

Vision 2030



केंद्रीय चावल अनुसंधान संस्थान
भारतीय कृषि अनुसंधान परिषद
कटक (उड़ीसा) ७५३ ००६



Central Rice Research Institute
Indian Council of Agricultural Research
Cuttack (Odisha) 753 006



Vision 2030



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India



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Message



Indian rice production has nearly trebled between 1960 and 2010, with a compounded growth rate of 2.53%. The Green Revolution has helped the country to regional food surpluses with Punjab leading the country in rice production and productivity. However, despite the past achievements, rice productivity growth has to continue for obvious reasons. Looking to the future, Indian rice production will come under additional pressure from intense competition for land and water, a more difficult growing environment because of climate change, higher price for energy and fertilizers and greater demand for reduced environmental footprint. This requires a careful analysis of the current production scenario and perspectives with a view to identify researchable issues and strategies to address them.

Central Rice Research Institute, Cuttack, the pioneering rice research institute of the country is tasked with increasing rice production in rainfed areas burdened with chronic abiotic and biotic stresses. However, there is still scope for improving rice production in this handicapped ecology through proper scientific intervention and policy decisions. I am glad that the institute through prudent knowledge and research-driven strategy has shown its readiness to tackle the problem.

I am confident that the analytical approach and forward looking concepts presented in the '*Vision 2030*' document will help the policymakers, researchers and stakeholders to confidently face the future and bring smile to the millions of small and marginal farmers whose livelihood depends on rice growing.

June 06, 2011
New Delhi

A handwritten signature in blue ink, appearing to read 'S. Ayyappan', with a stylized flourish at the end.

(S. AYYAPPAN)

Secretary, Dept. of Agricultural Research & Education (DARE)
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Preface

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 and keeping in harmony with the fragile environment.

Rice is the most important food crop of the developing world and the staple food for more than 60% of the Indian populace, who are also highly vulnerable to inflationary pressure due to high rice price. In India, the annual compounded growth rate (ACGR) of rice production has declined from 3.55 per cent during 1981-90 to 1.74 per cent during 1991-2000. Although an all time high production of 99.50 million tons of rice with a productivity of 2.20 tons per hectare was achieved during the year 2008-09, India needs to produce 120 million tons by 2030 to feed its one and a half billion plus population by then. A real-time analysis of this scenario provides sufficient justification for strengthening, intensifying and introducing cutting edge science and technology for increasing rice productivity in India.

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 2020'. The Central Rice Research Institute, Cuttack also made effort under the caring guidance of ICAR to prepare visionary document for 2020 that was upgraded to "*CRRRI Perspective Plan – Vision 2025*" to address the changes that had taken place. The present document, '*CRRRI Vision 2030*' 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 environmental quality with focus on rainfed rice production.

I am 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 including the one with the RAC Chair, Prof. (Dr.) R.B. Singh has been of great support. I would also like to personally thank Prof. (Dr.) Swapan Datta, DDG (Crops) for critically going through the draft document and introducing latest views from his huge repertoire of rice knowledge.

I appreciate the efforts of my team of specialists including Drs. S.G. Sharma, K.S. Rao, O.N. Singh, Mrs. U. Dhua, B.N. Sarangi, M. Variar and K.B. Pun in developing 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 have a strong belief that '*CRRI Vision 2030*' document will be a strategy document to enlist the skills and capabilities, knowledge exchange and translation, and promoting innovation in rice research.

June 04, 2011
Cuttack



(T.K. ADHYA)

Director
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Preamble

Established in 1946 in the backdrop of the 'Great Bengal Famine', Central Rice Research Institute (CRRI) at Cuttack played a pivotal role in the rice research scenario of the country by initiating, strengthening and intensifying organized research in the sector, lifting the country from near famine situation to the second largest producer of rice in the world. During the last 65 years of its existence, the institute has released 82 high yielding rice varieties and several viable rice production technologies for their adoption in farmers' fields. With this research support from the institute, SAUs and other research stations, and infrastructural support and extension services of the Government agencies and NGOs and above all the herculean efforts of the rice farmers of the country, rice production has increased from 20.3 million tons in 1950-51 to an all time high value of 99.5 million tons in 2008-09.

Initially assigned with the responsibility of conducting research on all aspects of rice agriculture and associated transfer of technology, CRRI is currently entrusted with the solving of the challenges of the handicapped ecology of rainfed rice. In order to address the issues relating to such ecosystem specific research, two sub-stations were established namely, Central Rainfed Upland Rice Research Station at Hazaribag Jharkhand in 1980, and Central Rainfed Lowland Rice Research Station at Kharagpur, West Bengal) in 1986 (now Regional Rainfed Low Land Rice Research Station, Gerua, Assam. Two *Krishi Vigyan Kendras* (at Santhapur (district Cuttack, Odisha) and Jainagar (district Koderma, Jharkhand) are also associated with CRRI to speed up technology transfer.

CRRI plays a stellar role in identifying and solving problems of national interest in rice production with major emphasis on the eastern Indian States. Rainfed areas constitute nearly 52% of the area growing rice and pose immense challenge in terms of exposing the rice plants to extremes of its tolerance, especially in its edaphic and environmental relationships. The research done so far for the rainfed systems has opened the ways to raise the productivity of rainfed shallow lands and intermediate lowland; it has also indicated the possibility of raising productivity of semi-deep land situations. With the varieties developed for rainfed uplands, shallow lands and intermediate lands using their own production practices, the farmers' yields in uplands ranged from 2 to 3.5 t/ha and from 3 to 5 t/ha in shallow and intermediate lands. This indicates that varieties suitable for rainfed situations can play a vital role in augmenting the productivity and production in rainfed areas.

