperatures, altered patterns of precipitation, and possibly increased frequency of drought and floods, will depress yield and increase production risks. The increase in temperature may not be real constraint for Indian rice as the reproductive stage of the *kharif* rice which is the dominant rice system in India coincides with onset of winter. Moreover, *rabi* rice account only 18-20% of total rice production in India. The reproductive stage though coincides with the onset of summer, reduced humidity provides an window of opportunity for rice to tolerate higher degree of temperature. The real challenge to Indian rice will be from the extreme events of drought, floods and cyclones and other associated problems such as salinity.

Rice Quality

In recent past, rice production increased in several Asian countries faster than population growth due to use of modern varieties, fertilizers, irrigation and other inputs that resulted in increase in domestic and international rice supplies. The fall in price of rice in world market and the increase in per capita income together led to the increased domestic and international demand for quality rice. By 2050, the consumer will be better informed and more health conscious with higher purchasing power. In addition to varied preference for grain cooking quality, demand for nutrient rich rice will increase. The nature of this demand will be highly variable in different regions, countries and among different consumers. Besides, rice grain and nutritional quality characteristics are likely to be adversely affected by the climate change and global warming. Environmental factors such as drought, salinity and temperature extremes that impose water deficit stress place limits not only on plant productivity, but also on the quality of the produce. Improving and maintaining eating, cooking and nutritional quality of rice thus would be far more challenging as we go along.

Rice Information

One of the most effective means to promote the flow of agricultural information among the different stakeholders including farmers, consumers, extension personnel, administrators, policy makers and traders is the use of modern communication facilities, which allow gathering, disseminating, and facilitating interaction and exchange of such information among a large number of people and institutions working in the same field. As we approach 2050, a huge information bank of rice science and technology will be available. Selection of appropriate information and its timely sharing among all the stakeholders will need new initiatives, coordination, leadership and considerable use of super-computing and newer and more efficient ICT systems.

Inadequacy of Farm Power and Machinery with the Farmers

The average farm power availability needs to be increased from the current level of 1.7 kW/ha to at least 3.0 kW/ha to assure timeliness and quality in undertaking heavy field operations like sub soiling, deep ploughing, summer ploughing, handling of agricultural produce and by-products efficiently, process them for value addition and generate more income and employment. Fragmentation of land holding is often not suitable for the machineries developed for large farm lands of developed countries. While consolidation of land holdings is proving to be difficult on one hand, on the other hand further fragmentation is expected due to disaggregation of joint family system. Farm mechanization for smaller land holdings will remain the key to success of Indian Agriculture.

Environmental Problems

The hydromorphic rice produces methane when the soils are flooded and no methane is emitted under the dry soil condition. The irrigated rice may cause problems of waterlogging, ground water depletion, salinity and alkalinity. Fertilizer application (especially N), may contribute to greenhouse gas emission, due to the potential losses of applied nitrogen as nitrous oxide. The excessive use of fertilizers and pesticides in rice production may cause water pollution and health hazards through drained water. Maximization of production and productivity with judicious use of chemical inputs without any detrimental effect on the quality of the environment and different life forms will be far more difficult to address.

OPERATING ENVIRONMENT

The Central Rice Research Institute is one of the oldest and premier research institutes of India dealing with the most important cereal crop which is the staple food not only for India but also for about half of the world population. There is a cadre strength of 120 scientists, of which 90 are in position working in the disciplines of Cytogenetics and Plant Breeding, Genetic Resources, Biotechnology, Agronomy, Soil Science, Microbiology, Biochemistry, Plant Physiology, Plant Pathology, Entomology, Agricultural Engineering, Agricultural Economics, Statistics and Extension Education. There are well-equipped laboratories, library, a well laid-out research farm of 70 hectares, net-houses, engineering workshop, office buildings and staff residential buildings accommodated within the institute premises.

