Training Programme

on

Contribution of ICAR-NRRI in Rice Research and Development in India

(June 6-12, 2019)

Training Manual

ICAR- National Rice Research Institute
(An ISO 9001:2015 Certified Institute)
Cuttack 753006, Odisha, India
Training Programme

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Contribution of ICAR-NRRI in Rice Research and Development in India

June 6-12, 2019
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Course Directors
N. N. Jambhulkar
S. K. Mishra
J. P. Bisen

Head, Social Sciences Division
G. A. K. Kumar

Director
H. Pathak

ICAR-National Rice Research Institute
Cuttack - 753 006, Odisha, India
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National Agricultural Research System: An Overview

The Indian Council of Agricultural Research (ICAR) is an autonomous organisation under the Department of Agricultural Research and Education (DARE), Ministry of Agriculture and Farmers Welfare, Government of India. Formerly known as Imperial Council of Agricultural Research, it was established on 16 July 1929 as a registered society under the Societies Registration Act, 1860 in pursuance of the report of the Royal Commission on Agriculture. The ICAR has its headquarters at New Delhi. The Council is the apex body for coordinating, guiding and managing research and education in agriculture including horticulture, fisheries and animal sciences in the entire country. With 102 ICAR institutes (ICAR-NRRI being one of them) and 73 agricultural universities spread across the country this is one of the largest National Agricultural Research Systems in the world.

The ICAR has played a pioneering role in ushering Green Revolution and subsequent developments in agriculture in India through its research and technology development that has enabled the country to increase the production of foodgrains by 5.4 times, horticultural crops by 10.1 times, fish by 15.2 times, milk 9.7 times and eggs 48.1 times since 1951 to 2017, thus making a visible impact on the national food and nutritional security. It has played a major role in promoting excellence in higher education in agriculture. It is engaged in cutting edge areas of science and technology development and its scientists are internationally acknowledged in their fields. While the ICAR Institutes have the Departments of Extension, the Agricultural Universities have the directorates of extension to identify, test and refine the transferable agricultural technologies and other related information emanating from research as well as to establish effective liaison among various departments and other stakeholders both the public and private for their transfer.

To ensure effective transfer of the technologies and scientific information related to the farm sector to the farmers, line departments and other end users at the district level, the Indian Council of Agricultural Research (ICAR) has established a network of 706 Krishi Vigyan Kendras (KVKs) in the country. The KVKs are mandated to conduct frontline extension through the assessment and demonstration of technologies/products and its dissemination through number of extension programmes including training of farmers through specific training programmes developed by KVKs on improved technologies related to agriculture and allied fields, benefiting the farmers in terms of increased crop production as well as farm income. To coordinate, monitor and implement the activities by KVKs in their respective zone, 11 Agricultural Technology Application Research Institutes (ATARIs) have been setup at zonal level. At state level, the responsibility of coordination and monitoring is with Directors of Extension of State Agricultural Universities in coordination with ATARI. For effective monitoring of mandated activities of KVKs, a local monitoring committee at State Agricultural University level is formed. The Quarterly review of KVKs is done by Vice-Chancellor of
respective SAUs to monitor the technical, administrative, financial and developmental activities. KVKs conduct one Scientific Advisory Committee meeting every year to monitor the progress of technical, administrative, financial and developmental activities.

The KVKs function in close harmony and partnership with all developmental agencies/organizations, farmers and other stakeholders. KVKs also provide technological backstopping to ‘Agriculture Technology Management Agencies’ (ATMA), a scheme funded by the Department of Agriculture Cooperation and Farmers Welfare (DAC&FW) and other agencies at the district level. A district level Joint Action Plan for enhancing interface between scientists, extension functionaries and farmers is prepared through a joint meeting of KVK and ATMA officials under the chairmanship of the District Collector. A quarterly interface meeting, involving all line departments of the district, is held by all KVKs to monitor the implementation of the Joint Action Plan and to share new information and technologies for wider dissemination in the district.

The Indian Council of Agricultural Research also maintains effective linkages with other key programs of the Government of India like RKVY, MNREGA and NHM and other extension activities including those related to public sector, farmers’ organizations, NGOs, Commodity Boards and private sector. ICAR contributes through technology backstopping in the National Rabi and Kharif conferences organized every year in which extension agencies from all the states also participate. Besides, the Agricultural Technology Information Centres (ATIC) are also established at various ICAR Institutes and Agricultural Universities which function as “single window” support system linking various units of a research institution with intermediary users and end users (farmers). They provide advisories, inputs and diagnostic services for soil and water testing, plant and livestock health as well as provide information through published literature and communication materials as well as audio-visual aids.

Rice is Life

Rice is the staple food of more than fifty per cent of people around the globe and more than two-thirds of Indians. Worldwide the crop is grown in an area of 170 million ha with a production of 475 million tonnes of milled rice. India ranks first in terms of area (43 million ha) and second in terms of production (113 million tonnes) in the World. Therefore, all round development of the crop in a sustainable way is important for the benefit of mankind.

Introduction: ICAR-NRRI

The ICAR-National Rice Research Institute (formerly Central Rice Research Institute) was established in 1946 at Cuttack, as an aftermath of the great Bengal famine in 1943, for a consolidated approach to rice research in India. The administrative control of the Institute was subsequently transferred to the Indian Council of Agricultural Research (ICAR) in 1966. The Institute has three research stations, namely at Hazaribag in Jharkhand, Gerua in Assam and Naira in Andhra Pradesh. The NRRI regional station, Hazaribag was established to tackle the problems of rainfed uplands, the regional station, Gerua for problems in rainfed lowlands and flood-prone ecologies and the regional station, Naira was established for solving problems associated with coastal rice ecologies. Two Krishi Vigyan Kendras (KVKs) also function under the NRRI, one at Santhapur in Cuttack district of Odisha and the other at Jainagar in Koderma district of Jharkhand. The research policies of the Institute are guided by the recommendations of the Research Advisory Committee (RAC), the Quinquennial Review Team (QRT) and the
Institute Research Council (IRC). The NRRI also has an Institute Management Committee (IMC), for formulating administrative policies.

**Vision:** To ensure sustainable food and nutritional security and equitable prosperity of our Nation through rice science.

**Goal:** To ensure food and nutritional security of the present and future generations of the rice producers and consumers.

**Mission:** 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**

- 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.

Major Themes of Research Programmes

- Programme 1: Genetic improvement of rice
- Programme 2: Enhancing the productivity, sustainability and resilience of rice based production system
- Programme 3: Rice pests and diseases-emerging problems and their management
- Programme 4: Biochemistry and physiology of rice in relation to grain and nutritional quality, photosynthetic efficiency and abiotic stress tolerance
- Programme 5: Socio economic research and extension for rice in development

NRRI for the First Time

- Developed two high protein rice varieties in the world in 2016 – CR Dhan 310 with 10.5% grain protein and CR Dhan 311 with 10.1% grain protein content.
- Developed a set of primary trisomics in the background of Sona and Ratna.
- Started the japonica x indica hybridization programme 1952 which led to the development/release of ADT-27 (1952) & Mahsuri and Malinja (1955) and Cirncana (Australia) varieties.
- Identified Oryza longistaminata, which is a source for many resistance genes including ‘Xa21’ for bacterial blight resistance.
- Gave a new lead for the development of semi-tall, profuse tillering and low input efficient varieties suitable for rainfed lowland systems. CR 1009, first variety to be released at national level during 1983 for rainfed lowlands became popular in India (Odisha, Tamil Nadu, Andhra Pradesh etc.) and other countries like Burundi and Sri Lanka.
- Pioneer to develop and release high yielding indica rice varieties in India through anther culture approach.
- Developed and released first long duration (114-145 days) hybrid CR Dhan 701 (CRHR-32) for irrigated & shallow lowlands of Bihar & Gujarat.

Technologies for Various Stakeholders

- Credit of releasing 132 rice varieties in a span of 73 years.
- Our most popular varieties are Pooja, Durga, Sarala, Gayatri, Savitri, Vandana, Anjali, Geetanjali, Naveen, Ajay, Varshadhan, Sahabhadhan and Hazardhan.
- Three hybrid varieties Ajay, Rajalaxmi and CR Dhan 701 to meet the needs of Indian Farmers.
- Short grain aromatic rice for higher income (Geetanjali, Ketekijoha, Chinikamini, Nua Kalajeera, Nua Dhusara).
- Varieties for all ecosystems and major stress conditions.
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<td>Upland</td>
<td>Phalguni, Virendra, Hazardhan, Sadabahar, Anjali, Vandana, Heera, Kalinga-III, CR Dhan 100(Satyabhama), Sahabhagi Dhan, CR Dhan 40(Kamesh), Annada</td>
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<tr>
<td>Aerobic Rice</td>
<td>CR Dhan 204, CR Dhan 202, CR Dhan 201, CR Dhan 200(Pyari)</td>
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<td>Irrigated</td>
<td>Ajay, Rajalaxmi, Naveen, Geetanjali, Tapaswini, Shatadhi, Abhishek, Chandrama, CR Dhan 305, CR Dhan 304, CR Dhan 303, CR Dhan 300, Improved Lalat, Improved Tapaswini, CR Dhan 801(Phalguni), CR Dhan 10(Satyakrishna), Khitish</td>
</tr>
<tr>
<td>Shallow Rainfed Lowland</td>
<td>Swarna sub-1, Ketekijoha, Nua Dhusara, Nua Kalajeera, Nua Chinikamini, Pooja, Padmini, Savitri, CR Dhan 401(Reeta)</td>
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<td>Medium Deep water logged</td>
<td>Varshadhan, Durga, Sarala, Gayatri, Moti, Tulasi, Panidhan, CR Dhan 503(Jayantidhan), CR Dhan 500</td>
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<tr>
<td>Coastal Saline</td>
<td>Lunishree, CR Dhan 403 (Luna Suvarna), CR Dhan 402 (Luna Sampad), Sonamani, CR Dhan 406 (Luna Barial), CR Dhan 405 (Luna Sankhi)</td>
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<td>Boro/Dry Season Rice</td>
<td>CR Dhan 601, CR Boro Dhan 2 (Chanadan)</td>
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<td>Hybrid Rice</td>
<td>Ajay, Rajalaxmi, CR Dhan 701 (CRHR 32)</td>
</tr>
<tr>
<td>Aromatic Rice</td>
<td>CR Sungadh Dhan 907, CR Sungadh Dhan 902, Nua Chinikamini, Nua Kalajeera, Nua Dhusara, Geetanjali</td>
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<td>Climate Smart Varieties</td>
<td>(Tolerant to both submergence and drought) CR Dhan 800, CR Dhan 801 and CR Dhan 802 (Subhas)</td>
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<td>High Protein Rice</td>
<td>(With more than 10.0% grain protein content) CR Dhan 310, CR Dhan 311 (Mukul)</td>
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- Integrated Crop Management practices, involving the application of best management practices such as planting young seedlings, judicious use of water and nutrient, integrated pest management and the like.
- Organic Rice cultivation a holistic system of crop production utilizing local resources at affordable prices that maintains a relatively pollution free environment providing food of higher nutritional quality, has been standardized.
- Aerobic Rice - Appropriate varieties have been identified and its method of cultivation has been demonstrated.
- Leaf Colour Chart (LCC) developed by the institute has been found effective for need based nitrogen management in rice.
- Integrated Nutrient Management (INM) - A combined use of various sources of nutrients viz., chemical, organic and bio-fertilizers have been formulated to increase crop production and the productivity. Use of organic manures (FYM, green manures, azolla, poultry manure etc.) in conjunction with chemical fertilizers was found to be attractive.
- Rice-fish diversified farming system and multitier rice-fish-horticulture based farming system for increasing farm productivity, income, employment, sustainability and household food and nutritional security developed. The net income is around 82,000 per ha in the 1st year, which increase to 1,30,000 or more in the 6th year (Rice-fish diversified farming system)
farming system). The net income in this system is around 1,00,000/ha in the first year and this will increase to 1,50,000 or more from the eighth year onwards (Multitier rice-fish-horticulture based farming system).

- Developed several various low cost, labour saving and improved agricultural implements such as rice husk stove, manual 4-row rice transplanter, drum seeder, multicrop bullock and tractor drawn seed drill, flat disc harrow, finger weeder, cono star weeder, mini parboiler and power threshers with the sole aim of reducing both drudgery and cost of rice cultivation.

- Wet direct-shown rice – Direct seeding, using a drum seeder, is one of the methods of crop establishment. Trials conducted on direct wet seeding of irrigated and rainfed lowland rice crops by using NRRI developed drum seeder showed promising results.

- Azolla bio-fertilizer for rice – Aquatic fern Azolla is promising nitrogen-fixing biofertilizer for rice. It adds adequate organic matter and improves soil fertility and soil health. It also checks weed growth, enhances efficiency as applied chemical N fertilizer and reduces environmental pollution. Azolla increases rice yields by 1-2 t/ha, and is suitable for rice varieties of all durations.

- Evaluated, developed and tested several plant products with pesticide potential against field and storage insects and pathogens.

- Identified biochemical and biophysical parameters for submergence and other abiotic stress tolerance in rice.

- ITK-based botanicals such as Neem (Azadirachta indica), Karanja (Pongamia pinnata), Kochila (Strychnos nux-vomica), Water Pepper (Polygonum hydropiper), Parasi (Cleistanthus collinus) and Wild Sugarcane (Saccharum spontaneum) etc. were validated and refined for higher efficacy and user-friendly applications.

- Developed crop modelling of G x E interaction studies that showed that simulation of crop growth under various environments could be realistic under both irrigated and favourable lowland situations.

- Developed suitable rice production technologies for rainfed uplands, lowlands and irrigated ecology including production technologies for hybrid rice and scented rice that were field tested and transferred to farmers.

- For commercialization of NRRI rice hybrids and other technologies namely agricultural implements and Customized Leaf Colour Chart (CLCC), institute signed 17 MoUs with private seed companies.

- Eleven NRRI varieties were registered with PPV&FR Authority and 17 more were submitted as new application.

- During the year 2014, 99 research papers were published by NRRI scientists, out of which were in journals with NAAS rating > 7.0.

**Outreach Programmes**

The NRRI through its KVKs and various collaborative projects interacts with the farmers for testing newer technologies that improves the livelihood of the farmers and makes the rice production systems more remunerative. The institute plays a major role in strengthening the extension system by providing support at national and state levels through internet (maintenance of rice portal), extension advisory service, trainers training, audio-video presentation of production technologies for the farmers and farmwomen to review and learn.
Also the institute publishes quarterly Newsletters, Annual Report and Technology Bulletins regularly to provide information on research achievements. The institute showcased its technologies in different exhibitions.

- Evaluated and popularized its varieties through frontline demonstrations (FLDs) in farmers’ fields.
- Provided farmers’ advisory service through regular radio talks and TV telecasts on rice production technologies.
- Developed 15 training modules for farmers and extension workers.
- Imparted short-term and long-term training for personnel from the State Departments of Agriculture, State Agricultural Universities (SAUs) and other educational institutions.
- Institute succeeded in implementing the 'Participatory Seed Production' programme for the 3rd year in row, in Mahanga, Odisha. Near about 57 tons of seed of NRRI varieties, mainly of the popular variety Pooja, were produced during the year.
- Institute Foundation Day, Agriculture Education Day, Farmers Innovators Day, ICAR-SAUs-State Departments Interface Meet etc. are organized regularly for effective coordination among stakeholders involved in sustainable rice production.

The State-of-the-art Facilities

The institute obtained the ISO-9001:2015 certification for quality management system. The State-of-the-art facilities include: Oryza museum, Gene bank, Transgenic laboratory, Genomics and Quality Testing Laboratory, Biotechnology laboratory, High temperature wind tunnels, Salinity screening facility, Open top chambers for CO\textsubscript{2} enrichment study, Maintains more than 30,000 accessions of rice germplasm including nearly 6,000 accessions of Assam Rice Collection (ARC) and 5,000 accessions from Odisha. Compiled Passport information on more than 30,000 germplasm, Data base on various aspects of rice, Auditorium with over 500 capacity, Conference Hall, Guest Houses, Students Hostel (Girls & Boys) etc.