Semi-dwarf stature of rice facilitates better partitioning of the biomass into grain. Increasing the production of biomass *per se* will

rely on extending the duration of the cultivar for growing them in certain seasons (e.g. *boro*), when the prolonged duration becomes beneficial for yield. Redistribution of the biomass in grain by changing the shape and quality of kernels for the same grain weight will add value to the product. Recombination breeding for yield increase has to be backed by basic studies on photosynthetic efficiency, cold tolerance, diverse sources for plant type, and selection among land varieties for combining ability.

An alternate method for enhancing yield levels is exploitation of heterosis through the development of hybrids. The gains are readily visible. But much back-up research is needed in developing the parental lines, simplification of seed production technology and in broadening the genetic base of the parents by utilizing wide compatibility genes.

Resistance breeding is in various stages of development. Progress has been rapid in case of a limited number of abiotic (drought, submergence and salinity) and biotic stresses (gall midge, brown plant hopper, bacterial leaf blight, blast); but multiple resistance to these stresses by bringing in a rational mix is yet to be realized. Biotechnological tools like gene pyramiding, transgenic approaches, marker aided selection etc. have been exclusively exploited for imparting host plant resistance to abiotic and biotic stresses. Resistance breeding in respect of some insects (e.g. borers, leaf folder, hispa, *gundhi* bug) and some diseases (e.g. sheath blight) has not been much successful. It remains to be seen whether new knowledge on ecology will help, or if novel techniques of biotechnology can provide breakthroughs. Research on epidemiology of diseases, genetics of the pathogen and ecology of insects may provide new insights for generation of plant protection technologies. Expanding the enterprise options in rice growing will entail no-till farming of crops, which can be grown in rice fallows with the use of residual soil moisture. The opportunities for rice-fish-livestock farming system in the lowlands of eastern India are indisputably great.

Emphasis on crop management practices synergistically with fertilizer use, and research on placement and timing of fertilizer application is expected to lead to an improvement in fertilizer use efficiency. An in-depth research on fertilizer use in lowlands might ensure more judicious and economic use of fertilizers and conservation of natural resource base. A strong extension system would, however, be required for transferring the technologies to farmers' field.

CRRI has been conducting research in the areas of contemporary interest with the major emphasis on the welfare of the rice farmers, consumers and other stake holders in the rice production and supply chain. All efforts are directed towards becoming the leading rice research institute in the world.*

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Rice Scenario and SWOT Analysis

Trends in Rice Area, Production and Productivity

Rice is the most important cereal food crop of India, which occupies about 24 per cent of gross cropped area of the country. It contributes 42 per cent of total food grain production and 45 per cent of total cereal production of the country. Rice production in India has increased during last 60 years by about 3.5 times from 250.3 lakh tons during the first 5-yr plan period to 857.3 lakh tons during the tenth plan period.

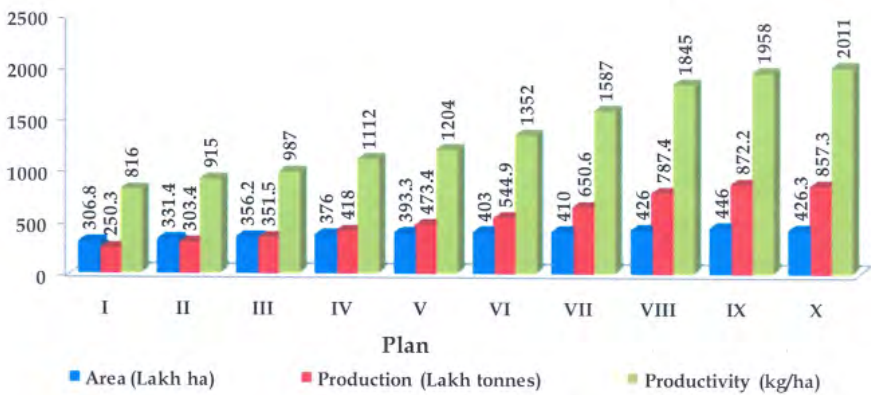


Fig 1. Plan-wise area, production and productivity of rice in India

The average productivity of rice in India, at present, is 2.2 tons/ha, which is far below the global average of 2.7 tons/ha. The productivity of rice is higher than that of Thailand and Pakistan but much lesser than that of Japan, China, Vietnam and Indonesia. Based on the estimates of population growth, projection for future rice requirement and supply up to the year 2030 is given in Table-1. The supply projections have been made at two historical growth rates, i.e. 1.34%

Table 1: Rice requirement at various levels of per capita availability and projection at different production growth rate (Kumar et al., 2000)

Year	Population (million)	Projected demand (mt)	Projected supply (mt) at growth rates of		Demand-supply gap (mt) at growth rates of	
			1.34%	1.14%	1.34%	1.14%
2005	1116	94.5	91.8*	91.8*	2.7	2.7
2010	1210	100.7	94.0*	94.0*	6.7	6.7
2015	1288	106.8	101.5	100.5	5.3	6.3
2020	1370	112.8	108.5	106.4	4.3	6.4
2025	1445	117.3	116.0	112.5	1.3	4.8
2030	1523	121.6	123.9	119.1	-2.3	2.5

*Actual figure for the year.

for the period 2000-2009 and 1.14% for the period 2006-2010. India is expected to surpass its demand by the year 2030, if the rice production grows at 1.34% per annum. But it will remain in deficit of around 2.5 million tons, if the present growth rate of 1.14% continues up to the year 2030.

The average trend in rice area for major rice growing states of the country from ninth plan (1997-98 to 2001-02) to tenth plan (2002-03 to 2006-07) is given in Fig. 2. Among the major states, rice had the largest area coverage in West

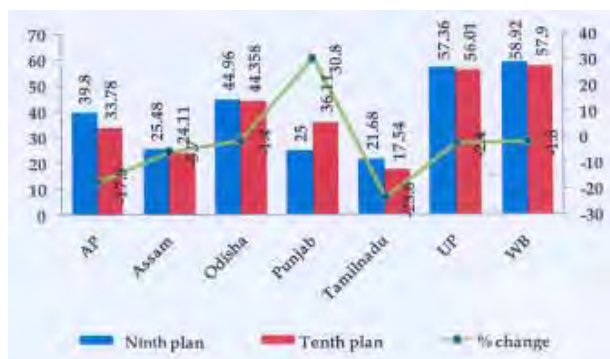


Fig. 2. Trend in rice area (lakh ha) of some major states (averaged over the period of ninth and the tenth plan).