The institute has over the years built up a repository of rice germplasm of more than 30,000 accessions with a wide range of genetic diversity and these are utilized in conventional and innovative plant breeding approaches to meet the new challenges to rice production. During the previous years a large number of breeding lines have been developed, which are at different levels of evaluation and are likely to result in release of valuable varieties and hybrids with many desirable traits. Several capital saving technologies and farm implements have also been developed to cater to the anticipated requirements of the farmers.

A transgenic glass-house, open top chambers for CO_2 enrichment study, an Eddy covariance system for continuous CO_2 monitoring, rain out shelters, high temperature tunnels and salinity screening facility have been developed. The institute library has been provided with e-connectivity with access to more than 2250 research journals. A newly established Oryza Museum provides a glimpse of rice research and development highlighting significant contribution of the institute. Drought and rice blast disease phenotyping facilities and biotechnology facilities have been created at CRRI regional centre located at Hazaribagh, Jharkhand. Six MoUs have been signed by the institute with private seed companies for production of CRRI hybrid seeds and parental lines. For its significant contribution to the rice research and development, the CRRI was judged as the best ICAR institute in 2008. As the national active germplasm site for rice, the institute routinely multiplies and supplies lines to the rice researchers in the country and abroad. However, there are many more areas that need to be explored for novel germplasm lines. The gene bank materials need to be evaluated for various attributes at morphological physiological, biochemical and molecular levels. This requires more trained manpower and facilities.

In view of the shortage of labour force at peak times and its increased cost, rice farming needs to be mechanized for which better machines are yet to be developed to reduce drudgery in rice farming and to ensure timely planting or sowing. Rice cultivation is not considered profitable but still practiced being a part of culture rather as a income generating enterprise. Rice is cultivated for domestic consumption and growing of other crops is not possible in these lands during the *kharif* season. Rice farmers are less entrepreneurial due to which their economic status is low. The research farm of the institute is under constant threat of flooding by the river Mahanadi, Taldanda irrigation canal and a city drainage channel, which in the past have damaged the experimental plots on several occasions. Although new pumps have been installed to drain out the flood water, the drainage system is required to be made fool-proof.

The 21st century is the age of bio-science. Science in all its branches is advancing very fast. The Institute has been lagging behind to create the required infrastructure and skilled human resources to harness the benefits offered by new science. The food habit, preference and the human nutrition requirements are changing. With globalization of agriculture, the rice trade scenario is also undergoing sea change. Keeping these dynamic features in view, the institute needs to modernize, modify and improve upon its research strategies, infrastructure facilities and human resources.

For its existence and visibility it has to be competitive inside the country as well as at the international level, particularly under the WTO regime, which is effective since the end of 2004. Climate change with its impact on agricultural production and productivity is looming large over the horizon. The challenges to enhancing yield and quality, preventing or combating pests, diseases and weeds, and generating crops adapted for future environments are issues that require urgent attention. There is more risk in terms of vagaries of weather in general and rainfall in particular, which becomes erratic in certain years, thereby making rainfed agriculture more risky and unstable. Problems related to soil health (nutrient and humus depletion), uncertainty about monsoon and unpredictable environmental conditions, floods, and pest and disease outbreaks have in the past made the rice production highly unstable. With the organized cash crop sector being lucrative, a sizeable area of rice lands might be diverted to cash crops. However, the efforts to diversify the rainfed uplands to other crops have not received much success so far. For various socio-economic reasons, these lands will continue to be cultivated with rice.

NEW OPPORTUNITIES

Approaches for Increasing and Sustaining Rice Production and Productivity

Rice functional genomics for precise trait modification: The rice genome was sequenced completely to gold standard and published in the year 2005. Since then many researchers across the continents have been striving hard to understand genome function employing many different tools of functional genomics to unravel the mysteries surrounding trait expression. Our knowledge in this area is still very limited that does not allow precise and directed manipulation of traits to gain maximum economic benefits. Most traits of importance are genetically complex. It needs special efforts first to understand and then manipulate such traits. However, the opportunities provided by the functional genomic tools of trancriptomics, proteomics and metabolomics that can seamlessly be combined with mutagenesis and germplasm diversity are immense. The rate at which these areas are developing and expanding, providing newer avenues, is unthinkable. Linking variation in the germplasm/mutants with molecular variation in genes/ proteins/metabolites will pave the way for precise genetic improvement of rice. CRRI will remain in the fore front of rice research in this area to harness full benefits of the new science.