Important Awards

- Govt. of India Award 2015 for contribution for bringing India’s Green Revolution in 1965-66.
- Mahindra Samridhi India Agri Award 2013 for release of varieties like CR Dhan 701 and Sahabhadhan
- Think Odisha Leadership Award for Educational Institute of Excellence 2011 by The Times of India and Tefla’s for its path-breaking rice research that led to the development of various technologies for the upliftment of farmers
- Sardar Patel Outstanding ICAR Institution Award 2008 for Outstanding Contribution in the field of Agricultural Research and Extension

Consultancy

The institute has a strong force of experienced scientists and other researchers with expertise in diversified disciplines. The institute has been offering consultancies and advisory services to the public sectors all over the country and abroad on different technologies related to rice grain quality, post harvest technology, new agricultural chemicals, soil/plant sample analysis, genetic purity analysis, project preparation, project evaluation etc. Besides these, the institute conducts customized training programmes as per the requirements of various state agriculture departments, NGOs, Central Government organizations.
**Academic Scope / Human Resource Development Program**

The scientists of the Central Rice Research Institute have been playing an important role in developing quality Human Resources by training students and staffs of several Universities of India and abroad. These trainings are imparted in the field of Biotechnology, Genetics, Genomics, Molecular Breeding and Bioinformatics, Cytogenetics, Plant Breeding, Economic Botany, Seed technology; Agronomy, Fisheries, Microbiology, Soil Science, Agricultural Chemistry and Soil Microbiology, Agricultural Engineering including Food technology; Biochemistry, Plant Physiology, Environmental Sciences; Plant Pathology, Entomology, Nematology, Agricultural Chemicals, Statistics, Economics and Extension including Home Science covering various aspects of rice research, within the mandate of NRRI. These trainings are structured under the following three categories:

- HRD program for six months duration (provision for dissertation for M.Sc./M. Tech./M.Phil./ equivalent degree).
- HRD program for three years (with provision to work for Ph.D. degree).
- HRD training for up to six months (no provision for degree/diploma).

**Linkages**

The NRRI has linkages with several national and international organizations such as the Council for Scientific and Industrial Research (CSIR), Indian Space Research Organization (ISRO), SAUs, State Departments of Agriculture, and the institutes of the Consultative Group for International Agricultural Research (CGIAR), such as the International Rice Research Institute (IRRI), Philippines and International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Hyderabad.

**Contact:**

The Director, ICAR-National Rice Research Institute, Cuttck-753006, Odisha, India  
Phone: +91-671-2367768-83 / Fax: +91-671-2367663, Email: director.nrri@icar.gov.in / directorcrricuttack@gmail.com, Website: http://www.icar-nrri.in
An Overview of ICAR-NRRI

Social Science Division, ICAR-NRRI, Cuttack

Introduction
India has the world's largest area and is the second highest producer of rice. The crop is grown under varying climatic and soil conditions under diverse ecologies spread over about 43 million hectares. The crop is cultivated round the year in one or the other parts of the country. It is the staple food for more than two thirds of Indian population contributing more than 40% to the total food grain production, thereby, occupies a pivotal role in the food and livelihood security of people. During the last decades, significant advancements have been made on developing high yielding and disease-resistant rice varieties and production technologies for different ecologies. The country, so far has released about 1200 varieties. Several viable rice production technologies have also been developed for adoption in the farmers' fields. Along with increasing the productivity, emphasis has been given on developing varieties with improved stress-tolerance and nutritional quality to ensure food and nutritional security for the large section of the population depending on rice as staple food. Currently, about 85% of rice area is covered with high-yielding varieties. With the concerted efforts of researchers, farmers, extension agencies and policy-makers, the country is harvesting about 110 million tons (Mt) in last few years. Almost all the states of the country are now self-sufficient in rice. Rice has now become foreign exchange earner as the country exports about 10 Mt of rice annually.

Origin of CRRI/NRRI
The outbreak of devastating epiphytotic brown spot disease of rice (*Helminthosporium* spp) in the then Bengal province (the areas of which are now in the state of West Bengal and Bangladesh) in 1942 resulted in a serious shortage of rice, resulted in a disastrous situation called the Great Bengal Famine of 1943. With this background, the Central Government, in the year 1944, decided to intensify research on all aspects of rice crop. In the following year, the Government decided to establish a Central Institute for Rice Research and this culminated in the establishment of the Central Rice Research Institute (CRRI) on April 23, 1946 at Bidyadharpur, Cuttack, Odisha. Dr. K Ramiah, an eminent rice breeder, was its founder Director. Subsequently, in 1966, the administrative control of the Institute was transferred to the Indian Council of Agricultural Research (ICAR). NRRI is one of the institutes of ICAR under Crop Science Division.
**Mandate of the Institute**

The institute not only played a key role in ushering the country in an era of green revolution heading to self-sufficiency in food grain supply in about 25 years from its inception, but also brought glory to the nation by providing research support to rice crop, thus becoming the second largest exporter of rice in the world in the recent years.

The overall goal of the Institute is to improve the income and quality of life of rice farmers in India. With this goal the following objectives were set for the Institute:

- 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 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.

The Institute has five divisions in various disciplines i.e. Crop Improvement Division, Crop Production Division, Crop Protection Division, Crop Physiology and Biochemistry Division; and Social Sciences Division.

**Crop Improvement Division**
The Crop Improvement Division is engaged in basic, strategic and applied research for genetic improvement of rice besides knowledge generation on relevant aspects. The division undertakes research on varietal improvement through various means along with research on taxonomy, plant genetic resources, classical genetics, cytogenetics, mutagenesis, in-vitro culture, bioinformatics, genomics etc. of rice. Molecular marker assisted breeding has now become an integral part of crop improvement programme of the division. Till date, 129 pureline varieties and 03 hybrids have been released for different rice ecologies of India. Nucleus and breeder seed of the released varieties are produced for all the released varieties as per the indent received from the Department of Agriculture and Cooperation, Government of India.

**Crop Production Division**

The Crop Production Division is engaged primarily in applied, strategic and basic research on effective and eco-friendly utilization of natural resources like soil, water, nutrient, labour, etc. Division also focuses on managing abiotic and biotic stresses for sustainability, productivity and profitability of rice production system. The division undertakes research on enhancing resource use efficiency with special emphasis on water and nutrients, resource conservation technology on rice and rice based systems, weed management, exploration of microbial technology for enhancement of production and productivity in rice and rice based systems. The division is also involved in designing, developing and evaluating rice based farming system for enhancing profitability and ensuring livelihood support. Design and development of farm machinery for small farmers, value addition and post-harvest technology, etc. is also a major area of research. Climate resilient agricultural technologies, greenhouse gas emission-mitigation and ecosystem service estimation have now become an integral part of research programme of the division. Till date more than 40 crop production technologies and more than 25 farm machineries for different ecologies have been developed and validated by the division.

**Crop Protection Division**

The Crop Protection Division is conducting applied, strategic and basic research on integrated management of rice pest to improve productivity, quality and profitability from rice cultivation. The division is engaged in different aspects of rice protection sciences, e.g. exploration of new sources of resistance for insect pest and diseases of rice, bio-ecology of rice insect pest and diseases for climate smart protection strategies; bio-intensive approaches for pest management in rice and optimization of chemical pesticide-use for management of rice pest in different
ecosystems. Major thrust has been given on multiple pest resistance genotypes, pest modelling and forecasting, tri-trophic interaction of rice, pest and predators/parasites under climate change, novel molecules and formulations for eco-friendly pest management and stored grain pest management. The work on host plant resistance and its mechanism, bio-ecology and epidemiology of rice pest, integrated pest management has been recognised worldwide. The division is also involved in designing, validating and popularizing pest and ecology based IPM modules for the farmers to ensure profitability.

**Crop Physiology and Biochemistry**

The division has identified several rice germplasm with higher protein and micronutrient content in the past and contributed to development of high protein and high zinc rice varieties from NRRI. Several germplasm with tolerance to drought, submergence, salinity, high temperature, low light and those with multiple abiotic stress tolerance have been identified and evaluated, some of which are already in use for developing abiotic stress tolerant varieties. The research program of the Division is aimed at identifying and developing rice varieties with desirable grain and nutritional quality traits, tolerance to various abiotic stresses and improving photosynthetic efficiency of rice keeping in view the changing climate scenario.

**Social Science Division**

The division of social sciences under takes broadly the socio-economic research pertaining to rice development. Characterization of resources, socio-economic and institutional constraint analysis, creation and maintenance of database are the major research activities. Besides, the division is engaged in capacity building of stakeholders, dissemination of rice production technologies through publications, advisory services, exhibition, workshop, interface, special days etc. Findings emanating from the various research projects have been used in developing policies, programmes, models and approaches for sustainable rice production.

The Institute has three regional research stations, one at Hazaribag, Jharkhand for carrying out rice research on rainfed upland ecologies, second at Gerua, Assam for carrying out rice research on flood prone rainfed lowland ecologies and the third one at Naira, Srikakulam, Andhra Pradesh for carrying out the research on coastal ecologies. Two Krishi Vigyan Kendras (KVKs) also function under the administrative control of NRRI. The KVKs are located at Santhapur, Cuttack, Odisha and Jainagar, Koderma, Jharkhand.
ICAR-NRRI-Central Rainfed Upland Rice Research Station (CRURRS) Hazaribag, Jharkhand

Central Rainfed Upland Rice Research Station (CRURRS) was established in Hazaribag of Jharkhand state in 1980 with specific mandate of catering to the need of improved technology for enhancing rice based agricultural productivity of rainfed uplands which covers about 13.5% rice growing area of India. Rainfed uplands are mostly located in the eastern parts of the country covering the states of Bihar, Jharkhand, Odisha, West Bengal, Assam, parts of Madhya Pradesh and Uttar Pradesh. Rainfed uplands in India are characterized by aerobic to semi aerobic soils conditions, absence of surface water accumulation, dependence on monsoon having erratic distribution, plain to slopping topography. These characters make the target ecology very much prone to unpredictable drought situations at various crop growth phases and a few biotic stresses, of which some of them are accentuated under drought stress.

Mandate of CRURRS, Hazaribag

- To develop suitable technologies to increase rice productivity and sustainability through applied and strategic research and to disseminate them.
- To collect, maintain and evaluate dryland rice germplasm.
- To characterize dryland rice situations and develop mixed and sequence cropping.

Thrust Area of Research:

- To breed resilient high yielding rice varieties suitable for drought-prone rainfed uplands
- To strategize management options for sustainable rice production under direct seeded rainfed ecology
- To evolve rice based farming systems for drought prone rainfed ecology
- To develop biotic stress management strategies for rainfed upland rice

Varieties of CRURRS

- For favorable uplands: Vandana, Anjali, CR Dhan 40, Purna & CR Dhan 103
- For unfavorable uplands: Sadabahar, Sahbhagidhan&Gangavatagi
- For drought-prone shallow lowlands: Hazaridhan, Abhishek & IR 64-Drt1
- For upland: Anjali & Vandana
- For medium land: IR64Sub1

ICAR-NRRI-Regional Rainfed Lowland Rice Research Station (RRLRRS) Gerua, Assam

Rice contributes 95% of the total food grain production in the state of Assam and cultivated in three main seasons, viz. Ahu (February-March to June-July), Sali (June-July to November-December) and Boro (November-December to April-May). Of these three seasons, Sali occupies more area, which is flood prone. More than 23 districts suffers from
flood chronically, which affects the productivity of rice severely and shrink total production of the state. In order to develop suitable high yielding varieties and production technology, specially for flood prone lowlands a Regional Rain-fed Lowland Rice Research Station (RRLRRS) as a sub-station under ICAR-NRRI was established on September 15, 1997 in Gerua in the Hajo circle of the Kamrup district of Assam.

**Mandate of RRLRRS**

- To conduct basic, strategic, applied and adaptive research on crop improvement, production and protection for increasing and stabilizing rice productivity in rainfed lowland ecosystem.
- To cater to the research needs and requirements of rice farmers, of flood-prone lowland areas invariably affected by flash floods.
- To explore, evaluate, conserve and exchange rice germplasm.
- To develop high yielding and input responsive rice varieties resistant/tolerant to different biotic and abiotic stresses under rainfed lowland ecosystem.
- To generate appropriate agronomic and protection technologies for increasing and sustaining the productivity of rice-based production systems under rainfed lowland ecosystem.
- To import training to the farmers, field functionaries, extension specialists and research workers on improved rice production, rice-based cropping and farming systems.

**Trust Area of Research:**

- Strengthening the breeding strategy to evolve suitable *Sali* varieties with tolerant to flood.
- Development of short duration varieties with blast resistance and cold tolerance for *Boro* season.
- Evolution of HYV as pre-flood *Ahu* and post-flood *Sali* situations.
- Development of flood resistant rice varieties for lowland, semi-deep and deep water conditions.
- Development of appropriate integrated insect pest and disease management strategies.
- Development of strategies to avoid crop submergence through suitable cultural practices for both intermediate and semi-deep conditions.

**Varieties of RRLRRS**

- Released rice variety ‘Chandrama’ as *Boro* and *Sali* for Assam.
- Released aromatic high yielding rice variety ‘CR Dhan 909’ as *Sali* crop for Assam, Bihar, Maharashtra and UP for irrigated and rainfed lowland ecology.

**ICAR-NRRI-Coastal Regional Rice Research Station (RCRRS) Naira, Srikakulam, Andhra Pradesh**
ICAR-National Rice Research Institute, Cuttack has initiated steps to establish its Regional Station (Coastal Regional Rice Research Station) in the campus of one of its constituent College of Agriculture (Acharya NG Ranga Agricultural University (ANGRAU), Naira in Srikakulam district of Andhra Pradesh in 2017, to cater to the needs of the rice growers of coastal regions. Looking to the research in the fragile coastal ecology with high frequency of flood and drought, the Regional Station in Naira (AP) will focus on the rice research for rainfed coastal ecosystem.

**Mandate of RCRRS, Naira**

- To develop climate resilient varieties resistant/tolerant to biotic stresses suitable for coastal rice ecosystem.
- To explore, evaluate, conserve and exchange rice germplasm.
- To generate appropriate production and protection technologies for rice and rice based production systems suitable for coastal ecosystem for increasing and sustaining productivity and income.
- To impart training to rice stakeholders on improved rice production technology and rice based farming systems suitable for coastal ecosystem through extension methods and tools.

**Krishi Vigyan Kendra (KVK) Santhapur, Cuttack**

The Krishi Vigyan Kendra Cuttack was established at Santhapur, Cuttack on 14 November 1992. The KVK Cuttack, Santhapur is functioning under ICAR-National Rice Research Institute, Cuttack with the financial assistance from ICAR, Govt. of India since 1992 with a view to propagate latest technology in the agrarian sector among the farmers of the district to improve the socio-economic status.

**Mandate of KVK Cuttack**

- Assessment and refinement of technology through location specific on-farm testing in farmer’s perspective
- Frontline Demonstration of advanced technologies, varieties, inputs and others
- Vocational training to framers, farm women and rural youth
- In-service training to the grass root level extension officials on specified technologies for updating the knowledge, skill and attitude

**Krishi Vigyan Kendra (KVK) Koderma**

The Krishi Vigyan Kendra (KVK), Koderma (Jharkhand) is under the administrative control of ICAR - National Rice Research Institute, Cuttack, Odisha through it’s unit Central Rainfed Upland Rice research Station at Hazaribag, Jharkhand and started functioning on 7th February
2005 with the mandate of “Technology Assessment and Demonstration for its Application and Capacity Development”.

Objectives
Krishi Vigyan Kendra performs its activities as per the mandate set by the ICAR, New Delhi. Objectives of the KVK are as follows:
To organize on and off campus training programmes for farmers, rural women, youth, and officers of the Department of Agriculture to make them aware about the latest technologies in agriculture.

- To organize short and long term vocational training courses on vegetable, floriculture, beekeeping, dairying, mushroom, organic farming and protective cultivation etc. for rural youth for self-employment.
- To arrange conduct front-line demonstrations and on-farm trials at farmer’s fields on improved technologies and refinement of existing technology so as to suit the need of the farmer.

Activities of KVK, Koderma

- On-farm testing to identify the location specificity of agricultural technologies under various farming systems.
- Front-line demonstrations to establish production potentials of technologies on the farmers’ fields.
- Training of farmers to update their knowledge and skills in modern agricultural technologies.
- Training of extension personnel to orient them in the frontier areas of technology development.
- Training of Rural youth for income generation.
- Act as resource and knowledge centre of agricultural technology for supporting initiatives of public, private and voluntary sector for improving the agricultural economy of the district.