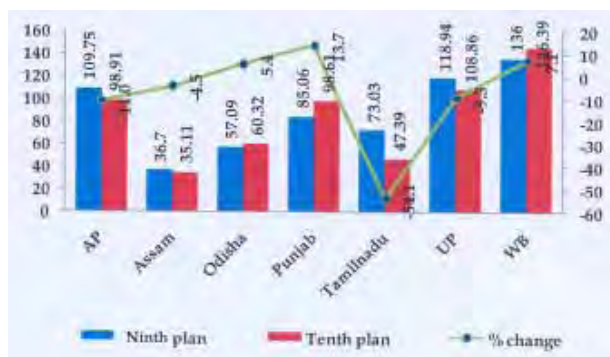


Fig 3. Trend in rice production (lakh tons) of some major states (average over two periods from ninth plan to tenth plan)

followed by Andhra Pradesh and West Bengal. Tamil Nadu showed a negative trend in rice production during the average period of tenth plan as compared to that of ninth plan period (Fig. 4). The states of Assam and Odisha indicated positive trend in productivity. There has been considerable increase in productivity of rice in India during the recent past. The productivity of rice has reached to 2.2 tons/ha at present compared to 0.8t/ha in the first plan. The trends in increase in productivity of rice in states has been almost identical to production, which is mainly due to introduction of high yielding varieties coupled with improved package of practices. Though there is considerable increase in

Bengal followed by Uttar Pradesh. There was a sharp decrease in the area during the average period from ninth plan to tenth plan in Tamil Nadu (23.2 lakh ha) and Andhra Pradesh (17.8 ha).

Like the rice area, the production in West Bengal was also found to be highest followed by Uttar Pradesh (Fig. 3). Also, there was a sharp decrease in production during the average period from ninth plan to tenth plan in Tamil Nadu (54.1 lakh tons), Andhra Pradesh (11.0 lakh tons) and Uttar Pradesh (9.3 lakh tons). West Bengal, Punjab and Odisha revealed an upward trend.

The productivity of rice was found to be highest in Punjab

area, production and productivity of rice in the country from 1950-51 to 2006-07 (Fig. 2), a lot of variations exist especially in production and productivity of rice.

Constraints in rice production

The problems/constraints in rice production vary from state to state and also from area to area.

Eastern zone covers maximum rice growing area. This zone generally experiences high rainfall and severe floods as well as drought almost every year and as a result, the crop loss is considerably high. Besides, in upland areas, the crop gets setback mostly due to drought condition. It has also been observed that some types of soils do not respond to the application of N, P and K due to some inherent characteristics. In certain areas, non-availability of suitable high yielding varieties and quality seeds also contribute to a great extent to the constraints in rice production. However, some of the states/agro-ecologies experience following constraints:

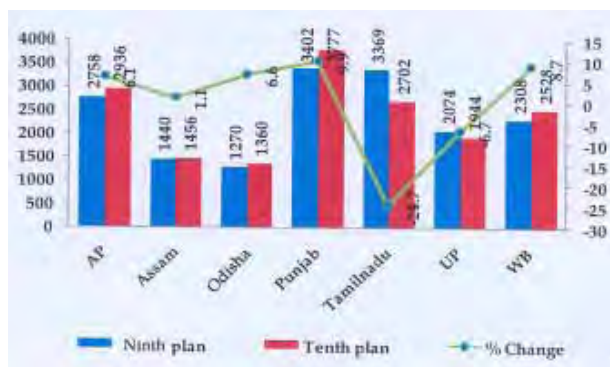


Fig 4. Trend in rice productivity (kg/ha) of some major states (average over two periods from ninth plan to tenth plan)

Constraints	States/agro-ecologies
Small and marginal farmers with poor resources to use optimum/recommended inputs	Mostly Eastern states of India
Erratic rainfall with poor soils	Madhya Pradesh, Odisha and some parts of Uttar Pradesh
Flash floods, water logging due to poor drainage	Assam, West Bengal, North Bihar and Eastern Uttar Pradesh
Use of traditional varieties	Mostly Eastern states
Low and imbalanced use of fertilizers	North-eastern and Eastern states
Delayed and prolong transplanting due to delay in monsoon	Mostly rain fed lowlands
Poor adoption of production technology	Mostly in uplands and lowlands
Saline and alkali soils	West Bengal, Odisha, Andhra Pradesh, Tamil Nadu, Kerala, Karnataka, Maharashtra, Gujarat, Western Uttar Pradesh, Punjab, Haryana etc.

Rice Export

Basmati rice constitutes the major share of rice export from India. Nearly two-third of Basmati rice produced in India is exported. The export of Basmati rice during 2001-02 was 667.07 lakh mt, which showed a quantum jump of 66.91 per cent at 1515 lakh mt in 2009-10. It is revealed that export of basmati rice increased from 2001-02 to 2009-10 whereas, the export of non-basmati rice increased from 667.07 lakh mt in 2001-02 to 5286.08 lakh mt in 2007-08 and then decreased to 139.37 lakh mt in 2009-10, mainly due to policy decision.

Table 4: Average trend in rice (basmati and Non-basmati) export during the period from 2001-05 and 2006-09

Rice	Export (lakh tons)			Foreign Exchange (Rs. Crores)		
	2001-05	2006-09	% change	2001-05	2006-09	% change
Basmati	824.3	1450.35	43.17	2352.26	6863.32	65.73
Non-basmati	2546.0	2514.89	-1.24	2880.45	3438.82	16.24

SWOT Analysis

Strengths

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 planet. There is a cadre strength of 120 scientists, of which 84 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, Instrumentation, 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 bio-diversity and these are utilized in conventional and innovative plant breeding approaches to meet the new challenges of rice research. During the past several 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 the anticipated requirements of the farmers.