Development of multiple abiotic stress tolerant rice with climate resilience: Crop yields are limited by a combination of biotic stresses, abiotic stresses, and nutritional factors. Various analyses have suggested that abiotic stress primarily due to drought, heat, cold, salinity and submergence is the major factor that prevents crops from realizing their full yield potential. Abiotic stresses often occur in combination. For example, heat and drought stress, submergence and salinity frequently occur simultaneously. The situation will be further complicated in future as the climate keep changing with rapid fluctuations in occurrence of such stresses. Stress tolerance is complex and no single approach can provide a solution to the multiple environmental stresses that a plant might experience during its lifecycle. Further evaluation of novel germplasm and putative stress-related genes under field conditions will be required to develop a robust set of new germplasm better adapted to withstand the stresses a plant may be exposed to. Identification and pyramiding of multiple genes for stress tolerance in high-yielding genetic backgrounds are feasible and would be practicable to tailor novel rice genotypes in future.

Pyramiding of yield QTLs to create next generation super rice: Many yield QTLs have been identified for different traits in different populations and locations. Meta QTL analysis has led to identification of genomic regions affecting trait expression. Regions/QTLs with major impact on trait individually or in combination need to be identified, validated and combined to create next generation rice lines that would break yield barriers. Genes/QTLs from diverse sources including different ecotypes, landraces and wild relatives can easily be transferred/combined in a single genotype with the help of linked markers can easily be mobilized. Such lines with very high yield can be further fortified with genes for better nutrition and stress tolerance.

Increasing heterosis: Hybrid rice is expected to give a quantum jump to overall rice production in India in the coming decades. Although rice hybrids developed by public and private sectors have made some progress in irrigated areas of semi-arid to sub-humid regions, the yield realization need to be enhanced through increased heterosis as well as introgression of known pest and disease tolerance genes in the parents. There is also need to develop hybrids for rainfed lowlands of high rainfall areas. The yield potential of hybrids for such situation needs to be enhanced by increasing the degree of heterosis through development of suitable parental lines. Molecular understanding of hybrid vigour underpins technology-based plant modifications to stave off future food shortages. This will enable us to predict precisely which parents will produce the best hybrid and to fine-tune genetic improvement in yield, quality and stress tolerance.

Nutrient dense rice: In spite of remarkable progress in rice production, protein calorie and micronutrient malnutrition is widespread among the rural and poor population. The pharmaceutical and diet diversification based approaches have achieved little success due to poverty and educational unawareness. Bio-fortification of staple food crop like rice will serve as vector to combat the problem of protein, calorie and micro-nutrient malnutrition. All available approaches (conventional and modern biotechnological) should be used to utilize existing genetic variability with respect to grain protein and micronutrient contents. Using transgenic approaches new pathways can be created and blocks at specific steps in some biosynthetic pathways removed in order to obtain the desired end products in the form of protein, vitamin, anti-oxidants, micronutrients etc.

Resource-use efficient rice: It had been known for centuries that climate, weather, soils, nutrients, crop duration, water and management were the principal determinants of yield. Solar radiation and water are dispersed in space and time, carbon dioxide is a trace constituent of the atmosphere and mineral nutrients are in dilute solution in the soil. Other environmental factors are conditions, experienced but not consumed, such as temperature, pH and salinity of the soil. Temperature is especially influential, constraining crop occurrence to sites suitable for arable agriculture and to growing seasons. Productive agriculture maximizes the resources gathered by the crop by eliminating competition from weeds and by minimizing losses of processed resources to pests and diseases. The biochemistry of the crop plant processes that convert the resources to make crop biomass, part of which is harvested as cereal grains is to be understood in order to identify more resource efficient rice genotypes.