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Broadening Gene Pool of Rice through Wide Hybridization
Lotan Kumar Bose
ICAR-National Rice Research Institute, Crop Improvement Division, Cuttack, Orissa, India
e-mail: lotankbose@yahoo.com

Abstract
Variability in the cultivated germplasm for economic traits such as resistance to rice tungro virus, sheath blight, yellow stem borer, drought and salt tolerance is limited. This necessitated search for the genes in secondary and tertiary gene pool of genus *Oryza*. Fortunately, wild species are an important reservoir of useful genes for resistance to major disease, pests and tolerance to abiotic stresses. Wide hybridization in *Oryza* is normally difficult to achieve because many wild species of genus *Oryza* are difficult to cross with cultivated rice because of difference in chromosome number or genetic constitution. Fertilization may occur, but the embryo is aborted. Embryo rescue is used to maintain the hybrid embryos and F1s through several cycles of back crosses until fertility is restored. Interspecific hybridization has been attempted by a number of workers and resulting hybrids and progenies have been used for taxonomic and phylogenetic analysis with limited efforts to transfer desirable traits from wild species to cultivated rice. Transfer of grassy stunt virus resistance from one accession of *O. nivara* has been achieved successfully. Another species belonging to the AA genome, *O. longistaminata* has been exploited for transfer bacterial blight resistance gene to cultivated rice. Wild species with genomes non-homologous to the AA genome of *O. sativa* such as *O. officinalis*(CC), *O. australiensis*(EE) and *O. minuta*(BBCC) possessing resistance to brown planthopper , white backed planthopper, bacterial blight and blast have been used to transfer these desirable alien traits to cultivated rice. Therefore, wide hybridization is one of the key component in programme aiming at transferring alien genes from diverse sources surmounting sexual barriers. Advances in embryo rescue, anther culture, chromosome engineering and genetics have facilitated in the transfer of genes and in precise monitoring and characterization of alien introgression from different genomes of *Oryza* into cultivated rice. Integrating conventional breeding with advanced methods of alien introgression offers great potent to develop disease and insect resistant varieties.

Keywords : *Oryza sativa*, Wide hybridization, Integrated pest management, Amphidiploidy, Anuploidy, *in vitro*, Brown planthopper, White backed planthopper Bacterial blight, Yellow stem borer, Green leaf hopper, Cytoplasmic male sterility
**Introduction:**

Integrated Pest Management is a broad ecological pest control approach aiming at best mix of all known pest population below economic threshold level. It is a dynamic concept and sustainable system of crop protection that leads to maximum productivity with the least possible adverse impact on the total environment. Improvements in plant breeding techniques in present century have resulted in increased yield and solve many problems associated with diseases, insects, harvest and quality. The plant breeders have, historically, utilized the variability in land races for selection and improvement of crops. The variability and germplasm resources available for many cultivated varieties are becoming extremely limited (Harlan, 1976). As additional genetic resources are required to enrich the germplasm, unique and imaginative procedures are required to exploit fully the potential of our crop plants. Utilization of wild species (Sen et al., 2005, Nayak et al., 1996, Sahu, et al., 1994, Bose et al., 1990), therefore, is one method designed to introduce additional germplasm into cultivated varieties (Stalker, 1980).

**Why wide hybridization:**

During last few decades, considerable attention has centered round the importance of wild species in plant breeding. The interest in wild species and primitive cultivars has been strengthened through FAO's pioneer work on genetic resources of crop plants, as well as, by the concerted efforts of many national and international crop research centers in promoting gene bank activities. It is also due, in no small measures, to breeders clear needs for a wider genetic base from wild germplasm to help and solve problems of resistance to diseases, pests and a greater range of environmental adaptation, better yields and better nutritional and economic characters in the plants concerned.

**Wild species of Oryza and its Importance:**

The genus *Oryza* consists of about twenty wild (Sampath, 1961; Tateoka, 1964; Vaughan, 1989) and two cultivated species. The common cultivated rice *Oryza sativa* is distributed world wide while the African cultivated rice *Oryza glaberrima* is confined to West Africa only. Most of the wild species have similar genomes (AA) as that of *O. sativa* and *O. glaberrima*, other distantly related species have BB, CC, BBCC, CCDD, EE, FF, GG, HHJJ and HHKK genomes (Khush, 2004). Comprehensive list of potential wild species available in the genus *Oryza*, their genome, distribution along with their reaction to biotic and abiotic stresses are presented to reinstate the genetic diversity of the species into the rice-breeding program (Table-1).

**Table-1. TAXA IN THE GENUS ORYZA: GENOME AND USEFUL TRAITS**

<table>
<thead>
<tr>
<th>Wild Species</th>
<th>Genome</th>
<th>Distribution</th>
<th>Useful Traits</th>
</tr>
</thead>
</table>

18
| **O. sativa** | AA | World Wide | Cultigen |
| **O. glaberrima** | A³A⁴ | Primarily West Africa | Cultigen |
| **O. nivara** | AA | Tropical Asia | Resistance to grassy stunt virus and blast |
| **O. rufipogon** | AA | Tropical Asia and Australia | Tolerance of acid sulphate soils and stagnant flooding, source of CMS |
| **O. barthii** | A³A⁵ | Tropical Africa | Resistance to bacterial leaf blight |
| **O. longistaminata** | A¹A¹ | Tropical Africa | Floral characteristics for out crossing |
| **O. glumaepatula** | A⁰A² | Central and South America | Deep water rice |
| **O. meridionalis** | A⁸A² | Tropical Australia | Drought avoidance |
| **O. punctata** | BB, BBCC | Tropical Africa | Multiple pest resistance |
| **O. officinalis** | CC | Tropical Asia, Papua New Guinea | Resistance to BPH, GLH and WBPH |
| **O. rhizomatis** | CC | Sri Lanka | Drought resistance |
| **O. eichingeri** | CC | Sri Lanka, Tropical Africa | Resistance to BPH, GLH and WBPH |
| **O. minuta** | BBCC | Philippines | Resistance to BPH, GLH and WBPH, blast and bacterial leaf blight |
| **O. latifolia** | CCDD | Central and South America | High biomass production |
| **O. grandiglumis** | CCDD | Central and South America | High biomass production |
| **O. australiensis** | EE | Tropical Australia | Resistance to BPH and drought |
| **O. brachyantha** | FF | Papua New Guinea, Tropical Africa | Resistance to stem borer and rice whorl maggot |
| **O. ridleyi** | HHJJ | South East Asia, Papua New Guinea | Resistance to rice whorl maggot, bacterial leaf blight and blast |
| **O. longiglumis** | HHJJ | Indonesia, Papua New Guinea | Resistance to bacterial leaf blight and blast |
| **O. granulata** | GG | Tropical Asia | Shade tolerance |
| **Porteresia coarctata** | HHKK | Tropical Asia | Tolerance to salinity |

**BPH**: Brown planthopper, **GLH**: Green leaf hopper, **WBPH**: White backed planthopper, **CMS**: Cytoplasmic male sterility


Several pre and post-fertilization barriers to crossibility are known to limit the production of hybrids between distantly related species. Different approaches have been explored to overcome pre-fertilization barriers and also recent studies have pointed out the potential application of embryo, ovule and ovary culture to obtain fertile hybrids (Sen et al., 2005; Jena and Khush, 1989). Although considerable work has been done to produce wide hybrids for taxonomic and phylogenic analysis (Nezu et al., 1960; Wuu et al., 1963; Chu et al., 1969; Tateoka, 1964; Vaughan et al., 1989; Sitch, 1990), limited effort has been made to transfer desirable traits from wild species to cultivated rice. \( O. \) \( sativa \) \( f. \) \( spontanea \) source of the wild abortive (WA) male sterile cytoplasm, which, is successfully exploited for hybrid rice production in China and in other hybrid rice breeding programs (Lin and Yuan, 1980). Two notable example include the transfer of a gene for resistance to grassy stunt virus from \( O. \) \( nivara \) (Khush et al., 1977) and the transfer of a gene for resistance to BB from \( O. \) \( longistaminata \) (Khush et al., 1990). More recently (Jena and Khush, 1989, 1990; Multani et al., 1994) develop monosomic alien
addition lines of *O. sativa* having alien chromosome of *O. officinalis*, *O. australinsis* and locate the genes for resistance to BPH, WBPH and BB from *O. officinalis* and *O. australinsis* to cultivated rice. (Amante et al., 1991) also transferred genes for resistance to blast and BB from *O. minuta* to cultivated rice (Table-2).

**Table-2. Successful transfer of alien genes in rice through MAALS/Back crossing**

<table>
<thead>
<tr>
<th>Introgression lines through</th>
<th>Donor species used With accession No.</th>
<th>Recipient cultivar</th>
<th>Genes for</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAALS</td>
<td><em>O. australiensis</em> (100882)</td>
<td>IR 31917-45-3-2</td>
<td>BPH, BB</td>
<td>Jena &amp; Khush, 1990</td>
</tr>
<tr>
<td>MAALS</td>
<td><em>O. officinalis</em> (100896)</td>
<td>IR 31917-45-3-2</td>
<td>BPH, WBPH</td>
<td>Multani et al., 1994</td>
</tr>
<tr>
<td>MAALS</td>
<td><em>O. punctata</em> (W 1514)</td>
<td>Nipponbare</td>
<td>-</td>
<td>Yasui &amp; Iwata, 1991</td>
</tr>
<tr>
<td>Back crossing</td>
<td><em>O. nivara</em> (101508)</td>
<td>IR 24</td>
<td>GSV</td>
<td>Khush &amp; Ling, 1974</td>
</tr>
<tr>
<td>Back crossing</td>
<td><em>O. longistaminata</em></td>
<td>IR 24</td>
<td>BB</td>
<td>Khush et al., 1990</td>
</tr>
<tr>
<td>Back crossing</td>
<td><em>O. glaberrima</em> (TOQ 5674, TOQ 5681)</td>
<td>ITA 212</td>
<td>RYMoV</td>
<td>Matsuo et al., 1997</td>
</tr>
<tr>
<td>Back crossing</td>
<td><em>O. minuta</em> (101141)</td>
<td>IR 31917-45-3-2</td>
<td>Blast, BB</td>
<td>Amante-Bordeos et al., 1991</td>
</tr>
<tr>
<td>Somaclonal variation</td>
<td><em>O. eichingeri</em> (RN 1041)</td>
<td>Swarnaprabha</td>
<td>BPH, WBPH</td>
<td>Sen et al., (2005)</td>
</tr>
</tbody>
</table>

**Disease and pest resistance:**

The most common reason for wide hybridization is to transfer disease resistance when the resistance source in the cultivated gene pool becomes inadequate, the most valuable genes conditioning disease resistance are found in species distantly related to the cultigen with which interspecific hybrids are difficult to make. Further genes conditioning resistance that would justify interspecific transfer often behave as monogenic dominant genes for immunity or very high resistance (Clayton, 1954). Horizontal resistance is often desirable but transferring such gene complex to the cultigen requires very long time. Major diseases of rice are BB, blast, tungro (RTD) and Sh.B, which affect rice productivity. Breeding for resistance to many of these have been achieved using resistance source from cultivated germplasm. However, like Sh.B effective sources of resistance are not present in primary gene pool and in this regard wild species of *Oryza* might be extremely useful in providing alien genes for transfer into elite rice varieties. Similarly the insect species that cause severe damage to rice are stem borer, green leafhopper, BPH and gall midge. Though resistant varieties for these have been developed, the emergence of new biotypes often cause serious threat to rice crop and hence, there is need to continue incorporation of genes from diverse sources (Khush, 1971; Brar and Khush, 1997).
Conclusion:
In the foregoing review an attempt was made to put together the information available on various areas of wide hybridization, which is assuming special significance in present days. The main interest in wide hybridization is to select genotypes possessing a very limited alien chromatin material, hence precise methods are required in monitoring such introgression. In rice, chromosome and isozyme analyses are the commonly used methods for characterization of wide cross progenies. Recently, molecular markers such as RFLP and genome specific DNA probes have been available which offer potential to facilitate monitoring of alien gene introgression. The choice of a particular method like alien addition lines, anther culture, somaclonal variation and recombinant DNA technology for alien gene transfer through wide hybridization depends upon genomic relationship, extent of chromosome pairing and recombination between the genomes of the alien wild and cultivated species. If there is no restriction on chromosome pairing and recombination in wide hybrids, direct hybridization and backcrossing to the recurrent cultivated parent are followed. When the chromosomes of wide cross hybrids do not pair certain chromosome manipulation techniques like alien addition lines, alien substitution lines, induced homoeologous pairing and amphiploids are utilized.

References:
Rice-based Integrated Farming Systems for livelihood security under scenario of climate change

Dr. B. S. Satapathy and Dr. A. Poonam
ICAR-National Rice Research Institute, Cuttack, Odisha

Farming in our country is mainly dependant on south west and north east monsoon. The uncertainty and vagarious nature of monsoon makes the rainfed farming more vulnerable and risky and this is more pronounced under scenario of climate change. Majority of the farmers of India belongs to small and marginal categories and farming is the main source of their family income. It becomes difficult for small and marginal farmers to sustain their livelihood with the single farm enterprise unless resorting to integrated farming system (IFS) for the generation of sufficient income and year round employment with in their small farms (Mahapatra, 1992). Rice is the leading food crop and rice-based cropping system is the backbone of Indian Agriculture. Rice-based farming system involving rice-based cropping system and horticultural crops, agro-forestry, fishery, poultry, diary, goatery and other income generation enterprises like apiary, mushroom, sericulture and vermin-composting etc. will be the right approach to meet the demand of food, nutrition and livelihood security of individual house hold. Integrated farming is the one of the viable option which can take care of increasing demand for food as well as environmental safety.

What is integrated farming system?

Farming system may be defined as a positive interaction of two or more components within the farm boundaries to increase productivity of the farm and to enhance the income of the far family in a sustainable way. An inter-related set of enterprises are integrated in such a manner that the “waste” from one component becomes an input for another part of the system, which reduces cost and improves production and income. With the adoption of resource-saving practices not only achieves high and sustained production levels but it also minimizes the negative effects of intensive farming and preserving the Environment. The goals of IFS are to sustain agricultural production, maintain farm incomes, safeguard the environment and respond to consumer concerns about food quality issues. Integrated farming is an ideal agricultural system with the principle of management and utilization of agriculture biomass and organic waste.

An appropriate combinations of available and adoptable different agricultural enterprises like crop, dairy, poultry, piggery, fishery, sericulture etc. suited to the given agro-
climatic conditions and socio-economic status of the farmers would bring prosperity in the farming. Major features of integrated farming system are; i) by-product or waste recycling, a by-product of one component which otherwise may have been wasted become an input to other component, ii) efficient utilization of space by multiple cropping. The main benefits of the system are i) higher and stable farm productivity, ii) better diet for farm family, iii) more cash flow and income, iv) better employment v) less risk (biological and economic), vi) environment friendly and vii) optimum resource utilization. Integrated farming system thus can ensure food, nutritional and household security on sustainable way under the changing climate scenario.

Concept of farming system:

The Farming System, as a concept, takes into account the components of soil, water, crops, livestock, labour, capital, energy and other resources with the farm family at the centre managing agricultural and related activities. The farm family functions within the limitations of its capability and resources, the socio-cultural setting, and the interaction of these components with the physical, biological and economic factors. The term "farming system" refers to a particular arrangement of farming enterprises that are managed in response to physical, biological and socio-economic environment and in accordance with farmer’s goals, preferences and resources. “The household, its resources and the resource flows and interactions at the individual farm levels are together referred to as a farm system” (FAO, 2001).

Farming system focus on;

• The interdependencies between components under the control of household and,
• How these components interact with the physical, biological and socio-economic factors, which is not under the control of household.
• Farm household is the basic unit of farming system and interdependent farming enterprises carried out on the farm.
• Farmers are subjected to many socio-economic, bio-physical, institutional, administrative and technological constraints.
• The operator of the farming system is farmer or the farming family.

Types of farming system

(1) Indigenous farming systems (2) Modern integrated farming systems

(1) Indigenous rice-based farming systems in India

Traditional rice-based farming system is ecologically sound and based on need of the society. India is rich in traditional farming systems and practiced in different regions rich in biodiversity and managed on community basis for sustainable food security and environmental
safety. Different location specific indigenous rice-based faring system practices in various parts of the country described below.

(1.1) **Rice-based farming system of Apatanis:**

The Apatani community inhabited in the Apatani plateau of the Lower Subansiri district of Arunachal Pradesh follows rice-based farming system in traditional manner. The rice-based farming system of the Apatanis includes *kharif* rice cultivation in terrace land with integration of fish and conservation of forest areas around them. The farmers grow local tall rice during rainy season on terraces and finger millets on the terrace bunds. Fishes like common carp were reared concurrently along with the paddy in the terraces. The rice + fish farming purely based on-farm natural resources like biodegradable waste and inputs without using any chemical fertilizer and pesticides. Recycling of agricultural wastes is the main process of nutrient management of the system. Millets on terrace bunds acts as soil erosion barriers and provides some additional nutritional food grains. The system produces 4-5 tons of rice and 150-200 kg of fishes in a season. The economic and energy efficiency of this agro eco-system is higher than sole rice cultivation and meets the demand of the local community (Rai, 2005).