A transgenic glass-house, open top chambers for CO₂ enrichment study, a Eddy covariance system for continuous CO₂ monitoring, rain out shelters, high temperature wind 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 Rice Museum is another achievement of the institute. Drought and blast phenotyping facilities and

biotechnology facilities have been created at CRURRS, Hazaribag to give impetus to research on specific stresses. Five MOUs have been signed by the institute with private seed companies for production of CRRI hybrid rice seeds and parental lines. For its contributions, the CRRI was judged as the best ICAR institute in 2008.

Weaknesses

Although, a large rice germplasm has been collected from various parts of the country and safely preserved, there are many more areas that need to be explored, the gene banks material evaluated for various attributes, and data stored for easy retrieval as and when required. This requires more trained manpower and facility. Moreover, a modern rice grain and nutritional quality laboratory is the need of the hour to help identify/develop varieties/germplasm with superior grain and nutritional quality.

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 and it serves more as a culture rather than agriculture as it is cultivated for domestic consumption and growing no other crop is possible in these lands during the kharif season. There is low entrepreneurship of the local population and thus low economic status.

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, this is required to be made fool-proof.

Opportunities

India has the largest area under rice cultivation and is second only to China in rice production. There are huge gaps between yields currently obtained by farmers and that achieved with improved varieties and management practices. Post-harvest losses are estimated to be about 20–30%. Efficiencies of utilization of nitrogen fertilizer or water remain 30–50% below levels that can be achieved with good management. The priority therefore, would be on closing yield and efficiency gaps, reducing postharvest losses, and adding more value to cropping or farming systems to enhance rice production, increase farmers' income while keeping the environment clean.

Recent scientific advances in marker-assisted breeding and genomics can be used to exploit gene bank materials on a large scale to identify and embed the genes responsible for more complicated target traits. Transgenic technologies can be used to engineer new rice plants such as those using a new photosynthetic pathway and N_2 -fixing rice. New developments such as the advent of nanotechnology, improved sensors and analytical methods have potential to change how field experiments are conducted, and can lead to required improvement in precision agriculture to help increase input-use efficiencies.

Uttar Pradesh, West Bengal, Assam and Odisha, which occupy the largest percentage of rice area in the eastern states, have so far kept pace in production with population growth. Improved varieties for rainfed upland, shallow and intermediate lowlands and hybrids are now available which can increase rice yield in these areas further. Hybrid rice technology has started showing potential in eastern sector and private investment is beginning to flow in this direction. Also, moving the surplus production to the market through post-harvest processing could be a lucrative alternative for the industry.

Research during the past decade on rainfed system has exhibited the existence of a vast untapped production potential not only in shallow low lands but also intermediate and semi-deep situations. Ample opportunities also exist to raise production levels from rainfed uplands. Promotion of short grain aromatic rice for export presents vast opportunity for breeders and exporters.

Threats

The 21st century is the age of bio-science. Science in all its branches is advancing very fast. The food habit, preference and the human nutrition requirements are also 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. For its existence and visibility it has to be competitive inside the country as well as at the international level, particularly with the WTO regime becoming effective from the end of 2004.

Climate change with its impact on agricultural production and productivity is looming large over the horizon. The challenges in rice production like enhancing yield and quality, preventing or combating of pest, 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 rain fed agriculture more risky and unstable.

Problems related to soil health (nutrient and humus depletion), uncertainty about monsoon and unpredictable environmental conditions, floods, pest and disease outbreaks have in the past made the rice production highly unstable. With the organized cash crop sector being lucrative, 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.*

National Rice Research System

After the infamous 'Great Bengal Famine' in 1943, the Central Rice Research Institute (CRRI) was established in 1946 at Cuttack with the objective to increase rice production and to create a workforce of rice researchers in the country. The efforts of CRRI and the establishment of agricultural universities resulted in the considerable improvement in rice production. The All India Coordinated Rice Improvement Project (AICRIP) was established by the Indian Council of Agricultural Research (ICAR) in 1965 with its headquarters at Hyderabad, to organize and coordinate multi-locational testing of breeding lines and technologies generated across the country. The AICRIP is continuing with its active partnership of 47 funded cooperating centers affiliated to State Agricultural Universities (SAUs), State Department of Agriculture and other Research Institutes of ICAR and several voluntary centres. Since the 1960s, the Project was elevated to Directorate of Rice Research in 1975 with an added mandate of research on irrigated rice. CRRI was entrusted with research on rainfed rice.

India's rice production has improved with the use of better rice varieties, more precise nutrient management practices, and improved irrigation infrastructure, among other factors. However, erratic monsoons and extreme weather patterns especially in rainfed areas are proving increasingly challenging to the millions of rice farmers in India, not to mention of climate change related impacts on crop growing in general and rice in particular. So far, more than 800 High Yielding Rice Varieties have been developed for different ecosystems with CRRI contributing 84 high yielding rice varieties for various ecologies that include three hybrids and five aromatic rice varieties. Many SAUs and state Govt. departments have renowned identified dedicated rice research centres like TNRRI, Aduthurai, APRRI, Maruteru, and CNRRI, Chinsurah. The very recent entry of the private sector in product development is an additional opportunity to expand partnership beyond the public sector.