Bioprospecting of genes and allele mining: Genes from wild sources, japonica ecotype and landraces are to be incorporated strategically for further widening the genetic base of our genotypes. Bioprospecting novel genes and identification of superior alleles for tolerance to biotic and abiotic stresses, nutritional quality, resource use efficiency, male sterility/fertility restoration and yield traits would remain the focus of research. Genes/alleles available within crossable limits can be immediately accessed and incorporated into popular cultivars. Transgenic approach to transfer genes for improving the above traits would be far more relevant where the gene is sourced from distant sexually isolated species/organisms.

C_4 rice: Development of C_4 rice has a huge potential for higher productivity. C_4 plants produce higher yields for the same amount of light energy, have double the water-use efficiency of C_3 plants, and their leaves use about 40% less nitrogen to achieve 50% higher yields. A host of biochemical, cellular and anatomical features in the C_4 plant provides a mechanism that first concentrates CO_2 and then supplies it to RuBisCO of the C_3 pathway. It is believed that overcoming this inefficiency in C_3 plants could be the key to achieving a leap in the amount of food or energy a plant can produce from the same amount of sunlight and thus bringing a quantum jump in productivity despite changing climate. It is expected that genes present in C_3 species can be recruited into cell-specific functions in the C_4 pathway without alterations to their gene sequence. These results suggest the possibility that only some parts of the C_4 pathway might be needed in rice for other parts to fall into place.

Nitrogen fixing rice: Green revolution cultivars are fertilizer savvy but the way the fertilizer prices are going up, application of fertilizer in required quantity is slowly becoming unaffordable for small-scale farmers in the developing world. Nitrogen fertilizers also come with an environmental cost. Making and applying them contributes half the carbon footprint of agriculture and causes environmental pollution. Hence, a new method of nitrogen fertilization is needed for sustainable food security/rice production. Engineering nitrogen-fixing cereals is essential for sustainable food production for the projected global population of 9 billion people in 2050. This process will require engineering cereals for nodule organogenesis and infection by nitrogen-fixing bacteria. The symbiosis signalling pathway is essential to establish both bacterial infection and nodule organogenesis in legumes and is also necessary for the establishment of mycorrhizal colonization in rice root. However, establishing a fully functional nitrogen-fixing symbiosis in cereals will probably require additional genetic engineering for bacterial colonisation and nodule organogenesis.

Apomictic rice: Development of apomictic rice is an important approach for fixation of heterosis. Introducing/inducing apomixis in rice using introgression, mutagenesis and genomic approaches is being researched. Diverse species germplasm as well as interspecific hybrids are being studied using efficient screening techniques, such as embryo-sac (ES) clearing and flow cytometric seed screening (FCSS) that would enable researchers to understand the trait and its role in rice breeding. Identification of differentially expressed genes during apomixis like apomeiosis, parthenogenesis and functional endosperm development as well as ploidy-dependent regulation of these genes would be a key step in this direction. Genomics approach would enable identification of regions of rice chromosomes known to harbor genes for female meiosis and synteny with apomixis genes from other Poaceae species. Synergy of both 'evaluation' and 'synthesis' approaches would help achieve expression of apomixis components gathered in a single genetic background.

Exploitation of microbial resources: Exploitation of microbial resources for plant growth promotion, environmental changes, abiotic and biotic stress endurance through conventional and intensive use of molecular tools would alleviate the serious production constraints for the present and future. Deciphering and exploitation of almost 99% of hitherto unknown/uncultivable microbial resources and the anaerobes are the most important priorities for the future of agricultural sustenance. Development of customized nano-technology for smart delivery of PGPRs, biofertilizers, biocides with enhanced shelf life; focusing on the uncultivables, anaerobes and CO_2 fixers to endure present and climate change stresses; omics research of PGPRs, RNAi technology, plant-microbe interactomics and other omics research; direct and indirect exploitation of novel molecules etc. would sustain production in diverse rice ecologies.