(1.2) **Rice field capture fishery system**

In waterlogged or flooded rice fields, naturally occurring fishes and prawns enter the field during rainy season and grow concurrently in the rice crop. This situation is very common in the flood plain rice fields of Brahmaputra and Barak Valley of Assam (Das, 2002). This is a very common system among the local tribal and fishing community for collecting fish and other aquatic resources from the paddy. In addition to rice, the system produces fish and other aquatic foods to the tune of 45-280kg/ha/season.

(1.3) **Zabo system**

“Zabo” is famous traditional farming system of Nagaland. It has an integration of silviculture, agriculture and animal husbandry based on principles of conservation of soil and water for sustaining the productivity of the system. The system consists of forest crops in catchment area at higher elevation, water harvesting structures at middle and cattle yard and rice fields at lower end. The catchment area is kept under forest cover and serves as water source for water harvesting in ponds and feeding area for domestic cattle, pigs and poultry birds. Farmers grow local tall varieties during *kharif* season. During dry spells water reserved in tank allowed to pass through the cattle yard as supplementary irrigation which also served as fertigation of the rice field. In addition to cattle manures farmers use leaves of Aldar plant as ex-situ green manuring to maintain the soil health of rice field. Majority of the farmers grow fish in their rice field by constructing a pit in the rice field. The system yields 3-3.5 tons of rice
and 60-75 kg of fish per hectare of land in addition to milk, meat, eggs and forest products to meet food and nutritional requirement of the community (Das et al., 2012).

(1.4) Panikheti system of rice cultivation

Rice cultivation in uplands of high rainfall areas of Kohima districts of Nagaland and Sikim are popularly known as Panikheti. The production system consists of natural forest in upper portion of the hill and rice in bench terraces developed in middle and lower region of the hill. Farmers transplant rice seedlings of traditional varieties in puddle soil during June and harvest during October-November. Incorporation of crop residues, weeds and other succulent biomasses available near the field helps in fulfill of nutrition requirement of rice crop and also maintenance of soil health (Das et al., 2009). Farmers never use any chemicals for control of insect pests and diseases. The system produces 2-3 tons ha\(^{-1}\) of rice and forest products.

(1.5) Wild aqua cropping system

The practice of wild aquatic cropping is common in Assam, Manipur and foothills of other hilly states of northeastern India. The system is mostly carried out in lowland and deep water rice fields. Farmers normally grow traditional sali rice or bao rice in lowland and deep water ecosystem respectively. Through runoff water, seeds of aquatic fish and prawns from neighboring water resources enter in to the rice field. In addition to direct capture during the rainy period, the farmers also rear wild aquatic fishes in their rice field. The system in addition to rice also produces wild fishes ranging from around 200-300kg/ha/season.

(1.6) Kaipad rice farming

The Kaipad system of rice cultivation of North Kerala farmers grow local rice during rainy season, followed by salt water prawn in coastal brackish water marshes which is rich in organic matter. In central Kerala it is popularly known as Pokkali (Chandramohan and Mohanan, 2012). The less remunerative rice cultivation compliments a highly profitable prawn culture, making it a unique agro-ecological continuum. The productivity of rice is 0.7-1.0 t/ha and prawn 0.5-2.0t/ha

(1.7) Bhasabandha system in Sundarban of West Bengal

The production system spreads over about 30000 ha in deltas of Sundarban of West Bengal. Farmers cultivate traditional rice varieties during wet season and brackish water fish and prawn during dry season by utilizing the impounded natural brackish water. The system produces 1.0 t of rice ha\(^{-1}\) and 100-200kg ha\(^{-1}\) of fish and prawn.

(2) Improved rice-based farming system:

Rice- based farming system has received great focus in the recent past due to capacity to achieve lively hood security of farm family’s particularly small and marginal farmers of India. Agro ecological and biological diversification and intensification of traditional
systems based on social and environmental sustainability is need of the hour. Sever research institutes have developed location and ecosystem specific several modern rice-based farming systems with high productivity, profitability and environmental safety and are available for adoption.

(2.1) **Rice-duck farming**

The integration of rice cultivation with rearing of duck is not only economically viable but also environmental friendly. The system produces meat and eggs in addition to rice from same unit area of land. The ducks in the rice crop helps in biological control of insect pests as well as weeds which reduces the cost of production. An economic analysis of the integrated rice-duck system registered 50-60% higher net returns per hectare as compared to sole rice. The higher income was due to higher rice yield coupled with reduced cost of production and additional income from duck component (Hossain et al., 2005). In India rice-duck, rice-fish-duck system is common in important rice growing states like Assam, Tripura, West Bengal and other north east states of India.

(2.2) **Rice- Vegetables + mushroom+ poultry**

Study conducted at ICAR-Research complex, Goa revealed that. Integration of rice-brinjal cropping system with back yard poultry and mushroom cultivation with recycling of byproducts of rice like paddy straw, rice bran and broken rice registered highest system productivity of 21487 kg/ha/year of rice equivalent yield with highest net return of Rs.77305/ha and employment generation of 392 MDYS (Manjunath et al 2010). Recycling of paddy straw for mushroom production recorded highest sustainable index (0.75) as compared to other uses.

(2.3) **Rice + fish+ goat+ poultry**

Integrated rice-fish-goat-poultry farming system in one hectare area at Agricultural research Station, Siruguppa, Karnataka comprising field crops in 0.73 ha, 0.06 ha for fishery,30 poultry birds of Giriraj and 12 goats registered 26.3 and 32.3 per cent higher productivity and profitability , respectively over conventional rice-rice system. Employment generation and water requirement was 275 Man days/ha/year (Channabasavanna et al.,2009)

(2.4) **Rice-fish farming**

Integration of fish in to rice culture is an age old practice in South East Asia. FAO identified rice fish system as one of the Globally Important Ingenious Agricultural Heritage System (GIAHS), which appears to be important in present scenario of climate change. Integrated rice fish farming is more efficient in resource utilization, better productivity in terms of both quality and quantity and provides several socioeconomic and environmental benefits (Ahmed and Garnett, 2011). Rice fish culture practice has a long tradition in India.
Out of the 43 million hectares of rice cultivated land in India, about 20 million hectares is suitable for rice fish integration particularly in the flood plain wet lands and semi deep and deep water rice ecologies.

The modern rice fish farming involves a shift from completely farmer based technology to science based technology such as use of improved breeds, better recycling of nutrients and formulated feeds etc. (Das, 2002). The production system varies according to management practices, growing period, field design, composition of fish species and duration of production cycle (Goswami et al., 2004). Community based rice fish culture is technically feasible, more remunerative and socially acceptable. Similarly rice fish farming at individual farmer’s level ensures higher productivity, profitability and employment. Integration of fish with rice increases the productivity of rice (Bramhananda et al., 2009). In this chapter’s attempt is made to describe the few improved rice fish farming system practices in India

**(2.4.1) Fish and prawn seed production in rice field**

Irrigated rice, favourable shallow lowlands and water logged rice fields are suitable for rice-fish seed farming. The irrigated rice-fish seed culture produces 100-300 kg of fish fingerlings per season and to 8-12 t ha$^{-1}$ of rice. In favorable lowland about 4 t ha$^{-1}$ of rice and 100-190 kg of fish seed can be obtained under rainfed situation. Kar et al. (1993) reported that rearing of cat fish (magur) in irrigated and water logged rice fields with raised dykes and refuge can produce 2.8 t of rice and 50000-154500 fry/fingerlings ha$^{-1}$ season$^{-1}$, with additional income of Rs5000-15-450 ha$^{-1}$. Like fish seed production, fresh water prawn seed rearing can be taken in lowland rice ecosystem. Growing of rice prawn nursery after prawn rearing gives additional yield of 1 t ha$^{-1}$ of rice, besides 70% recovery of prawn juveniles with stocking density of 50-150 m$^{-2}$ (Sarangi et al., 2004)

**(2.4.2) Rice-grow-out fish farming**

In general there are 3 types of rice-fish farming (1): synchronous farming (ii) sequence farming and (iii) Relay farming.

**(2.4.2.1) Rice-fish sequential farming**

In sequential farming rice and fish are grown alternately or in sequence in a piece of land. Rice-fish farming in coastal saline areas of West Bengal involves growing of rain fed rice during wet season and a short duration brackish water aquaculture during dry season in sequence. The system produces around 2.3 t ha$^{-1}$ of rice and 1 t of fish (Bhaumic et al 2013). The integration of rice with prawn/fish culture established as economically viable option for best utilization of embanked coastal flood plains min Kuttanad, India (Kurup and Ranjeet, 2004)

**(2.4.3) Rice-fish-prawn system**
In rainfed medium land ecosystem rearing of fish and prawn in rice field registered about 7.9-8.6% increase in rice grain yield due to better aeration of water, greater tillering effect and additional supply of fertilizer in form of leftover feed and fish excreta. Irrespective of stocking density, the system produces about 4.55 t of rice equivalent yield with net profit of Rs. 10781.00 ha\(^{-1}\) (Mahanty et al., 2004). In rice–fish–prawn system the net return enhanced by 23-folds in comparison to rice mono crop with net water productivity of Rs 7.66/m\(^3\) and can be adopted and expanded in lowland/ waterlogged areas. (Mahanty et al 2010)

(2.4.4) Rice-ornamental fish farming

At ICAR-National Rice research Institute, Cuttack a technique of growing ornamental fish in waterlogged rice field has been developed, the system yields 25000-600000 ha\(^{-1}\) of ornamental fish and 3.5 and 5.0 t ha\(^{-1}\) of rice grain during wet and dry season, respectively.

(2.4.5) Rice-fish-Poultry farming system

Integration of rice-fish with poultry registered highest net return of Rs.57687/- and benefit ratio (2.73) at ARS, Sirugupa (Channabasavanna et al., 2002). Results of integrated rice-fish-poultry system demonstrated in 430 farmers field of different locations of Tamil Nadu reveals that the annual income of the individual household by Rs 33000/ to 50000/-/ha/year. Besides that about 11.4 to 19.6 t/ha of poultry dropping added to the system. The system also recorded pest suppression by 17 to 37 % (Srivastava, 2018).

(2.4.6) Rice-fish-vegetable farming system

Assam Agricultural University demonstrated the rice-fish-vegetables farming system in 160 ha ha areas of Lakhimpur, Kokrajhar and Karbi Anglong districts of Assam. The intervention consists of replacement of local rice varieties with high-yielding varieties like Ranjit, Gitesh, Jalashree and integration of composite fish culture in rice fields. Vegetables were grown in the rice field during dry season with residual soil moisture and providing supplementary irrigation by using water stored in pond refuge. Results of the demonstration revealed that system average productivity was 4.6 t ha\(^{-1}\) of rice, fish 41 kg ha\(^{-1}\) and vegetables 1.7 t/ha. The integration helped to increase the individual household income by Rs.29000/- per annum.

(2.4.7) Rice-fish in medium land

Integration of fish in medium land rice with insitu conservation of rain water in the refugee constructed at lower end of rice field enhanced the total productivity and recorded the highest net returns with BC ratio (2.78) as compared to the growing of rice alone. The average fish yield in this system was 1107 kg/ha in six months. The cropping intensity was increased from 100 to 131%. (James et al., 2005). At Ranchi, the improved rice (IR-64) + fish (mixed
carps), wheat (PBW-443) enhanced the net returns (Rs. 58557/ha) as compared to the farmers practice of rice fallow (Rs. 2770/ha) (TAR-IVLP, 2004).

(2.4.8) **Rice-fish system in deep water rice**

Dual culture of rice and fish in deep water rice ecosystem and horticulture in on-dyke is highly remunerative, environmental friendly and generates employment for the farm family. Mahanty et al., 2009 reported that integrated rice-fish-horticulture farming registered rice equivalent yield of 38.5 t ha⁻¹ and net water productivity (7.30/m³) and the system can be adopted and expanded in lowlands and waterlogged areas of Odisha. Rice-fish farming system for lowland rice ecosystem developed at ICAR Research complex, Goa registered 9 t ha⁻¹ of rice in two seasons and 1.25 t ha⁻¹ of fish. Community-based rice-fish farming is technically sound, economically viable and it can increase fish production to about 600 kg/ha/year in shallow flooded areas and 1.5 t/ha/year in deep flooded areas, without reduction in rice and wild fish yield (Dey et al., 2006).

A multitier rice-fish-prawn-horticultural crops- agro-forestry farming system model was developed in 0.6 ha area at ICAR-National Rice Research Institute, Cuttack for deep water rice ecosystem. The system I consist of 4 distant tiers based on land topography (i) tier I and II, covering 15% of area for upland crops followed by rainfed low land rice covering 40% of area (tier iii) and deep water (tier iv). The interventions includes growing of lowland rice in tier iii and deep water rice in tier iv during rainy season, fish in pond refugees, vegetable, fruit, tuber and tree crops in upland. The productivity of the system is about 8 t of rice, 1 t of fish and prawn, 20-25 t of vegetables and 8.5 to 51.7 t ha⁻¹ of tuber crops (Singhababu et al., 2007)

(2.4.9) **Rice + fish + azolla farming system**

In rice monoculture areas integration of rice with fish and azolla is a viable option to enhance the productivity of lowland rice ecosystem. It helps in recycling of nutrients within the system and reduces the cost of production. Integration of fish in to rice ecosystems utilizes the zoo and phytoplankton grown in rice field. Integrated Rice + Azolla + fish farming in Tamil Nadu recorded Rs 8,817/ha more over the rice monoculture (Balusamy et al., 2003)

(2.4.10) **Rice +fish + cattle farming system**

Kumar et al. 2012 tested 7 integrated models in Bihar and found that integration of rice with fish and cattle registered higher rice grain equivalent yield of 18.76 t/ha whereas rice+fish+goat model fetched highest average net return( USD 2655/year), higher sustainability net return (73.1%) with recycling of appreciable quantity of nutrients to the system

(2.5) **Diversified rice-based farming system**
Diversification of existing rice farming systems will help generation of additional income, regular employment to farm family and to improve their dietary standards. A judicious combination of available agricultural enterprises like poultry, duckery, fish, cattle rearing, green manuring, mush room, apiary etc will useful for recycling of nutrients, better efficiency of natural resources and biological control of weed and insect pest in field crops thus helpful in reducing cost of cultivation (Kathiresan, 2007). An adoptable rice-fish diversified farming system for rainfed waterlogged areas developed at ICAR-National Rice Research Institute, Cuttack. The system consists of components of rice in main field, fish in pond refugee, trenches and rice field during rainy season, poultry, duck, and goat in pond dyke. The system facilitates rain water harvesting in an in-built micro-watershed and its subsequent use for farm diversification. Intervention of dry season vegetables in rice field helps in enhancing the cropping intensity. Fruit, silvicultural and vegetables in bunds add more diversification of the system. Under optimum level of management the system produces about 16-18 t of food crops, 0.6 t of fish and prawn, 0.55 t of meat and 8000-12,000 eggs in addition to flowers, fuel wood and rice straw and for animals form one hectare of land. The system generates a net income of Rs55000-130000 along with generation of employment of 250-300 man-days over rice farming (Singhababu et al., 2006). Thus the system increases farm productivity by about 15 times and net income by 20 folds over the traditional rice farming. The technology validated in lowland ecosystem of Odisha and realized higher productivity and profitability over the traditional rice farming. Similarly the technology was refined taking into the consideration soil, weather and social culture of Assam and revalidated at Regional Rainfed Lowland Rice Station, Gerua, Assam for adoption in northeastern region of the country (Rautaray et al., 2005; Satapathy et al., 2014)

(2.6) Rice-based farming system under irrigated ecosystem
Assured irrigation facilities helps in further intensification and diversification of rainfed rice ecologies. A model of rice-based farming system was developed at NRRI, Cuttack with an objective of improvement of livelihood security of small and marginal farmers. The components of the system include rice, fish, horticulture, agro-forestry, mushroom, poultry and duckery. The system produces 800-100kg of rice which is sufficient to meet the staple food need of a farm family. Farm families can earn a sum of Rs.500-1000 from sale of paddy straw. The income from fishery component is Rs.20000 from 0.5 ha area. Pulses, vegetable and fruits grown on field bunds are enough to meet the protein requirement of the farm family (Poonam et al .2015)

Conclusion:
In due course of time climate is changing and its adverse effect on agriculture is already visible. In the chagrining scenario of climate agriculture needs multi-sectoral and multi-agency approach; well planned efforts for achieving sustainable agricultural productivity and profitability without deteriorating the environment. The diversification of existing farming practices with the integration of available suitable farm enterprises so as to increase the input use efficiency, to decrease the cost of production by reuse and recycle of waste/by product of on component as inputs of another component. Most of the constrains in agriculture can be addressed by integration of divers enterprises which will solve most of the existing economic and ecological problems besides increasing profitability by several fold.