Achieving further high yield in rice is possible given that India's yields are lower and only 47% of the total rice area is under irrigation. Rainfed rice area covers 52% of the total rice lands and contributes to 36.5% of the country's rice production. Less fertile soils, pests and diseases, faulty cropping patterns and lack of options for re-educating the farmers to use advanced or new technologies also add to low rice productivity in rainfed areas of the country. Rice contains a tremendous array of genetic diversity that scientists all over the world have only just begun to explore and exploit. Statistics reveal that nearly 40 percent of potential yield remains untapped, thus underlining the need to increase the present production levels. For this, India needs to bridge the yield gap through modern agricultural practices, new breeding tools including Marker Assisted Selection (MAS), exploiting new genetic resources, biotechnology and cultivation of hybrid rice.*

CRRI 2030

In view of the increasing demand of rice foreseen for the future in the backdrop of changing global trade scenario, decreasing natural resource base and impending climate change, rice research for the next 20 years needs to be reshaped and reoriented to convincingly meet the emerging challenges. Advent of latest scientific breakthroughs and techniques in the field of biology and molecular biology and biotechnology would effectively support such endeavors. The goal, mission, mandate and the research focus of CRRI for 2030 and beyond are developed based on such expectations.

GOAL

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

MISSION

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

MANDATE

- Conduct basic, applied and adaptive research on crop improvement and resource management for increasing and stabilizing rice productivity in rain fed rice ecosystems with special emphasis on rainfed ecosystem and the related abiotic stresses.
- 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, socio-economic 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 ecology, ecosystems, farming situations and comprehensive rice statistics for the country as a whole in relation to their potential productivity and profitability.

- Impart training to rice research workers, trainers and subject matter/extension specialists on improved rice production and rice-based cropping and farming systems.
- Collect and maintain information on all aspects of rice and rice-based cropping and farming systems in the country.

FOCUS

With a view to accomplish the vision and goal of the institute, the CRRRI constantly enriches its genetic resources by tapping the biodiversity and utilizes them for breeding rice varieties with higher yield potential, better grain quality and increased tolerance to diseases and pests utilizing traditional and innovative technologies. Capacity building of human resources including scientists, farmers and other stakeholders is always a priority for us, so as to be globally competitive and ensure food and nutritional security of the country. Research emphasis lies on developing climate-resilient rice production technology and conservation agriculture to address the problems of drought, flood, salinity and high temperature stress in rice cultivation. Newer molecules for disease and pest control including bio-pesticides and integrated pest management (IPM) are other area of focus at the institute. Management of rice related knowledge, with due attention on extension services and fostering linkages and collaborations with public, private, national and international organizations are other important areas on which the research in the institute is focused.✽

Harnessing Science

It is essential to harness the available rice knowledge to enhance the rice productivity, tolerance of the crop to abiotic and biotic stresses and the grain and nutritional quality to meet future demand of rice in the domestic and international markets. Issues related to input use efficiency, sustainable management of rice-based production systems, post harvest losses and value addition would continue to be addressed with the availability of newer research techniques, tools and technologies. The growing population demands a reorientation of the research efforts in rice based agricultural production systems to ensure higher productivity with less land, less water, and less labor, with environment-friendly technologies that are more resilient to climate change and minimize environmental footprints.

Harnessing genetic diversity to widen the horizons of productivity and quality

Multiple facets of rice genetic diversity from the molecular to the phenotyping is essential for effective conservation and use to meet both present and future needs. The increase in rice productivity in last few decades has been possible mainly because of the emphasis on collection, identification and utilization of rice germplasm from various ecologies and their utilization in breeding program. However, thousands of yet undiscovered genes can potentially benefit rice productivity and quality and the basic approach is to improve the conservation, characterization and use the global rice gene pool for varietal development. The institute has over 30,000 rice germplasm in its gene bank which forms the repository of various useful traits that can be transferred to newly developed varieties. Research will facilitate effective use of available genetic resources through (i) characterizing genetic diversity and sourcing novel gene pools, (ii) mining genetic and allelic diversity with informatics support for gene discovery, (iii) genetic enhancement and pre-breeding to confer stress tolerance and enhanced nutrition, and (iv) molecular breeding through tools like marker-assisted breeding and gene pyramiding.

Power of biotechnology

Recent advances in functional genomics and bioinformatics have opened up new vistas to undertake customized genetic engineering, keeping intact other characters. The complete genome sequence of rice having been achieved, it is now open to the scientists to incorporate required changes with relative ease. While existing transgenic research will be strengthened and field potential of developed lines will be tested through large-scale field testing, power of biotechnology would help in redesigning the rice plant for greater productivity for the future through (i) transgenic breeding for incorporation of genes for improving yield, resistance/tolerance against biotic/abiotic stresses and grain quality to cater to national and international markets, (ii) development of herbicide-tolerant transgenic rice as an input to direct-seeded rice growing under conservation agriculture, (iii) development of transgenic rice with nutrient acquisition properties like P-uptake and utilization and mining of essential macro- and micronutrients with genes sourced from the microbial world.

Apomixis in rice

Introducing/inducing apomixis in rice using introgression, mutagenesis and genomic approaches through diverse species germplasm as well as interspecific hybrids, using efficient screening techniques, such as embryo-sac (ES) clearing and flow cytometric seed screening (FCSS) would enable researchers to explore the role of apomixis 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 understanding their expression in rice. Genomics approach would include genetic engineering 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 through hybridization approaches.

Hybrid rice research

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 introgressing 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. While this institute has developed and released three rice hybrids, viz., Ajay, Rajalaxmi, and CRHR-32 for irrigated and coastal shallow lowlands, there is need to further strengthen the area of research inducing qualitative improvement like grain quality to cater to the consumer preference and tradability. Efficient and economic hybrid seed production is the key for the successful exploitation of hybrid rice in the country and more research effort is needed in this very important aspect of hybrid rice.



Rice hybrids developed by CRRI, Cuttack

Doubled haploid breeding

Doubled haploid breeding is an innovative and attractive approach to shorten the breeding cycle through production of homozygous doubled haploid recombinant lines in a single step thus saving time, labor, cost and space. CRRI

has progressed much in this area through refinement of protocols and using the new protocols, the Institute has produced a large number of anther derived plants and released two varieties after the mandatory multi-location evaluation. The method is also highly useful in purification of parental lines (A, B, R lines) of hybrid rice that can have a great impact in production of more productive uniform hybrid rice varieties in the near future.