Resource conservation technologies: The productivity and sustainability of the rice production systems are threatened because of combination of factors such as inefficient use of inputs (fertilizer, water, labor); increasing scarcity of resources, especially water and labor; changes in climate; changes in land use driven by a shortage of water and labor; socio-economic changes (urbanization, labor migration, changing attitude of people to drift away from farm work) and concern about farm-related pollution. These factors causing yield to stagnate over the past two decades. Conservation agriculture involves utilization of locally available resources, and manipulation of minimum tillage, residue management and crop diversification to sustain the productivity. The utilization of third and fourth generation machinery performing multiple functions such as sowing, fertilizer application and residue retention/incorporation with help of sensors and GIS platform would be the mainstay research in the days to come. Conservation agriculture may help to face the challenges to produce more food at less cost and improve water productivity, increase nutrient use efficiency and mitigate the effects of climate change with regard to the emission of greenhouse gases in rice-rice system.

Climate resilient production technologies: Production technologies such as modifying crop management practices; improving water management; adopting new farm practices such as resource-conserving technologies; crop diversification; improving pest management; making available timely weather-based advisories; crop insurance; and harnessing the indigenous technical knowledge of farmers are critical for developing location specific climate resilient production technologies.

Exploitation of nanotechnology: Although, nanotechnology has shown amazing applications in the field of medicine, energy, engineering etc., its potential in the field of agriculture is yet to be exploited. The prime focus is on developing simple gadgets for early detection of pests, diseases and nutrient deficiencies, evolving sustained release of pheromones and insecticide molecules for effective insect pests management and designing, fabricating and developing smart delivery systems to enhance input use efficiencies of nano-agricultural inputs. Another frontier area of nanotechnology research involves synthesis of a slow-release fertilizer composition based on urea-modified hydroxyapatite (HA) nanoparticles and Zinc aluminum-layered double hydroxide nano composites which have been used for controlled release of nutrients. Similar such formulations are having potential to be exploited for enhancing nutrient use efficiency.

Precision farming: Application of space sciences and mathematical modeling in weather forecasting, development of sensor based technologies, use of remote sensing in real time appraisal of water, nutrient stress in plant, pest and disease occurance coupled with GIS, GPS and variable rate applicators, crop growth models and decision support systems, and their deployment in rice farming may help in managing our resources efficiently. More sophisticated crop simulation models already used in basic and applied research can predict the changes in plant growth, development, and productivity in a given environment and thus help in the management of resources such as fertilizers and water in many horticultural and cash crops. However, the days are not far when precision farming will be a reality in rice crop as research institutions are already working on these aspects and the systems are already operational in developed countries. This will help in enhancing water, nutrient and other input use efficiencies while safeguarding the environment.

Approach to Socio-economic Research

The research programmes should be made on multi-disciplinary mode. All disseminable and field-triable technologies addressing socio-economic problems and issues should have social science components for field evaluations. Looking into the importance of social sciences in technology assessment, refinement and dissemination in the context of emerging socio-economic issues in coming years, research in this area needs to be strengthened. Field level research and extension programmes should be planned and executed through participatory mode in a functional manner involving all stakeholders including state line departments, KVKs, ATMA, NGOs, farmers organizations, agro-industries and marketing channels. Regular on-campus and off-campus interface among the stakeholders and conducting FLDs and OFTs would facilitate development of linkages and dissemination of Rice Production Technologies (RPTs) to the ultimate users. To make all states self-sufficient in HYV/hybrid paddy seeds, farmers' participatory seed production in seed village programme would be most vital in making quality seeds available at the door steps of the farmers of this country.

Entrepreneurship Development Model Approach

Educated rural youths having entrepreneurial qualities need to be identified and imparted specialized on-campus as well as off-campus certificate courses/ training on RPT for 2-3 months to encourage them taking up entrepreneurship and make them successful entrepreneurs. These youths will, in the long run, act as change agents in RPT dissemination and adoption in rural area. Potential areas for such courses may include, HYV and hybrid rice seed production, production and marketing of fine grain aromatic as well as non-aromatic rice, farm mechanization, value added rice products etc.