References


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Rice (Oryza sativa L.) is one of the most important staple food in India occupying one fourth of the total cropped area contributing around 40% of total food grain production and plays a vital role for the food security in India To feed the increasing population of India the productivity and total food grain production of rice has to be increased. The target can be achieved through numbers of methods like increasing the area of rice crop, increasing productivity, and avoiding the yield loss of rice. Biotic stresses are some major cause of yield loss etc. The introduction of hybrid rice or high yielding varieties have helped the farmers to increase the productivity but diseases still remain a major cause of yield loss. In India, rice is grown in 44.6 mha of which about 40% areas are rainfed low lands. About 14.6mha of rainfed low lands is located in eastern India comprising of Assam, West Bengal, Bihar, Odisha, eastern Madhya Pradesh and eastern Uttar Pradesh. The productivity of rainfed low land rice cultivated as mono-crop is around 1.5t/h due to different abiotic, biotic and socio-economic constraints. Among the biotic stresses fungal, bacterial and viral pathogens are major constrains in achieving the targets in rice production. Numbers of plant pathogenic fungi are responsible for the realization of lower yields than the potential. Some of them are obligate parasites which needs living host to grow and reproduce, but most of them are saprophytic and can survive without the presence of the living plant, in the soil, water or air.

Proper detection and identification of the disease and its causal organism should be taken seriously for management of the disease. It is always better to detect the pathogens at very early stage like in seeds, mother plants, and vegetative parts to be used as propagules to avoid the further spread of the pathogen and eradicate the disease and the entry of the disease in a new area. A disease is an abnormal condition that injures the plant or causes it to function improperly. Diseases can easily be recognized by their symptoms - associated visible changes in the plant. The organism which causes diseases is known as pathogen.

Agents that cause diseases:
The principal agents involved in plant disease are Biotic and Abiotic agents

Animals (Birds, Mammals, Insects, Mites, Slugs, Snails, Nematodes etc)
BIOTIC AGENTS: Microorganisms [Viroids, Viruses, Mycoplasmas (MLOs), Bacteria, Fungi, Protozoa (Flagellates)]
Plants [Angiosperms (Parasitic), Competitors (Weeds)]
Pollutants (Ozone, Nitric oxide, Heavy Metals, Fluorine, Organic Compounds, Salts etc.)

ABIOTIC AGENTS Chemical Factors (Extremes of pH, Mineral imbalances, Nutrient deficiencies)
Physical Factors (Extremes of temperature, Light, Water, Wind, Lightening)

DISEASE CYCLE:
The chain of events leading to the development of a disease is called disease cycle. It is completed involving two basic phases-
Dormant Phase (Survival)
Active Phase (Pathogenesis)
Graphical presentation of disease cycle is given below.
THE DISEASE TRIANGLE:

For the disease development to occur, three parameters are involved which constitute the disease triangle.

- A vulnerable host
- A virulent pathogen
- A favourable environment

Under such circumstances the pathogen completes its life cycle and may undergo repeated generations leading to epidemic development.
There are 65 diseases of rice. Among them there are seven major diseases viz. bacterial blight, sheath blight, sheathrot, false smut, blast, brown spot and tungro which may occur on rice varieties across the ecosystems. Their proper identification and management practices are given below. But first of all we have to sow healthy seeds to get healthy seedlings and plants.

**DIAGNOSIS OF DISEASES:**
Accurate disease diagnosis and precise identification of any pathogens involved is an essential prerequisite for understanding plant diseases and controlling them effectively. Traditional methods of identifying plant pathogens can be slow and inconclusive, and this has prompted the search for alternative diagnostic techniques so that proper treatment can be recommended.

**Bacterial Diseases**

**Bacterial blight**
It is caused by the bacterium *Xanthomonas oryzae pv. oryzae.*

**Symptoms:**
- Water soaked lesions move from tip downwards on the edges of leaves.
- Gradually symptoms turn into yellow and straw coloured stripes with wavy margins.
• In early morning in humid areas yellowish, opaque, turbid drops of bacterial ooze may be seen.
• In Kresek (wilt) phase, leaves roll completely, droop and plants die completely.

![Bacterial blight infected rice](image)

**Pre-disposing factors for the outbreak of Bacterial blight disease:**
• Lateritic and alluvial soil favour more bacterial blight diseases.
• Water logging condition encourages disease development.
• Excessive use of N fertilizers from tillering stage to maximum tillering stage encourages disease development.
• Growing of the crop under shade favours disease development.
• Pruning of leaves at the time of transplanting favours disease development.

**Mode of infection:**
- Water pores found on the hydathodes along the upper surface of the leaf near the edges, growth cracks caused by the emergence of new roots and wounds are the points where the bacterium enters and multiplies in the epitheme into which the vessel opens. When sufficient bacterial multiplication occurs in the epitherm, some of the bacteria invade the vascular system and some ooze out from the water pore.
- The leaf tips of the rice seedlings often cut before transplanting serves as the important source of infection.

**Management of Bacterial blight:**
• Use disease free seeds.
• Avoid field to field irrigation.
• Drain out excess water from the field.
• Apply moderate level of Nitrogen (80 kg N/ha) in 3 splits.
• Potash application, alternate drying and flooding in the field help in reducing infection.
• Avoid pruning the tips of seedling at the time of transplanting.
• Avoid raising the crop under the shade.
• Grow resistant varieties/resistance genes pyramided lines
• Seed treatment by soaking 10kg seeds x 20 liters’ of water containing 1.5gm Streptocycline + 20 gm Captan for 8-10 hours.
• Hot water treatment by soaking the seed in hot water at 53\(^0\) c for 30 minutes.
• Dip roots of the seedlings in solution of plantomycin (0.1%) or Streptocycline (0.01%) for 30 minutes.
• Give the spray of Plantomycin @ 1gm/l of water or Streptocycline (150mg) + copper oxychloride (1gm)/l of water.
• Spray fresh cow dung extracts (1kg cow dung in 5 liter water).

**Bacterial leaf streak:**

It is caused by the bacterium *X. oryzae pv. oryzicola*

**Symptoms**

• Initially, small, dark-green and water-soaked streaks on intervenes from tillering to booting stage.
• Streaks dark-green at first and later enlarge to become yellowish grey and translucent.
• Numerous small yellow beads of bacterial exudates on surface of lesions on humid conditions.
• Very small yellow beads instead of bacterial exudates during dry season.
• Lesions turn brown to greyish white then dry when disease is severe.
• Yellow halo around lesions on susceptible cultivars.
• Browning and dying of entire leaves.
• Bleached and greyish white leaves.
Predisposing factors

- Presence of the bacteria on leaves and in the water or those surviving in the debris left after harvest.
- Temperature range 26-32\(^0\)C
- High humidity between 80-94%
- More no. of rainy days with cloudy weather and less sun shine hours.

Host range

*Species of wild rice such as Oryza spontanea, O. perennis balunga, O. nivara, O. breviligulata, O. glaberrima, and some grasses like Leersia hexandra, Cyperus rotundus, Panicum repens are alternate hosts of the bacterial diseases.*

Management of Bacterial Diseases:

- Use disease free seeds.
- Avoid field to field irrigation.
- Apply moderate level of NPK (40:20:20 kg/ha) during sowing.
- Potash application in the field helps in reducing infection.
- Avoid pruning the tips of seedlings at the time of transplanting.
- Avoid raising the crop under the shade.
- Grow high yielding, intermediate height or tall, long duration photo period sensitive rice varieties with inbuilt tolerance to pest and diseases *viz*; Gayatri, Durga, Varsadhan, Rambha and Kanchan.
- Seed treatment by soaking 10kg seeds in 20 liters of water containing 1.5gm Streptocycline + 20 gm captan for 8-10 hours.
- Hot water treatment by soaking the seed in hot water at 53\(^0\)C for 30 minutes.
• Dip roots of the seedlings in solution of plantomycin (0.1%) or Streptocycline (0.01%) for 30 minutes.

• Just at the appearance of the disease, spray plantomycin 1g + copperoxychloride 1g/ lt. twice at an interval of 8 days.

• Spray fresh cow dung extracts (1kg cow dung in 5 liter water) thrice at eight days interval.

• Spray Amritjal and Pot manure three times at eight days interval which is quite effective for controlling micro organisms and repelling the insect pests.

Preparation of Amritjal: Mix 1 lit fresh cow urine + 1 kg fresh cow dung + 250gm jaggery in 10 lit of water in an earthen pot. The mixture is allowed to ferment for 24 hours and diluted with water in the ratio of 1:10 then filtered and sprayed on the crop. This mixture may be stored for 30 days but it requires stirring everyday. This preparation provides Nitrogen, repels insects and controls the micro-organisms.

Preparation of Pot manure: Mix 1 lit fresh cow urine + 1 kg fresh cow dung + 50gm jaggery in an earthen pot. To this slurry, 1 kg chopped leaves each of Neem, Callotropis (Arakha) and Pongamia (Karanja) are added. The pot is covered with a cloth and kept for 8 days to ferment. After 8 days, it is diluted with water 50 times then filtered and sprayed. This preparation provides Nitrogen, repels insects and controls micro-organisms

FUNGAL (कवक) DISEASES

Rice Blast

This is the most destructive disease in rainfed upland and irrigated rice caused by the fungus Pyricularia oryzae. The fungus produces lesions on leaves, nodes, neck and grains.

Symptoms:

• Spindle-shaped lesions with brown margin and grayish/ashy centre tapering towards both ends.

• Black necrotic lesions on the node and around the base of the panicles may occur resulting in breakdown of panicles and formation of chaffy grains.
Blast nursery showing highly susceptible reactions.

Young blast lesions on leaves.

Pre-disposing factors for the outbreak of Blast disease:

- Low night temperature of 20-240c with high RH 90% or more.
- Copious dew formation occurring in susceptible stage of crop.
- Light showers of rain continuing for few days or cloudy weather persisting for few days.
- Less sunshine hours.
- Acidic soils with pH 5-6.5 favour blast.
- Growing rice seedling on raised seedbeds. Dry soil favours blast occurrence.
- Application of high dose of N fertilizers, more than 80kg N/ha. Ammonium sulphate favours blast incidence.

Host Range

The fungus survives through infection of collateral hosts such as sugar cane, *Setaria intermedia*, *Leersia hexandra*, *Echinochloa crus-galli*, *Digitaria sanguinalis* and many other
grass hosts. It is possible that these grass hosts harbour different pathogenic races of the fungus which produce enough conidia to be disseminated by air currents to infect crops in the other localities.

Management of Rice Blast

- Use healthy seeds collected from disease free crops.
- Avoid raising seedlings in upland.
- Apply moderate levels of nitrogenous fertilizer in 3-4 splits (80 kg N/ha).
- Weed out other hosts viz; Cynodron sp and Paspalmn sp.
- Grow resistant varieties-
- Give need based spray of some effective fungicides or plant products-
  Carbendazim 50WP (Bavistin) 2g/l of water,
  Tricyclazole 75WP (Beam-75 or Sivic or Dream) 0.6g/l of water. Bael leaf extract
  (25g fresh leaves/1lit. water)
  Tulsi leaf extract (25gm fresh young leaves/1lit. water)
  Neem leaf extract (200g fresh leaves/1lit. water)

Brown Spot (Bipolaris oryzae/ Cochilobolus miyabeanus)

It is caused by the fungus Helminthosporium oryzae. The great Bengal famine of 1942 was caused by this disease

Symptoms:

Typically ellipsoidal, oval to circular brown colour lesions appear on the coleoptiles, leaf blade, leaf sheath and glume

Brown spot infected paddy leaves

Pre-disposing factors for the outbreak of Brown spot disease:

- The disease occurs in severe form at low N level.
- The plant grown in soil deficiency of K, Ca, Mg and Zn suffer from the disease severely.
- Relative humidity more than 89%.
- Plants grown in leached soil exhibit severe infection.
• Heavy rain fall in September accompanied by temperature of 25-30\(^0\) c followed by continuous cloudy weather favours severity of disease.

**Management of Brown spot**

• Use healthy seeds from disease free crops.
• Adopt deep summer ploughing.
• Apply balanced macronutrients N60P30K30 with soil amelioration by Zinc and Manganese (if necessary).
• Grow resistant varieties *viz:* Naveen, Padmini, Udaya, Komal-6, Komal-9, Sabitri, Rudra, Shankar, Parijat, Suphala and Shrabani.
• Treat the seeds with Captan or Thiram @ 3g/kg seed.
  Spray the crop with Tilt @ 1ml/l or 0.4% Mancozeb or 0.25% Ziram or 0.2% Carbendazim or 0.15% Saff

**Sheath Blight**

It is caused by the soil borne fungus *Rhizoctonia solani.*

• Irregular lesions with brownish margin or sheaths at the base of culms, usually near water level.
• Lesions gradually coalesce together and extend to leaf blades and give the appearance of snake scales.
• At times white sclerotia of mustard seed size found on infected sheaths.

![Sheath Blight infected paddy](image)

**Pre-disposing factors for the outbreak of Sheath blight disease:**

• An optimal temperature of 28-34\(^0\) with high RH 95%.
• Application of higher dose of N fertilizers, more than 80kg N/ha.
• More number of seedling > 4/hill invite higher disease incidence.
• Presence of root knot nematodes in the soil renders plants more susceptible to sheath blight.

**Management of Sheath blight**

• Use healthy seeds collected from disease free crops.
• Adopt deep summer ploughing so that sclerotia remaining inside the soil are brought to hot sunlight.
• Maintain field sanitation.
• Incorporate green manure (Dhaincha) *Sesbania* sp in Sheath blight endemic areas.
• Do not transplant > 3 seedling/hill.
• Grow sheath blight tolerant varieties in endemic areas.
  Give need based spray of effective fungicides-
  Validamycin (Sheathmar 3L @ 2ml/l of water) or
  (Rhizocin 3 L @ 2.5ml/l of water) or
  Hexaconazole (Contaf 5 EC @ 2ml/l of water) or
  Thifluzamide 24%SC (Spencer @ 1ml/l of water) or
  Carbendazim 50 WP (Bavistin 2.5 g/l of water)

**False smut**

It is caused by the fungus is *Ustilaginoidea virens*

**Symptoms:**

- The disease is found on the ear heads only.
- Individual grains are transformed initially into large velvety green masses which later on become black in colour.

![Infected panicle shows smut balls](image)

**Predisposing factors**

- High moisture favours disease development
- High fertility is favourable for disease development
- Cloudy weather followed by continuous drizzling rain at milky stage of the crop favours disease development

**Management of False smut**

- Use healthy seeds collected from disease free crop.
- Treat the seeds with Carbendazim @ 2g/kg seed.
- Pesticides spray should be taken up 2 week before Panicle Initiation.
- Spray 0.15% Carbendazim or 0.25% Captafol or 0.4% Mancozeb or 0.2% Saff twice at seven days interval at boot leaf stage.
- Drain out water from the field after grain formation.

**VIRAL (विशाणु) DISEASE**
Rice Tungro

It is caused by joint infection of two viruses’ *Rice Tungro Spherical RNA virus* and *Rice Tungro Bacilliform DNA virus*.

Symptoms:

- Freshly emerged leaves exhibit intervenial chlorosis.
- Gradually leaves turn pale yellow and later reddish orange in colour.
- Plants get stunted growth and numbers of tillers are reduced.
- At the maturity stage panicles do not exert completely.
- Tungro infected plants show impaired root growth.

![Tungro virus infected field (in set shows the green leaf hopper the vector of Tungro virus)](image)

Vectors and transmission

It is transmitted by the insect *Nephotettix impicticeps*. *N. apicalis* and *Recilia dersalis* are also slow transmitters of virus.

About 83% of population of *N. impicticeps* are active transmeters. The minimum acquisition and inoculation feeding periods are 30 minutes and 15 minutes respectively. The latent period in the plants is 6-9 days. There is no apparent incubation period in the insect which may transmit the virus in two hours including acquisition and inoculation feeding.

The insects only retain the virus for not more than 5 or 6 days. After that the insects are not effective unless they acquire the virus again.

The virus is not transmitted through the eggs, not by seed, soil or any other mechanical means.