Synergies of frontier sciences

The CRRI has already been using the frontier sciences such as nanotechnology (for controlled delivery of pesticides), information and communication technology for dissemination of information to stakeholders and geographic information system (GIS) as an integral part of some of the research projects to ensure high output from research. The same is likely to continue in future also.

Natural resource management

Producing more from less resource including land, water and nutrients will be the keyword for future agricultural production including that of rice. Potential of conservation agriculture including zero or minimum tillage, direct-seeded rice, precision agriculture, site-specific nutrient management (SSNM), system of rice intensification (SRI), aerobic rice etc. through utilization of decision-support system will enable both the farmers and the scientists to maximize rice yield. Also, closing the energy cycle through recycling crop residues and organic farming would result into sustainable development in soil physico-chemical status to get a right balance of productivity, growth and reduced environmental footprint.

Management of energy and agricultural waste

Profitable use of rice farming residues to produce energy, fertilizer, edible fat, and industrial raw material can contribute to overall energy security of the country. While ongoing research program on development of energy-efficient technologies like rice husk stove, solar rice bran stabilizer and solar drier for paddy grains and other crops, and biogas plants for utilization of animal excreta will be strengthened, project on power generation from biogas produced from cow dung for use in farm operations to ensure effective utilization of waste will be strengthened. Recycling and enrichment of rice straw and husk through

windrow composting and vermi-composting are important research agenda that is required to be integrated with high temperature tolerant actinobacteria and other polymer-degrading soil microbes.

Farm mechanization

In view of the labor shortage and the need to reduce cost of cultivation, mechanization of rice farming is to be followed at each step of farm operation. In this direction, (i) development and



Manual transplanter developed by CRRI, Cuttack

promotion of extensive use of tractor operated rotavator and power tiller (ii) power tiller operated seed drill, and tractor operated seed drill for dry seeding and drum seeder for wet seeding with lower seed-rate and (iii) self propelled 4 row 'mat' type transplanter and self-propelled power weeder perfected for extensive application, are priority research agenda.



Seed drill designed and developed by CRRRI, Cuttack

Post harvest and value addition

Total estimated losses of rice in post harvest process run over 10-37% and cutting post harvest losses could presumably add a sizeable quantity to the global food supply. Useful by-products such as broken rice, bran and husk are obtained during secondary processing of milled rice. Some of the value added products from these by-products are: rice floor from broken rice, edible oil/cake from rice bran and the husk as carbon/silica source. The tertiary processing includes conversion of milled rice to ready to eat food products like flaked rice, puffed rice, quick cooking rice, fortified rice, rice cake etc.

Due to change in the eating habits of both rural and urban population, a possible shift from the traditional use of rice as cooked food to some modern recipes is anticipated. The nutritional benefits of brown rice and germinated brown rice (GBR) are well known. Brown rice is rich in vitamin B₁, B₂, B₃, B₆ and iron as compared to polished white rice. Brown rice can be stored well in hermetic storage or freezing condition. Studies on *indica* varieties for quick cooking brown rice, crisp brown rice and GBR will be strengthened. The broken rice, a low value material, can be converted into several value added products like rice noodles, vermicelli, rice starch, rice flour and rice ethanol. Rice flour can also be used for production of rice analog (whole grain shaped pasta product) in conjunction with protein materials (wheat gluten, black gram flour, and gelatin) as functional supplements.

Bio-fortification

Zinc is essential for survival and is known to be required for more body function than any other mineral while iron deficiency is known to retard physical growth and mental development of children. Iron deficiency anemia is a major cause of women's death during child birth among the poor population. Bio-fortified foods including rice can reach millions of malnourished rural population who generally have limited access to commercially marketed fortified foods and supplements. CRRRI has identified rice germplasm containing more than 20 ppm Fe and more than 50ppm Zn in unpolished rice that are being used in the breeding program with a view to develop iron/zinc rich high yielding rice varieties. The target values for grain iron and zinc in polished rice are 13 and 24 ?g.g⁻¹ respectively. This is a cost effective one time investment process and does

not require continual financial outlays as required for traditional supplementation and fortification programs. Transgenic approaches incorporating 'ferritin' gene for Fe and genes for carotenoids driven by endosperm specific promoters could be a better solution for developing lines with high Fe or pro-vitamin A.

Rice production and climate Change

Global climate change has potential for grave consequences because of its potential threat to rice productivity and, consequently food security. Land-use



Open-top Chamber for studies on the impact of high CO_2 and temperature

systems in India are highly vulnerable to climate change and have only marginal capacity to withstand its impact. Conditions for rice production will deteriorate in many parts of India through water shortages, low water quality, thermal stress, floods and in the coastal areas, sea-level rise and more intense tropical cyclones. A 15% decrease in irrigated rice yields in developing countries and a 12% increase in rice price is anticipated as a result of climate change by 2050. It is feared that a 20% decline in rice yields can occur in North-West India due to elevated CO_2 levels and temperature as well as lack of water. In the low-lying deltas and coastal areas of India, like Ganga, Godavari and Cauvery deltas, similar decline in rice production is anticipated due to climate change impacted sea-level rises and associated intrusion of saline water.



Eddy covariance for continuous monitoring of the ambient CO_2 concentration

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Moreover, flooded intensively managed paddy releases large amounts of methane and more diversified rice-based cropping system emits less methane but more nitrous oxide and carbon dioxide – all the three gases having huge footprints in the global greenhouse gas (GHG) budget. On the positive side, of course rice cultivation favors C-sequestration.

Thus, climate change impacts demands (i) adjustments in our rice production methods and development of new rice strains that can withstand higher temperatures, (ii) grow multiple stress tolerant varieties that can integrate in future climate change

situations, (iii) adopt rice-based cropping system that is environment-friendly and have least environmental footprint and (iv) develop cultivation practices to maintain natural resource base and soil health for a sustainable rice production.