Strengthening Gender Research and Development

The participation of farm women in major activities of rice farming as reported by IRRI varies from 89-93% in transplanting, 70-89% in harvesting the crop, 70-83% in storage activities, 37-42% in threshing, 29-38% in transportation of harvested crop, 10-20% in nursery preparation, 10-15% in irrigation of the crop, 10-15% in land preparation, 5-15% in seed selection for sowing and 2-10% in fertilizer management. Women in tribal areas constitute the real work force in cultivation of this crop. But, gender equity in rice is a matter of concern as women enjoy a small share of benefits, unlike the benefits available to them in vegetable and livestock enterprises. With emphasis on women empowerment and sensitization among the members of the civil society on gender equality and equity, more and more women in rural areas will join the work force for social and economic reasons. Rural women would get legal, policy, development and family supports to play more productive and smart roles. Studies have shown that the male migration to urban areas and diversion of work force to non-farm sectors would bring women to centre stage of all household activities in which rice farming is the most important one. A large number of women would be *de facto* head of the families and may take part in decision-making related to adoption of rice production technologies and management of the rice-based farming systems. In the said backdrop, the rice researchers need to be sensitized to develop projects for generation of technology that would suit the needs, aspiration and problems of the farm women. Drudgery of farm women in rice farming would get special attention so that the hazards especially in transplanting, weeding and post-harvest can be mitigated and efficiency of women increased. The development of rice by participation of women would be speedier provided appropriate strategy and methodology be adopted by extension systems. The institute would plan to develop and test action research projects with a gender perspective to provide appropriate models, clues and guidelines for gender mainstreaming. The aforesaid strategy and approaches would provide equity to the women, which would lead to sustainable rice production.

GOALS/TARGETS

Our primary goal is to ensure food and nutritional security for 1.6 billion Indian population by 2050 and to provide livelihood security for present and future generation of rice farmers within the limits of natural environments. With a broader perspective, the institute aims to intensify basic, strategic and applied rice research, advance the frontiers of knowledge and contribute to sustainable global food security.

TARGETS OF VISION 2050

Rice Productivity

It is estimated that the demand for rice will be 121.2 million tonnes by the year 2030, 129.6 million tonnes by the year 2040 and 137.3 million tonnes by the year 2050. In order to achieve this, the production per unit area needs to be increased to the level of 3.3 tonnes per ha from the present 2.2 tonnes per ha assuming the rice area under plough remains at current level. However, due to competition from other crops, demand from urbanization and industrialization, there may be a decline of rice area by 6-7 million ha by 2050. Under such a scenario, the realistic productivity target would be around 3.9 tonnes per ha.

Value Addition through Development of Specialty Rice

Food habits are rapidly changing due to increased income and access to diversified food basket. In order to meet the future demand, CRRI needs to develop and popularise rice varieties suitable for bread making, specialty rice like diabetic rice, soak n eat rice, rice rich in protein, Fe and Zn, medicinal rice, aromatic rice, biofuel rice and ornamental rice. Besides, the straw, husk and bran have to be efficiently utilized for commercial purposes for generation of high income through agro-industry ventures.

Water Productivity

Currently, 2500-3500 litres of water are used to produce 1 kg of rice in India. In order to meet the challenges of declining water resource base and competition from other sectors, the water productivity of rice needs to improved by bringing down the water productivity from the current level to the level of 2000 liters/kg of rice.

Nutrient Use Efficiency

Nitrogen use efficiency needs to be enhanced by 20-40%, phosphorus use efficiency by 40-50% and zinc use efficiency by 50-100% for various rice production systems.

Energy Use Efficiency

In order to make rice cultivation as an efficient, competitive and profitable production system, the energy use efficiency has to be doubled from the current levels by deploying the modern resource conservation and energy efficient technologies.