Host range

Many species of wild rice and grass weeds such as *Eleusine indica*, *Echinochloa colonum* and *E. Crusgalli* are good alternative hosts of tungro virus. The host range includes 63 species in 26 genera an 8 tribes of wild grasses and many species and strains of wild rice.
Pre-disposing factors for the outbreak of Tungro disease:
- Early rain during April-May.
- Late planting (After Aug 15th).
- Nursery raising near the ratoon crops.
- Appearance of green leaf hopper within 50 days of the transplanting.

Management of Rice Tungro disease
- Avoid raising nursery near ratoon crop fields.
- Avoid late planting (beyond 2nd week of August) in Eastern India states.
- Clean out weeds *C. rotundus, H. compressa, Hydrobia Zeylanica* and *Phyllanthus niruri* from surrounding of the rice fields.
- Disease spread can be checked by controlling vectors population.
- Give need based application Caldan 4 G @ 10kg/ha. Or Carbofuran @ 12kg/ha.
- Give need based spray of Mnpocrotophos 36 EC @ 3ml/l of water or Imidaclopid 200 SL @ 1ml/l of water.
- Grow resistant varieties Ratna, Banaprava, Naveen, Lunishree, Vikramarya and Nidhi.

Grassy stunt
**Symptom:**
Diseased plant remain stunted and show profuse tillering there by giving the plants a grassy appearance. The virus is transmitted by a hopper Nilaparvata lugens.

**Management:**
- Rogue diseased plants
- Used resistant varieties
- Apply insecticides to control insectivector

Yellow dwarf (Mycoplasma)
**Symptom:**
- General chlorosis and yellowing of leafs
- Plants are stunted and show profuse tillering
- Later on the plants die before reaching maturity

**Management:**
- Rogue diseased plants
- Used resistant varieties
- Apply insecticides to control insectivector

Physiological diseases
Pansukh or dry leaf disease
**Symptoms:**
- Affected plants dry up and development of root and tillering is very poor.
- If the heads are produced, they are very light and the flowers are mostly sterile

**Management:**
- Drain out excess water from the field
- Apply light irrigation at short intervals
- Apply ammonium sulphate @ 15-22 kg/ha

Khaira disease (Zinc deficiency)
**Symptoms:**
- The disease appears in nursery but may appear in patches after 10-15 days of transplanting
- The leafs of diseased plants show chlorosis at the base
- Large number of small, brown or bronze spots appear on the lamina surface which coalesce to form bigger spots and ultimately the entire leaf turns bronze coloured and dries up
- The growth of diseased plant is stunted
• Root growth is also restricted and usually the main roots turn brown. The finer roots are destroyed.

In severe cases the plants fail to grow further and produce no ears but sometimes there is natural recovery after 45 days of transplanting.

**Management:**
- Apply 60 kg of zinc sulphate/ha at puddling in case the previous crop in the field had shown the symptoms of zinc deficiency
- Spray mixture of zinc sulphate (5 kg) and lime (2.5 kg) in 1000 litres of water after 10 days of sowing in the nursery
- Give second spray as above after 25th day of sowing in the nursery
- Give third spray as above in the main field after 15-20 days of transplanting if the symptoms appears in the field
- Zinc sulphate (5 kg), urea (2%) in 1000 litres of water can also be applied

**Conclusion**

The integrated management of the disease involves the following practices.
- Use of resistant varieties.
- Seed selection from disease free crops.
- Seed treatment.
- Field sanitation.
- Eradication of weeds.
- Application of pesticides at appropriate time.
- Management of water in the field.
- Judicious application of fertilizers.
- Frequent monitoring of disease incidence and taking appropriate measures.
Rice: Grain Quality and Value addition
Awadhesh Kumar
NRRI, Cuttack

Introduction
Rice is an integral part of the diet of about half of the global population and is a major source of calories consumed by more than three billion Asians. The demand for good quality rice has been increasing due to the higher return it provides to farmers. Although, more than one lakh rice accessions are preserved in the gene bank of the International Rice Research Institute (IRRI), Philippines and about 30,000 rice germplasm in the National Rice Research Institute, Cuttack, only a few thousand rice varieties and landraces are grown in the world at present. These germplasm form an important source for breeding quality rice. Proper water, nutrient and pest management practices add not only to grain yield but also to grain quality.

The crop is harvested as paddy or rough rice at 20-24% grain moisture with the mature rice grain (caryopsis) enclosed within an inedible cover called hull or husk. Some of the rice varieties have an awn (a stiff bristle projecting from the tip of the paddy seed) attached to the hull lemma which creates problem during milling particularly with the laboratory huller. Paddy is dried to a moisture content of 12-14% before processing for consumption and to 12%, if it is to be preserved for seed purpose. It takes about 3-4 months (ageing period) for the grain quality characters to stabilize, hence paddy grains are analyzed for quality parameters after at least 3 months of harvest.

Processing of paddy: During processing of paddy, the husk is removed (dehulling) along with the bran layer and the germ to yield white or milled rice with minimum breakage of whole grain. Some machines do it in one go like the traditional rice mills. A rubber roll sheller removes only the husk. The dehusked rice is called brown rice which has a colored (pink/brown/red/blue/black) coating that is rich in vitamins, minerals, oil and other nutrients and is thus prone to infestation by insects and microbes. When the brown rice is passed through an abrasive whitening machine the colored coat is removed as brownish powder called bran resulting in white rice grains called milled rice. The latter is sometimes further passed through a friction type whitening machine to get a smooth final product called polished rice. Milled rice (commonly eaten rice) is produced commercially by millers because it has longer shelf life, lesser cooking time and better appearance than the brown rice. Thus, normally, it is the milled rice characteristics we refer to while describing grain quality. Milled rice grain with 75% or more of the average length of the unbroken milled rice grain (whole kernel) is called head rice. Percentage of head rice recovered during milling of paddy is called head rice recovery (HRR). High HRR (> 60%) is the first condition for a variety to be successful. For long slender grains, it may be between 55-60%. The sum total of the amounts of head rice and broken rice obtained from a paddy
sample is called milling recovery or total milled rice which is generally about 68-72% depending on the rice variety.

**What is grain quality?**

Quality in general refers to the degree of excellence or worth or grade of something. Actually, the concept of rice grain quality varies with the consumer preference and the purpose (end use). But normally physical qualities like (grain size, shape and appearance), milling quality (the capacity to withstand the pressure of milling) and chemical quality which determines cooking characteristics and nutritional quality are the main determinants of rice grain quality. Though, the quality attributes are determined mainly by the genetic constitution, the environmental conditions and cultural practices have profound role in shaping the final product. Grain quality characteristics assume much more importance for rice compared to other food grains and are the prime determinants of market price, because most of the rice (almost 95% of production) is consumed as cooked whole grain. The current emphasis on quality rice is because of the increase in per capita income, which led to the increased demand for quality rice. Hence, breeding for improvement of grain quality has become a priority area of rice research.

**Features of quality rice**

Quality means different things to different people depending on their eating preferences and specific requirement. The rice trader would like to emphasize on attributes like purity, moisture %, grain size and shape, head rice recovery % and absence of colored, damaged and chalky grains in a stock of rice for domestic as well as international trade. However, medium or long slender translucent grains with high HRR, good cooking and eating quality (good elongating ability during cooking, tender, well separated grains, good mouth feel) and pleasant aroma are normally preferred.
Fig. 1. Product fractions from standard milling of rice (the percentage of hulling, milling, head rice recovery (HRR) and broken rice are calculated on paddy weight basis.)

Paddy or Rough Rice (100 kg)

Hulling

Husk/Hulls (20 kg)
Non edible cover of rice grain

Brown Rice (80 kg)
Rice kernels with a brown coating

Milling

Polished/Milled/White Rice (70 kg)

By Products (10 kg)

Head Rice (48 kg)

Broken Rice (22 kg)

Bran (7 kg)

Polish (3 kg)

Seconds (8 kg)

Screenings (10 kg)

Brewers (4 kg)

Grain size & shape: Grain size and shape are important criteria of rice quality for developing new varieties for trade and hence for quality evaluation. New technology uses image analyzer to measure these characteristics. Different countries have their own classification to categorize rice grains. In India, Ramiah’s classification (Govindaswami, 1985) is followed and is given below (Table-1):

Table 1. Rice grain classification followed in India

<table>
<thead>
<tr>
<th>Grain type</th>
<th>Milled Grain Length (mm)</th>
<th>Length : breadth ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Long slender (LS)</td>
<td>≥ 6 mm</td>
<td>≥ 3</td>
</tr>
<tr>
<td>Short slender (SS)</td>
<td>&lt; 6 mm</td>
<td>≥ 3</td>
</tr>
<tr>
<td>Medium slender (MS)</td>
<td>&lt; 6 mm</td>
<td>2.5 to 3.0</td>
</tr>
<tr>
<td>Long bold (LB)</td>
<td>≥ 6 mm</td>
<td>&lt; 3</td>
</tr>
<tr>
<td>Short bold (SB)</td>
<td>&lt; 6 mm</td>
<td>&lt; 2.5</td>
</tr>
</tbody>
</table>

Chalkiness, varietal characteristics and climate: A new insight has been obtained on the development of chalks in grains. The grains on primary branches are on highest priority for grain filling in the panicle and are translucent whereas grains on secondary branches are of lowest priority. As the supply of sugars from vegetative parts to panicle (sink) ceases the grain filling stops resulting in immature or chalky grains. Therefore, large panicles with a large number of secondary branches (like
IR 8) is more likely to form chalky grains when environmental conditions such as high temperature shorten the grain filling period (time for which panicle is sink) compared to those with a small panicle with few secondary branches like IR 60 (Resurreccion and Fitzgerald, 2007). The finding assumes importance in view of the threat of global warming looming large on humanity. *Pwgc*-8 has been identified as a single recessives gene controlling chalkiness.

**Cooking Quality and its evaluation**

The first indicator of good cooking quality of rice is that the cooked grain retains a firm shape and does not disintegrate during or after cooking. Varieties that do not meet this requirement are not commercially successful. Starch forms the major part of rice kernel, hence the *cooking quality* is mainly governed by the packaging of starch molecules and the amylose: amylopectin ratio.

The **cooking quality** of rice grains is determined by their *alkali spreading value* (ASV), *gelatinization temperature* (GT) *water uptake* (WU) value, *volume expansion ratio* (VER), *kernel length after cooking* (KLAC), *elongation ratio* (ER), *gel consistency* (GC) and *apparent amylose content* (AC). The criteria for *palatability* or *eating quality* evaluation consist of six sensory tests, which include *appearance, aroma, taste, stickiness, hardness* and *overall evaluation*. To assess the eating quality a 10-15-member panel gives description of cooked rice on a 7 point scoring scale system.

**KLAC** and **ER** measure lengthwise elongation during cooking. Rices that exhibit better lengthwise elongation during cooking command high price. **WU** value is a measure of the volume of water absorbed by 100g of grains and also an indicator of gelatinization. **VER** is a measure of the increase in volume of rice after cooking. **AC%** is a major determinant of eating and cooking quality and is normally measured by its color reaction with iodine. **GT**, the temperature at which the starch granules swell in water irreversibly losing their crystallinity, is indicated by alkali digestion. **ASV** is measured by treating rice grains in a Petri plate with KOH solution and looking for disintegration of grains, on a 1-7 scale. **GC** measures cooked rice texture i.e. the tendency of cooked rice to harden on cooling especially for high amylose rices. Rice varieties are also classified as *waxy or glutinous* (0-2% amylose) and *non-waxy* (>2% amylose) on the basis of their amylose content (Table 2).

Table 2. Classification of milled rice according to their apparent amylose content, alkali spreading value, gelatinization temperature and gel consistency

<table>
<thead>
<tr>
<th>Property</th>
<th>Type or Class of rice</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Apparent amylose content</strong></td>
<td>Waxy</td>
<td>0 – 2%</td>
</tr>
<tr>
<td></td>
<td>Very low</td>
<td>2-9%</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>10 - 20%</td>
</tr>
<tr>
<td></td>
<td>Intermediate</td>
<td>20 - 25%</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>25 - 33%</td>
</tr>
<tr>
<td><strong>Alkali spreading value</strong></td>
<td>Low GT</td>
<td>6 - 7 (GT &lt; 70°C)</td>
</tr>
<tr>
<td></td>
<td>Intermediate GT</td>
<td>4 - 5 (GT 70-74°C)</td>
</tr>
</tbody>
</table>
Nutritional quality

The well being of human body depends on intake of nutrients in appropriate and balanced amounts. At present, 49 nutrients are considered to be essential and indispensable for sustaining human life, which include water, carbohydrates, 9 essential amino acids, linoleic acid (18:2, an \( \omega-6 \) acid) and alpha-linolenic acid (18:3, an \( \omega-3 \) acid), 7 mineral macroelements, 16 mineral microelements and 13 vitamins.

Rice is staple food for at least half of the world population and meets 27% of the dietary energy and 20% of the dietary protein requirement of the people globally. Hence, nutritional quality is an essential component of the overall quality of rice grains. Rice contains about 90% starch, 7% protein, and 2% fat (Table 2). The biological value (BV) of rice protein is very high (80) compared to that of wheat (60) and maize (50). Only rice protein has 100% true digestibility among cereal proteins. The net protein utilization of rice protein is 75%. Among amino acids, rice is rich in aspartic and glutamic acids but limiting in lysine. As regards vitamins, rice grain is a good source of niacin, thiamin and riboflavin but has no vitamin A, vitamin D or vitamin C. The B vitamins are concentrated in the bran layer, as is alpha-tocopherol (vitamin E). Since rice does not have a complete amino acid profile, rice based foods should be taken together with pulses, fish or animal protein to make up for the deficiencies of amino acids and also the micronutrients. **Rice glutelin**, also called **oryzenin** is the major rice protein and constitutes about 84% of total grain protein. Recently, the CRRI, Cuttack identified some Assam Rice collections containing up to 16% protein (%N x 5.95) on dry weight basis.
TABLE 3 - Proximate composition of paddy and its milling fractions at 14 % moisture

<table>
<thead>
<tr>
<th>Rice fraction</th>
<th>Crude protein (g)</th>
<th>Crude fat (g)</th>
<th>Crude fiber (g)</th>
<th>Crude ash (g)</th>
<th>Available carbohydrates (g)</th>
<th>Neutral detergent fiber (g)</th>
<th>Energy content (kJ)</th>
<th>Energy content (kcal)</th>
<th>Density (g/ml)</th>
<th>Bulk density (g/ml)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rough rice</td>
<td>5.8-7.7</td>
<td>1.5-2.3</td>
<td>7.2-10.4</td>
<td>2.9-5.2</td>
<td>64-73</td>
<td>16.4-19.2</td>
<td>1580</td>
<td>378</td>
<td>1.17-1.23</td>
<td>0.56-0.64</td>
</tr>
<tr>
<td>Brown rice</td>
<td>7.1-8.3</td>
<td>1.6-2.8</td>
<td>0.6-1.0</td>
<td>1.0-1.5</td>
<td>73-87</td>
<td>2.9-3.9</td>
<td>1520-1610</td>
<td>363-385</td>
<td>1.31</td>
<td>0.68</td>
</tr>
<tr>
<td>Milled rice</td>
<td>6.3-7.1</td>
<td>0.3-0.5</td>
<td>0.2-0.5</td>
<td>0.3-0.8</td>
<td>77-89</td>
<td>0.7-2.3</td>
<td>1460-1560</td>
<td>349-373</td>
<td>1.44-1.46</td>
<td>0.78-0.85</td>
</tr>
<tr>
<td>Rice bran</td>
<td>11.3-14.9</td>
<td>15.0-19.7</td>
<td>7.0-11.4</td>
<td>6.6-9.9</td>
<td>34-62</td>
<td>24-29</td>
<td>670-1990</td>
<td>399-476</td>
<td>1.16-1.29</td>
<td>0.20-0.40</td>
</tr>
<tr>
<td>Rice hull</td>
<td>2.0-2.8</td>
<td>0.3-0.8</td>
<td>34.5-45.9</td>
<td>13.2-21.0</td>
<td>22-34</td>
<td>66-74</td>
<td>1110-1390</td>
<td>265-332</td>
<td>0.67-0.74</td>
<td>0.10-0.16</td>
</tr>
</tbody>
</table>

**Improving nutrient status of rice**: It is necessary to increase the nutritional value of the food consumed by increasing its nutrient load and reducing the amount of anti-nutrients to enhance the delivery of nutrients to the consumer. By nutritionally enhancing cereals, severe deficiencies can be eliminated in developing countries where largely cereal-based diets are consumed. However, in industrialized countries, where cereals constitute a lower percentage of the total diet, nutritionally enhanced cereals could be important amongst women and children in lower socio-economic groups and in reducing subclinical deficiencies among those, who choose poor diets.