Developing C₄ rice

Rice and wheat assimilate atmospheric CO₂ by the less-efficient C3 pathway of photosynthesis and at the same time lose net carbon gain and productivity by as much as 40% through photorespiration. This renders C3 plants less competitive to crops like maize and sugarcane that have evolved a biochemical “CO₂ pump” – the C4 pathway of photosynthesis, to concentrate atmospheric CO₂ in the leaf and overcome photorespiration. Construction of C4 rice in which the 3-carbon metabolic pathway of photosynthesis as present in rice plants is converted into a C4 one is a blue-sky research concept. C4 rice is expected to increase rice yields dramatically, as high as 50%, independent of the rice-growing environment while using water or fertilizer up to 30% more efficiently. Thus, our research work envisages engineering the C₄ traits in rice to enhance its productivity.

While the metabolic components already exist in C3 rice plants, the anatomical and biochemical features of C4 plants must be understood and transferred to C3 plants. The C₄ photosynthetic system has given us the indication that it may be experimentally feasible to genetically engineer all C₄ genes in single cell of C₃ plants i.e. rice to enhance its photosynthetic activity and productivity. This may lead to improved CO₂ concentrating mechanism in a single cell favoring carboxylation and thus C4-ness.

Transfer of technology

While it is important to continuously strive to develop new and efficient technologies, their effective delivery would ensure bridging the gap between the potential and effective implementation. In the changed scenario of 2030, the extension system of the country would be required to address rice farmers' concerns in a systematic, holistic and specific manner in addition to the support of the state departments and the KVKs. The rice farmer would not only require to be provided with the knowledge about the technology but also linkages with input supply agencies and marketing channels. CRRRI will have major role of strengthening the extension system by providing support at national level through (i) Internet (maintenance of rice portal), (ii) extension advisory service supported by mobile phone based SMSs and MMSs (iii) Training through Virtual Classrooms, (iv) audio-video presentation of production technologies for the farmers and farmwomen to view and learn, (v)



Seed-storage bins distributed among tribal farmers

CRRI Designed Demonstration (CDD) and (vi) CRRI Entrepreneurial Module (CEM) for capacity building of potential agricultural entrepreneurs.

Institutional mechanism and policies

India can occupy 1st position in world rice production, provided appropriate policies and institutional mechanisms are implemented. In this context, (i) identification of areas having high potential growth, (ii) necessary policies to expand irrigation facility in terms of minor irrigation and bore well schemes and (iii) policy and program especially for the high potential growth areas can work wonders once these areas are located precisely and institutional arrangements to implement the policies are worked out in advance. Besides these, the institute is expected to provide policy inputs related to rice growing and marketing.*

Issues, Strategies and Framework

Rainfed rice research issues being highly divergent, call for concerted research efforts for specific farming situations. Problems of rain fed uplands being distinctly different from those of rain fed lowlands, the plant type for rain fed uplands, management of plant population, weeds, water and soil need separate considerations. The rainfed shallow lands can benefit by research on irrigated lands as both are similar to some extent. However, shallow lowlands differ in certain major aspects like possible drought at any part of crop growth, submergence at initial stages, low light at different periods of crop growth, specific pest and disease problems and difficulty in controlling them due to unpredictable weather. Therefore, the irrigated rice technology requires modification and fine tuning for these specific needs.

Out of 44.6 million hectares of total rice area in India, upland rice occupies 7.1 million hectares of which 6.2 million hectares are located in Eastern India. Moisture stress at critical stages of crop growth, lack of resistance/tolerance to diseases, insects, severe weed growth, inadequate plant population and low nutrient status of soil are responsible for low yields under such situations. For the lands where water stands above 30 cm and up to about 75 cm depth during major period of crop growth, almost an altered plant type and matching technologies are required. This group of lands require a separate research effort. The next group of lands where water stands at 75 cm to 1.5 meters (deep and very deep water) and more than 1.5 meters (floating rice) also require separate consideration.

Varietal development still remains the major strategy for increasing production and productivity of upland rice ecosystem. Extra early to early duration, early seedling vigour and semi-tall characters can help to tackle the problems. Gene pyramiding for built-in tolerance to biotic stresses will help in stabilizing the yields. The Central Rice Research Institute has so far developed 17 high yielding rice varieties for this ecosystem. Extra early varieties like Heera, Dhala Heera and Sneha maturing 68-75 days were found suitable for low rainfall drought prone areas, while early varieties namely Kalinga-III, Vanaprabha, Neela, Annada, Vandana, Anjali, Virendra, CR dhan 40, Sadabahar and Sahbhagi dhan maturing in 85-105 days have become already popular in high rainfall rainfed uplands. Harvesting of rain water, fertilizer management, better crop stand and intercropping of rice with legumes and other short duration crops as an insurance against erratic rainfall will help in maximizing production.

For the rain fed uplands the varietal development programme profitably utilised the concept of extra-earliness. These varieties starting from 60 days to less than 90 days showed a promise of 2.5 to 4.0 t/ha. In addition, these efforts also had a pay-off for pre- and post-flood crops of rice. These varieties are grown during the assured rainfall period of an area and hence escape drought. However, tolerance to drought was incorporated to some extent in the variety Vandana. Hence the work on drought tolerance coupled with higher yield, resistance/tolerance to blast, brown spot, stem borer and *gundhi* bug will have to be intensified based on the leads obtained so far.

Incorporation of weed competitiveness in upland rice varieties, management of weeds through replacement of broadcast method with line sowing and use of improved weeders are the strategies to be pursued vigorously.