Labour Productivity

Rice production can remain a profitable proposition only if the current level of dependence on labour is reduced by one-third. This can only be achieved through mechanization of labour intensive components of rice farming, particularly in case of small farms.

Green House Gas Emissions

Deployment of low green house gas emission resource conservation technologies for reduced methane and N_2O emissions from rice paddies, would be essential for sustainable and ecologically safe rice farming.

Climate Resilient Rice Production Technologies

Climate change impacts demand (i) adjustments in our rice production methods and development of new rice strains that can withstand higher temperatures, (ii) developing multiple stress tolerant varieties that can withstand and perform under climate change situations, (iii) adoption of rice-based cropping system that is environment-friendly and has least environmental footprint, (iv) development of cultivation practices to maintain natural resource base and soil health for a sustainable rice production, (v) accelerating adaptation to climate change and better management of agricultural risks towards resilient agriculture, and (vi) development of partnership with rural communities and other stakeholders in a climate-smart model for agricultural development that includes a range of innovative agricultural risk management measures.

Networking and Co-ordination for Consolidation of Gains

Space and information technology, virtual laboratories and class room for communication and training from across the national and international institution required to be deployed for consolidating the gains in the field of rice science.

Socio-economic and Policy Research on Rice

Development of robust methodology for correctly assessing the impact of Government programs including safety-net ones and rice policies will be targeted to provide insights to research system on the one hand and policy (Food Security Act) making and program planning on the other.

Human Resource, Infrastructure and Skill Development

State of the art research facilities in the field of biotechnology, nanotechnology, climate science, soil and grain quality and toxicology, etc. will be developed at CRRI for strengthening both basic/strategic and applied rice research, and impart training to create a pool of skilled manpower to handle R&D in rice by 2050.

WAY FORWARD

Keeping in view the vision and goal of the institute, the CRRI aims at further enriching and diversifying its genetic resources by tapping the biodiversity and utilizing them for breeding rice varieties with higher yield potential, better grain and nutritional quality, enhanced input use efficiency and increased tolerance to major biotic and abiotic stresses through conventional and innovative techniques such as marker assisted breeding, development of transgenics, functional genomics, improvement of degree of heterosis, and improvement of photosynthetic efficiency through C_4 mechanism. Identification of potential new donors for abiotic and biotic stresses and unraveling the underlying tolerance mechanisms will also receive due attention. Genomics, proteomics, metabolomics and phenomics tools will be employed for understanding multiple abiotic/biotic stress tolerance mechanism. Redesigning rice plants for improving photosynthesis and plant productivity under multiple abiotic stress environments through transgenics would also be one of the approaches.

Research emphasis will be on improving water and nutrient use efficiencies with special emphasis on conservation agriculture, climate-resilience, rice and rice-based cropping and farming systems. Rice physiology and biochemistry under high CO_2, ozone and temperature would be unraveled for defining climate resilient rice cultivars. Innovative approaches involving nano-technologies will be taken up for efficient use of fertilizers and pesticides. Design and development of nano sensors, nano molecules, nano delivery systems will be made to achieve desired input use efficiency in environment friendly manner. Use of newer molecules for control of diseases and insect pests, including bio-pesticides, and integrated pest management (IPM) are other areas of focus. Host-parasite/pathogen interaction at molecular level including QTL identification to design suitable control strategy will be the approach for resistance breeding.

Management of rice related knowledge, with due attention on extension services and fostering linkage and collaboration with public, private, national and international organizations are other important areas on which the institute will be focused. Strategic planning, priority setting and impact assessment of rice research in India with a global perspective will be taken up to consolidate the gain. Development of state of art research facilities in the field of bio-technology, nanotechnology, climate science, soil and grain quality and toxicology, etc. would be the priority. Capacity building of scientists, farmers and other stakeholders will be given due importance, so as to be globally competitive and ensure food and nutritional security of the country. We hope with this vision and strategy, we will be able to address the food and nutritional security with equity in future.

हर कदम, हर डगर

किसानों का हमसफर

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