There are two distinct ways in which the nutritional value of cereals can be enhanced. The first is by utilizing the genetic variation available through breeding or genetic engineering. Another approach is through cultural methods, including fertilizer technology.

Rice lacks vitamin A and is deficient in essential minerals like iron and zinc. Protein-calorie malnutrition and deficiencies of iron, protein, iodine and vitamin A are common mainly in rice consuming countries. More than 3 billion people suffer from iron deficiency the world over resulting in poor health, inferior life quality and diseases. Likewise, zinc deficiency is also not uncommon. Balanced food has dramatic effect on those suffering from deficiency diseases.

Various approaches like supplementation, fortification and bio-fortification have been used to address the problem of nutrient deficiency with efforts directed towards developing nutrient dense rices particularly those rich in protein, β-carotene (precursor of vitamin A), iron and zinc. Programs like Harvest Plus (an international alliance of scientific institutions that began breeding biofortified rice, maize and other staples consumed by the poor in 2004) were initiated to enhance the micronutrient status of food grains. Eating iron-biofortified rice (3.21 mg/kg) caused 20% increase in body iron status.
of Filipino women within 9 months over control (0.57mg/kg). But this increase was observed only in non-anemic women. Serum ferritin level increased but not hemoglobin.

**Golden rice:** Rice grain does not have any detectable amount of β-carotene (precursor of vitamin A) because two of the genes required for its synthesis are turned off during grain development. These genes were introduced (from daffodils and *Erwinia*) by I. Potrykus and P. Beyer into rice in 1999 to obtain golden yellow rice kernels called golden rice that contained 1.6 µg β-carotene/g. The latest golden rice (SGR 2) developed in 2005 contains 36 µg pro-vitamin A carotenoids/g in mild rice. The SGR-2 has more β-carotene perhaps because a seed specific promoter was used for the phytoene desaturase gene (and not a constitutive promoter which is active throughout the plant). Though, one mole of β-carotene yields two moles of vitamin A in the body, only 1/6th of its amount is converted to the vitamin (RDA ,700-1300 µg).

**Specialty Rices and value addition**

Rice cultivation is not considered a profitable venture. The possible approaches that may help address the problem include promotion of specialty rices which are higher in value due to some unique quality for which they are sought and hence command higher price in the market than the commonly eaten rices. The specialty may lie in their external appearance, aroma nutritional/medicinal value, cooking/eating quality or suitability for making some value added product like beaten rice, puffed rice, popped rice, *idli*, *dosa*, *pulao*, cake glue, rice paper etc. Thus, aromatic, long slender grain, nutrient rich, medicinal, organic, pigmented, soft, feed and wine rices may be considered as specialty rices. Consumer demands for convenient, inexpensive, nutritious and ready to eat products result in value addition. Utilization in diversified ways by converting them into a variety of products such as infant foods, health foods/mixes, convenience foods and specialty foods, make a significant impact on consumer acceptability.

**Aromatic rices:** Among the aromatics two types of rices are known. The Basmati rice is the most popular due to its grain and cooking qualities. Of the several traditional basmati varieties available in India only six (Basmati 370, Basmati 386, Type 3, Taraori basmati, Basmati 217 and Ranbir basmati) are approved under traditional basmati category. Others which had one of the parents as basmati rice during the varietal development process are called evolved basmati rices (Pusa basmati 1, Punjab basmati, Haryana basmati, Kasturi and Mahisugandha). The parents for the Sugandh varieties released by the IARI, Pusa, New Delhi are Pusa basmati 1 and Haryana basmati, both being crossed and evolved lines.

Besides basmati, the aromatic short grain rices are also very popular in Indian states. *Kala namak*, Bindli, Kalikhasa, Katarni, Sugandha, and Randhunipagal etc are well known short grain scented rices which are almost as good as basmati in all respects except grain length. The market for these grains needs to be created by promotional activities.

The pleasant aroma of scented rice is similar to the aroma of the leaves of the plant *Annapurna* or pandan (*Pandanus amaryllifolius*) which is mainly due to the compound 2-acetyl-1-pyrroline (2-AP). In fact, 2-AP is the principal component of aroma of scented rices. Gas chromatograph coupled with a
mass spectrometer (GCMS) is used to identify and measure the 2-AP accurately. More than 150 compounds have been reported to contribute to the aroma of scented rice.

The **long and medium slender grain rices** command higher price than the short or long bold grains. *BPT 5204, Sharbati, CR 1014, Sarala and Padmini* are a few examples of such rices. *Sharbati* is non-scented rice which is often grown to adulterate *basmati* rice because of their resembling physical features and cooking quality.

**Nutrient Rich Rice:** There is wide diversity for nutrient content in rice which includes iron, zinc, protein and antioxidants. However, systematic efforts for promotion of nutrient rich rice are yet to be undertaken. Rice is most nutritive when eaten as *brown rice* or *cargo rice* as it is rich in fiber, zinc, iron, vitamins, oil and many nutraceuticals and antioxidants. It takes a little longer to cook but the **germinated brown rice** (GBR) is not only easier to cook or chew but also nutritionally much superior. The GBR is highly rich in gamma amino butyric acid (GABA) which accelerates brain metabolism, reduces blood pressure, insomnia and mental irritation and activates kidney functions. It has higher levels of antioxidants like gamma oryzanols, tocopherols and tocotrienols which provide good protection against tumor/cancer development, reduce blood cholesterol and triglyceride levels, improve heart function and delay ageing. An enzyme prolylendopeptidase which is present in GBR is claimed to provide some protection against Alzheimer’s disease also (Ito and Ishikawa, 2004).

**Medicinal rice:** Several rice germplasm grown in Indian states of Kerala, Chhattisgarh, MP, Orissa and others are claimed to have therapeutic value. Most well known are the *navara* rices of Kerala. Many others are also thought to cure various ailments of man and animals; examples include, Gudmatiya (diabetes) Aalcha (pimples), Gathuwan (rheumatism), Kalimooch(skin problems) , Sarra (arthritis) etc.

**Organic Rice:** As people have become more health conscious, the demand for organically grown fruits, vegetables and rice, free from toxic residues of harmful agricultural chemicals has been consistently increasing although such products are often highly priced in the market compared to their traditionally grown counterparts. India, Indonesia, Myanmar, Pakistan, Philippines, Canada, USA, France, Italy, China and Spain are the major producers of organic rice. The major organic rice supply to the EU comes from France, Italy and Spain.

**Pigmented/color rice:** The term stands for brown rice whose outer layer is colored due to the presence of anthocyanin pigments. High anthocyanin levels impart black color to rice kernels. *Jieguno*, a purple-black Chinese rice is said to strengthen immune system and heal fractured bones when used with some herbs. The black rices contain about 37% more protein, 22% more fat and 178% more crude fiber apart from being rich in lysine, vitamin B1, Zn, Fe, Ca and P by 20-50% than other local rices.

**Soft/Glutinous/Waxy/Sweet Rice:** It is the name given to *Oryza sativa* var. *glutinosa*, also known as white sticky rice, sweet rice, etc. It is grown in China, Thailand, Japan and Vietnam and contains little or no amylose and absorbs relatively small amount of water during cooking and exhibits little volume expansion, becomes quite sticky i.e. glue like and glossy when cooked. It is different from other Asian rices that become sticky on cooking. It does not contain gluten. The rice Mochiminori (<1% amylose) is
an example. Glutinous rice commands high price and is used in sweet dishes, snacks and in brewing beer.

**Wine rice:** Both indica and japonica rices are used to make wine. Jiahu 4 (1 mha) is used to produce “yellow rice wine”. China alone uses over 1 million ton of wine rices to prepare wine. Some of the popular alcoholic rice beverages of Nagaland are Yi, Azu, Zu and Sahma.

**Feed Rice:** Certain rices are developed to feed the grain/leaf, stem and young panicle to animals. Gugan 202 is one such feed rice developed by the Chinese through mutagenesis with grain yield of 7.0t/ha. It is rich in protein (11.2%) and other nutrients in straw.

**Soak n eat rice** and **Quick Cooking Rice:** The quick cooking rices are those which take significantly less time to cook compared to that taken by raw milled rice (15 - 25 min). The term quick cooking rice also means those rices which are prepared by soaking raw white long grain rice in some chemicals and autoclaved (Smith et al, 1990) so that they can be eaten just by adding hot water. Some of the rice grown in Assam exhibit soak n eat characteristics and need to be characterized and promoted.

**Wild Rice:** The term wild rice has two connotations. It stands for the wildly growing rice which easily shatters on maturity and is rich in protein (11-12%) and commands premium price as its availability is less. The term is also used for seeds of a water grass (Zizania sp); the sweet tasting nutty textured grain is considered to be one of the most flavorful grains known to exist in the world today and is served in hotels and flights.

**Rice based value added products:** About 95% of rice is consumed unprocessed i.e. simply as cooked whole grain. The remaining 5% is used to make processed foods and industrial products including bakery products and alcoholic beverages. The physicochemical properties of a rice variety and the ratio of amylose to amylopectin decide its suitability for making a particular processed product. Some common products are beaten rice, puffed rice, popped rice, noodles, cakes, desserts, wine/beer and idli/dosa powder etc. Rice varieties with good volume expansion (5-6 times) during puffing are suitable for making puffed rice (*moodhi*). Work at CRRI has resulted in identification of Panidhan, Padmini, Foundation (local), Gangasiali, Sarubozni, Nalikama, and Bedamanji for the purpose. Lalat and Baitalpakhia also are suitable for the purpose. Popped rice (*Kheel/Khai*) is popularly eaten in north India on the occasion of the festival Deepawali. Freshly harvested sample with a mean harvest moisture percentage of 20-24, heavy grain type (without chalkiness, sun cracks or fissures) give larger popped volume. The rice Mayurkantha and the salt tolerant rice SR 24B also give excellent quality popped rice. *Idli & dosa* are popular food preparations made from rice and black gram mix in southern India. Varieties with high amylose content are suitable. The CRRI variety Savitri (called Ponmani in Tamil Nadu) is very popular for making idli employing parboiled rice. For cakes, waxy rices with low GT are preferred. For puddings, short/medium grain rice with low amylose content is required. *Pulao* is a very popular dish in India, Pakistan and the Middle East. Long slender grains, preferably basmati (about 20% amylose) which exhibit high grain elongation after cooking with medium GT and soft GC are suitable for the purpose.
**Rice bran oil (RBO) and nutraceuticals:** Rice bran contains about 20% oil. The RBO blended edible oils like *Sundrop heart* and *Saffola gold* containing up to 80% RBO are available in the market. It is judged as the best cooking medium by the American Heart Association and the National Institute of Nutrition, Hyderabad. Of late, Indians are becoming increasingly prone to lifestyle induced diseases such as high serum triglycerides, cholesterol and cardiovascular diseases. The RBO has been found to be of help under such situations. It is not only the cheapest cooking medium in the market; it is very light too and is about 15-20% less absorbed compared to other oils. Thus, it is not only economical, but also adds lesser calories to the fried food. It is least allergenic and little degraded during cooking due to its high smoke point (255°C). It has no *trans* fats which are said to cause cancer. The food fried in RBO is tastier and has pleasant flavor. It is good for grilling or baking food and for salad dressings. It has the nearly ideal combination of saturated, polyunsaturated and mono-unsaturated fatty acids (SFA, PUFA and MUFA %, 22:35:43) which is very close to the recommendations of the nutritionists. But it is advisable to use RBO after blending with an edible oil rich in *w-3* fatty acids.

Rice Bran Oil is especially good for heart because it is naturally rich in several **nutraceuticals** (a food or part of food that provides medical or health benefits including prevention or treatment of a disease). The refined RBO contains two kinds of vitamin E (*tocopherols*, 0.02-0.08% and *tocotrienols* 0.025-0.17%) and **gamma-oryzanol**s. These antioxidants not only add to the shelf life of RBO (2 years in sealed container and 6 months after opening) but also provide some protection to the consumer against ageing, cardiovascular diseases, tumors and even cancer. It has the highest antioxidant content (2417 ppm). No popular cooking oil other than RBO contains **gamma-oryzanol**s.

**RBO** is used in **cosmetics** also as it imparts glow to skin. It is used in skin creams (that are claimed to slow down ageing and appearance of facial wrinkles). It is also used in sun screen products as it intercepts the UV rays and impedes the melanin pigmentation.

**Glycemic index of rice:**

Glycemic index (GI) is a number associated with a particular type of food that indicates its effect on a person’s blood glucose level. A value of 100 represents the standard, an amount equivalent to pure glucose. GI represents the total rise in a person’s blood sugar level following the consumption of a particular food. It is a measure of the relative ability of carbohydrates in foods to raise blood sugar levels after eating. High GI food is easily digested and absorbed by the body, which can result in fluctuations in blood sugar levels. Foods with low GI, on the other hand, are those with slow rates of digestion and absorption, causing a gradual and sustained release of sugar into the blood, which is beneficial to health and reduces the chances of developing Type II diabetes. Slow digesting starches lower the body’s insulin response, thus helping people with diabetes to normalize their blood sugar.

Currently, 285 million people, mostly in developing countries, have Type II diabetes and another 344 million are at risk of developing it due to impaired glucose tolerance. If diabetes is undiagnosed, it leads to chronic conditions and death. Consumption of cereals is not necessarily a cause of Type II diabetes, but cereals containing particular structures of starch offer a solution for prevention and management of the condition.
Generally GI is classified into three categories:

- 55 or < = Low GI
- 56 – 69 = Medium GI
- 70 or > = High GI

GI value of rice generally shows wide variation (48-92) with an average of 64 depending on the type of rice. Further, most commonly consumed rice show medium to high GI irrespective when eaten with or without polishing. Physicochemical and metabolic properties of rice are influenced by numerous factors. One of these factors is amylose content (AC), which is often used to predict starch digestion rate, blood glucose and insulin responses to rice. Several investigators have reported that high-amyllose rice exhibited lower GI values than the low-amyllose varieties, although, some investigators suggested that rice with similar amylose content could differ in starch digestibility and glycemic responses. This is understandable because apart from amylose/amylopectin ratios, starch properties such as granule size, architecture, crystalline pattern, degree of crystallinity, surface pores or channels, degree of polymerisation, and non-starch components influence starch digestibility.

Apart from amylose, resistant starch (RS) has recently received much attention for both its health benefits and functional properties. It positively influences the functioning of the digestive tract, microbial flora, the blood cholesterol level, the GI and assists in the control of diabetes. The RS is the residual fraction of starch, resistant to enzyme hydrolysis, entering the large intestine along with dietary fibre. Though the RS accounts only a small proportion of the total calorie intake, its effect is similar to those of other fibre components. Based on the cause of enzyme resistance, RSs are categorized into five types. Type 1 RS is starch that is physically inaccessible, such as that in whole grains. Type 2 RS is often found in raw potato and banana, and its enzyme resistance is a result of the tight packing of starch within the starch granules. Type 3 RS is retrograded starch, which is formed when cooked starchy foods are cooled. Cooling allows the amylose and linear parts of amylopectin to form crystalline structure that reduces digestibility. Type 4 RS results from chemical treatment/modification of starch. Finally, type 5 RS is starch wherein the amylose component forms complexes with lipids (amylose-lipid complex), which makes it more thermally stable. Digestibility of cooked rice starch is usually determined by the amount of amylose in the grain. The more amylose there is, the slower is the digestion of rice and the lower is the glycemic index, which indicates the effect on blood sugar. However, in rice with type 5 RS, such starch may take several hours to digest or may not be digested at all, like a form of dietary fibre. This is because the amylose-lipid complex in type 5 RS restricts swelling of the starch granule during cooking, making it resistant to hydrolytic enzymes. Thus, an increase in the amount of type 5 RS could make rice safer for people with diabetes or for those who simply would like to avoid the extra calories. Varieties with low GI and high RS content tend to lower the glycemic response (GR) due to slow release of glucose in small intestine, thus lowering the insulin response and controlling the rise in blood glucose.
New Dimensions of Insect Pest Management in Rice

S D Mohapatra
ICAR-National Rice Research Institute, Cuttack
email: sdmanto73@gmail.com

The insect problem is accentuated in intensive rice cropping where the insects occur throughout the year in overlapping generations. Over 800 insect species damaging rice in one way or another, although the majority of them do very little damage. In India, about a dozen of insect species are of major importance but the economic damage caused by these species varies greatly from field to field and from year to year. Insect pests cause about 10-15 per cent yield losses. Farmers lose an estimated average of 37% of their rice crop to insect pests and diseases every year. Insect pests and predator population in rice fields are closely associated with each other. Majority of rice pests are controlled by a complex and rich web of predators and parasitoids that live in or on the rice plant, rice water or soil. Warm and humidity in rice fields favour the survival and proliferation of insects. If biotic stresses in rice are taken care; the rice production may be enhanced by 30-35%.