The research on irrigated rice shall continue to focus on breaking the existing yield barriers and sustaining such high yields through pyramiding the resistance genes for biotic stresses. Improved management of costly inputs like nutrient, water and pest control chemicals is crucial to raise and stabilize production. The rice grown under rain fed shallow lands, which are also favourable for production, requires incorporation of moderate photosensitivity and tolerance to BLB, blast, sheath blight, tungro, stem borer and gall midge.

The major requirement of semi-deep lands where water stands up to 75 cm for the major period of crop growth require semi-tall, stiff-culmed, photosensitive and thermo-tolerant varieties of 155-180 days duration with sheath elongation character. In this situation, pests and diseases like BLB, tungro, yellow stem borer, caseworm and cutworm need to be controlled, in addition to solving soil problems like iron toxicity and zinc deficiency. Crop stand, nutrient management coastal salinity etc. are other researchable issues. These lands also offer excellent opportunity to increase cropping intensity by utilizing residual moisture and augment farmer's income through rice-fish prawn culture. The deep water and floating rices require a different strategy. So far new leads have not been received and the major effort centres on collection of germplasm, its evaluation and hybridization. The varieties require submergence tolerance, elongation ability, tolerance to yellow stem borers, nematodes and weeds. There is also scope to improve fish production from these areas. In general tremendous scope exists for basic and strategic researches in the entire rain fed systems and use of modern tools of genetic engineering, biotechnology, simulation modelling, remote sensing etc. to improve production/productivity.

The researchable issues relating to crop production, economic viability and environmental quality improvement are enormous in rainfed systems. To address such issues, capital-intensive research efforts are necessary, to help generate capital saving technologies for resource poor farmers. Besides, the input intensive technology options could also be made available for progressive farmers.*

Epilogue

Rice is life for almost half of the global population and majority of the Indian people. The living and livelihood of majority of the Indian farming population also depends on growing rice. Rice production increased almost three fold over the last five decades and contributes handsomely to the nutritional security of the country. While green revolution brought productivity increase and regional food surpluses as far as rice is concerned, it also created huge negative environmental footprint. Climatic change casts a huge shadow in the horizon of agricultural productivity. Erratic monsoon behaviour also affects the grain production, especially in rainfed areas which occupy 62% of the total rice area of the country. A variety of factors including (i) declining yields and less land, water and labour, (ii) effects of economic growth, (iii) pressure on land use, and (iv) climate change, threatens future rice production.

On the brighter side, rice contains a tremendous array of genetic diversity that scientists have only just begun to explore. And this huge genetic diversity also empowers rice to remain productive in environments where most other crops would fail. Rice production systems are unique and the longevity of rice farming speaks for itself. In fact, given to itself, the overall environmental footprint for rice would remain only subtle. However, with the population growth maintaining a northward progress, increasing production remains the sacred duty of all the stakeholders associated with rice.

Whichever way rice is looked at—quantity, productivity, value of produce, number of farmers, number of consumers, affordability to the common man or dietary importance – it will retain the dominant feature in the nutritional and agricultural landscape of many developed and developing countries in the foreseeable future. With further area expansion being unlikely and also traditional rice-growing areas being lost to industry and urbanization, rice yield must increase faster than in the recent past, because in most of the developing world including India, rice availability is equated with food security and social serenity. It is the endeavour of the Central Rice Research Institute to undertake research and development to produce more, augment farmers' income, conserve natural resource base and increase value addition so that the future generation can have a mouthful of nutritious rice.✽

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Annexure 1 : Strategic framework

Goal	Approach	Performance measure
Harnessing genetic diversity	Gene mining from rice germplasm for identification of new and highly efficient alleles for different abiotic/ biotic stresses	Alleles for different abiotic and biotic stresses mined
	Phenomics, proteomics and metabolomics of multiple abiotic/biotic stress tolerance for functional characterization of stress tolerance with special emphasis on drought and submergence	Genotypes evaluated and characterized
	Designing and developing new plant types (NPT) and super rice hybrids for increased productivity in rainfed areas	Breeding lines developed
Accelerating development of improved rice genotype	Development of resource efficient crop varieties including nutrient and water	Resource efficient breeding lines developed
	Host-parasite/pathogen interaction at molecular level including QTL identification to design suitable control strategy	Genetic basis of resistance identified and designed
	Intensification of source of tolerance to nematode pests of rice	Resistant lines developed
Increasing the productivity, sustainability and resilience of rice-based production systems	Development of direct seeded rice (DSR) technology for rainfed conditions including production technology and mechanization Integrated cropping system innovations for future intensive rice production systems to optimize carrying capacity of production systems	Resource efficient crop production technologies developed
	Promoting resource conservation agro-technologies for increasing adaptability of rice production system and restoration of soil organic-C pool under changing climatic conditions	Climate resilient production technologies developed

Contd....

Goal	Approach	Performance measure
Enhance opportunities for inclusive growth	Climate change impacts on the emergence of minor pests and diseases into major ones and their management	Improved livelihood opportunities developed
	Enhance ecological resilience for pest and disease control IPM Strategies for rice pest/pathogen complex	
	Improving livelihood options through exploitation of short-grained aromatic rice	
	Ensuring nutrition security through research on nutrient-dense and fortified rice through innovative approaches	
	Post-harvest and value addition technologies developed to improve supply-chain efficiency	
Policy and technology intervention for improved rice production and marketing	Develop demand driven, high-value products like rice alcohol, fast foods	Competitiveness of rice production system enhanced
	Technologies and business models for improved rice marketing	
	Strategic foresight, priority setting and impact assessment of rice research in India on a global perspective	
	Technology transfer using innovative extension approaches	
Cutting edge technology for rice production beyond 2050	Impact analysis of climate change and rice productivity from socio-economic perspective	Development of C-4 and N ₂ -fixing rice
	Redesigning rice plants for improving photosynthesis and plant productivity under multiple abiotic stressful environment	
	Rice physiology and biochemistry under high CO ₂ , ozone and temperature for defining climate resilient rice cultivars	
	Develop N ₂ -fixing rice	

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