Major Insect Pests: National Importance
1. Yellow stem borer, Scirpophaga incertulas Walker
2. Brown plant hopper, Nilaparvata lugens Stal
3. White backed plant hopper, Sogatella furcifera Horváth
4. Leaf folder, Cnaphalocrocis medinalis Guenée
5. Gundhi bug, Leptocorisa acuta Thunberg
6. Gall midge, Orseolia oryzae Wood-Mason

Major Insect Pests: Regional Importance
1. Termite, Odontotermes obesus Rambur
2. Swarming caterpillar, Spodoptera mauritia Boisduval
3. Rice Hispa, Dicladispa armigera Oliver
4. Rice Ear Cutting Caterpillar, Mythimna separata Walker
5. Caseworm, Nymphula depunctalis Guenée
6. Thrips, Stenchaetothrips biformis Bagnall
7. Mealy bug, Brevennia rehi Lindinger
8. Panicle mite, Steneotarsonemus spinki Smiley
9. Leaf mite, Oligonychus oryzae Hirst
10. Root weevil, Echinochernes oryzae Marshall

Need for IPM
Integrated Pest Management is the approach of mutual integration of available pest control tactics to maintain the pest numbers below economic threshold levels with an aim of
least or no hazards to the environment. The IPM is the alternative to pest control. The pest control activity was aimed at eradication of pests by use of chemical (synthetic) pesticides. Overuse and misuse of chemical pesticides have led to development of a series of negative ecological consequences like:

- Residual toxicity in plant parts and eatables, soil, water etc.
- Health hazards to animals and human beings
- Destruction of natural enemies (predators and parasitoids)
- Development of insecticide resistance in insects
- Resurgence and outbreak of insects
- Conversion of minor pests to major pests

**Tools of IPM**

**Cultural Practices**

- Raise pre-crop *kharif* grow *Sesbania* and incorporate 45 days old crop in soil during land preparation wherever possible.
- In termites endemic areas, seed treatment with chlorpyriphos 20% EC @ 10000 ml/ha along with 10% solution of gum arabica or imidacloprid 200 SL (20%) @ 0.25 litre/100 kg seed along with 10% solution of gum Arabica in 3.75 litre of water just before sowing.
- Normal spacing with 30-36 hills/ m² depending on the duration of the variety.
- 30 cm alley formation at every 2.5 to 3 m distance in plant hopper endemic areas.
- Balanced use of fertilizers and micro-nutrients as per local recommendations. Proper water management (alternate wetting and drying to avoid water stagnation) in plant hopper endemic areas. Maintain a thin layer of water on soil surface to minimize weed growth.
- Harvest close to ground level to destroy insect pest present in the internodes/stubbles. This will also expose the insects to birds thus help in natural biocontrol of insect pests.
- After harvest, the fields should be thoroughly flooded with water and ploughed with discs or rotators to kill hibernating larvae of stem borer present in the stubbles. Summer ploughing of fields also expose larvae and pupae of rice swarming or ear cutting caterpillar (climbing cutworm) hidden in the soil to birds and weather factors.

**Mechanical Practices**

- Collection of egg masses and larvae of pest to be placed in bamboo cages for conservation of biocontrol agents.
- Removal and destruction (burn) of insect pests infested plant parts.
- Clipping of rice seedlings tips at the time of transplanting to minimize carryover of rice hispa, case worm and stem borer infestation from seed bed to the transplanted fields.
- Use of coir rope in rice crop for dislodging case worm, cut worm, swarming caterpillar
and leaf folder larvae etc. on to kerosinized water (1 L of kerosene mixed on 25 kg soil and broadcast in 1ha).

Biological Control Practices

- *Trichogramma japonicum* and *T chilonis* may be released @ 1 lakh/ha on appearance of egg masses / moth of yellow stem borer and leaf folder in the field.
- Biocontrol agents, spiders, drynids, water bugs, mirid bugs, damsel flies, dragonflies, meadow grasshoppers, staphylinid beetles, carabids, coccinellids, *Apanteles, Tetrastichus, Telenomus, Trichogramma, Bracon, Platygaster* etc. should be conserved.
- Collection of egg masses of stem borers and putting them in a bamboo cage-cum-percher till flowering will permit the escape of egg parasites and trap and kill the hatching larvae.
- Management of farmland and rice bunds with planting of flowers like marigold, sun hemp increases beneficial natural enemy population.
- Provide refuge like straw bundles having charged with spiders to help in build up spider population and to provide perch for birds

Behavioural Control

Mass trapping of yellow stem borer male moths by installing pheromone traps @ 20 traps/ha with lures containing 10-15 mg pheromone at 20 days after transplanting.

Chemical Control

Chemical pesticides are to be applied on need base and judiciously. Recommended chemicals are to be applied at right time at recommended dose. The details of the chemical control measures to be adopted against insect pests are given. Spraying should be undertaken based on the ETL values.

Economic threshold level (ETL) of major pests of rice crop stage wise

<table>
<thead>
<tr>
<th>Crop stage</th>
<th>Pest</th>
<th>ETL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nursery</td>
<td>Yellow stem borer</td>
<td>1 egg-mass/m²</td>
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<tr>
<td></td>
<td>Root-knot nematode</td>
<td>1 nematode/g. soil</td>
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<tr>
<td></td>
<td>BLB: <em>Kresek</em> Phase</td>
<td>2-3 plants/m²</td>
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<tr>
<td>Early to late</td>
<td>Leaf-folder</td>
<td>2 Fully damaged leaves (FDL) with larva/hill</td>
</tr>
<tr>
<td>tillering</td>
<td>Stem borer</td>
<td>2 egg-mass/m² or 10% dead heart or 1 moth/m² or 25 moths/trap/week</td>
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<tr>
<td></td>
<td>Gall midge</td>
<td>1 gall/m² or 10% Silver shoot</td>
</tr>
<tr>
<td></td>
<td>Brown planthopper/WBPH</td>
<td>10-15 hoppers/hill</td>
</tr>
<tr>
<td></td>
<td>Rice hispa</td>
<td>2 adults or 2 dead leaf /hill</td>
</tr>
<tr>
<td></td>
<td>Rice caseworm</td>
<td>2 FDL/hill</td>
</tr>
<tr>
<td></td>
<td>Swarming caterpillar</td>
<td>1 damaged tiller/hill or 2 larvae/ m²</td>
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<tr>
<td></td>
<td>Foliar blast</td>
<td>3-5 lesions/leaf</td>
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<tr>
<td></td>
<td>Brown spot</td>
<td>2-3 spots/leaf &amp; 2-3 infected plants/ m²</td>
</tr>
<tr>
<td></td>
<td>Sheath blight</td>
<td>Lesions of 5-6 mm in length &amp; 2-3 infected plants/m²</td>
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<tr>
<td></td>
<td>Sheath-rot</td>
<td>Lesion length 2-3 mm on sheath &amp; 3-5 infected</td>
</tr>
<tr>
<td>Stage</td>
<td>Pests</td>
<td>Control measures</td>
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<td>---------------------------</td>
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<tr>
<td>Panicle initiation to</td>
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<td><strong>In the stem-borer endemic areas,</strong> install pheromone traps @ 8 traps/ha for pest monitoring and 20 traps/ha for direct control through mass trapping</td>
</tr>
<tr>
<td>booting</td>
<td>Stem borers</td>
<td><strong>Apply carbofuran 3G @25kg/ha or fipronil 0.3 G @ 33 kg/ha in nursery at 5 to 7 days before uprooting the seedlings or spray with chlorpyriphos 20 EC @ 2,500 ml/ha or quininalphos 25 EC @ 2,000 ml/ha or lambda-cyhalothrin 5 EC@ 250ml/ha.</strong></td>
</tr>
<tr>
<td></td>
<td>Leaf-folders</td>
<td>Clipping of leaf tips of the seedlings at the time of transplanting will help in destruction of egg masses.</td>
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<tr>
<td></td>
<td></td>
<td>Removal of excess nursery and incorporation into soil.</td>
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<tr>
<td></td>
<td></td>
<td>Apply chlorantraniliprole 0.4 G @ 10kg/ ha or imidacloprid 0.3 G @15kg/ha or cartap 4 G @ 25 kg/ha or fipronil 0.3 G @ 25 kg/ha.</td>
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<tr>
<td></td>
<td></td>
<td>Install pheromone traps with 5 mg lure @ 8 traps/ha for pest monitoring or 20 traps/ha for direct control through mass trapping. Replace lures at 25 to 30 days interval during the crop period.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Inundative release of egg parasitoid, <em>Trichogramma japonicum</em> @ 100,000 adults/ha for 5 to 6 times starting from 15 days after transplanting.</td>
</tr>
<tr>
<td>Flowering to milky grain</td>
<td>Gundhi bug</td>
<td>Apply fipronil 0.3 G @ 25 kg/ha</td>
</tr>
<tr>
<td></td>
<td>Rice panicle mite</td>
<td>If possible, do alternate wetting and drying the field.</td>
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<td></td>
<td></td>
<td>Prepare alley at 6ft interval to facilitate the exposure of sunlight to the basal portion of the plant and spraying operation</td>
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<td></td>
<td></td>
<td>Don't apply nitrogenous fertilizer which will facilitate the BPH infestation</td>
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<td></td>
<td></td>
<td>Spray pymetrozine 50 WG @ 300g/ha or imidacloprid 200 SL @ 125 ml/ha or thiamethoxam 25WG @ 100 g/ha or ethofenprox 10 EC @ 500 ml/ha or acephate 75 WP @ 1000 g/ha or BPMC 50 EC @ 600 ml/ha.</td>
</tr>
<tr>
<td>Insect</td>
<td>Control Measures</td>
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</tr>
<tr>
<td><strong>Green leafhopper</strong></td>
<td>• Spray triflumezopyrim 10SC @ 234g/ha, pymetrozine 50 WG @ 300g/ha or flunicamid 50WG @ 150g/ha or dinetofuran 20SG@150g/ha or clothianidin 50WDG @20g/ha or imidacloprid 200 SL @ 125 ml/ha or thiamethoxam 25WG @ 100 g/ha.</td>
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<tr>
<td><strong>Hispa</strong></td>
<td>• Spray acephate 50 WP @ 700 g/ha or ethofenprox 10 EC @ 500 ml/ha or imidacloprid 200 SL @ 125 ml/ha or thiamethoxam 25 WG @ 100 g/ha. Alternatively, apply fipronil 0.3 G @ 25 kg/ha.</td>
<td></td>
</tr>
<tr>
<td><strong>Leaf folder</strong></td>
<td>• Spray acephate 50 WP @ 700 g/ha or ethofenprox 10 EC @ 500 ml/ha or imidacloprid 200 SL @ 125 ml/ha or thiamethoxam 25 WG @ 100 g/ha. Alternatively, apply fipronil 0.3 G @ 25 kg/ha.</td>
<td></td>
</tr>
<tr>
<td><strong>Whorl maggot</strong></td>
<td>• Apply fipronil 0.3 G @ 25 kg/ha or chlorpyriphos 20 EC @ 1,500 ml/ha</td>
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</tr>
<tr>
<td><strong>Case worm</strong></td>
<td>• Drain water from the field and spray carbaryl 50 WP @ 1000 g/ha or apply carbaryl 10DP @ 25 kg/ha</td>
<td></td>
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<tr>
<td><strong>Mealy bug</strong></td>
<td>• Spot application of phorate 10 G granules</td>
<td></td>
</tr>
<tr>
<td><strong>Stem-borer</strong></td>
<td>• If possible, do alternate wetting and drying the field. • Prepare alley at 6ft interval to facilitate the exposure of sunlight to the basal portion of the plant and spraying operation. • Don't apply nitrogenous fertilizer which will facilitate the BPH infestation. • Spray triflumezopyrim 10SC@ 234g/ha, pymetrozine 50 WG @ 300g/ha or flunicamid 50WG @ 150g/ha or dinetofuran 20SG@150g/ha or clothianidin 50WDG @20g/ha or imidacloprid 200 SL @ 125 ml/ha or thiamethoxam 25WG @ 100 g/ha. • Resurgence causing insecticides like chlorpyriphos or synthetic pyrethroids (cypermethrin, deltamethrin) or quinalphos or methyl parathion should not be sprayed. • During spraying, keep the nozzle towards the basal portion of the plant as the nymphs and adults of BPH rest in the basal zone.</td>
<td></td>
</tr>
<tr>
<td><strong>Brown planthopper, White backed planthopper</strong></td>
<td>• Spray chlorantraniliprole 18.5 SC @ 150ml/ ha or flubendiamide 20 WG @125g/ha or chlorpyriphos 20 EC @ 1,500 ml/ha or carbaryl 50 WP @ 1000 g/ha or quinalphos 20 EC @ 1250 ml/ha or chlordantraniliprole 18.5 SC @ 150ml/ ha or flubendiamide 20 WG @125g/ha or chlorpyriphos 20 EC @ 1,500 ml/ha or carbaryl 50 WP @ 1000 g/ha or fipronil 5 SC @ 600 ml/ha or triazophos 40 EC @ 1250 ml/ha. • Inundative release of egg parasitoid, <em>Trichogramma chilonis</em> 5 to 6 times @ 100,000 adults/ha starting from 15 days after transplanting</td>
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<td></td>
</tr>
</tbody>
</table>

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67
<table>
<thead>
<tr>
<th>Issue</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ear-cutting caterpillar/ cut worm</td>
<td>Spray quinalphos 25 EC @ 1,600 ml/ha or chlorpyrifos 20EC @ 2,000 ml/ha or carbaryl 50 WP @ 1,500 g/ha</td>
</tr>
<tr>
<td>Leaf/Panicle mite</td>
<td>Spray sulphur wettable powder @ 3 g/lit, dicofol @ 5.0 ml/lit or profenophos 50 EC @ 2.0 ml/liter water.</td>
</tr>
<tr>
<td>Gundhi bug</td>
<td>Spray carbaryl 50 WP @ 1,500 g/ha during afternoon hours.</td>
</tr>
<tr>
<td></td>
<td>Dust methyl parathion 2 D @ 25kg/ha or malathion or carbaryl 10DP @ 30 kg /ha</td>
</tr>
</tbody>
</table>
Beneficial Use of Microbial Resources for Rice
Upendra Kumar
*ukumarmb@gmail.com
ICAR-National Rice Research Institute, Cuttack-753006

Rice is staple food of almost the entire population of Odisha, which covers about 69% of the cultivated area; therefore, the state economy is directly linked with improvements in production and productivity of rice. The rice production in Odisha mainly depends on only chemical fertilizers. Indiscriminate and imbalanced use of chemical fertilizers, especially urea, along with chemical pesticides and unavailability of organic manures has led to considerable reduction in soil health and collapsing sustainability of the agriculture systems. Odisha’s food grain requirement to feed the estimated population of 46.5 million by 2020 will be 13 million tonnes which will require about 2 million tonnes of nutrients (1.25 million tonnes for food grains and 0.75 million tonnes of nutrients for other crops) from various sources of plant nutrients, i.e. fertilizers, organic manures and bio fertilizers, while their availability will be only 1.2 million tonnes being a deficit of about 0.8 million tonnes.

Today, biofertilizers have emerged as a highly potent alternative to chemical fertilizers due to their eco-friendly, easy to apply, non-toxic and cost effective nature which can fulfill the demand of chemical fertilizer of Odisha. In addition, biofertilizers are one of the promising technologies for agricultural productions which are not popular among farming community particularly rice growers in Odisha due to lack of knowledge and awareness to use in an effective way. However, government has taken many steps to improve use of application of bio fertilizers in agriculture.

Biofertilizers means the product containing carrier based (solid or liquid) living microorganisms which are agriculturally useful in terms of nitrogen fixation, phosphorus solubilization or nutrient mobilization, to increase the productivity of the soil and/or crop plants. The commercial history of bio-fertilizers began with the launch of ‘Nitratin’ by Nobbe and Hiltner, a laboratory culture of Rhizobia in 1895, followed by the discovery of Azotobacter, Azospirillum, blue green algae, Arbuscular Micorrhizae (AM) and Azolla. In India, the Ministry of Agriculture, Department of Agriculture and Cooperation, Government of India, New Delhi, vide their order dated 24th March, 2006 included bio-fertilizers under section 3 of the Essential Commodities Act, 1955 (10 of 1955), in Fertilizer Control Order (FCO), 1985.

Biofertilizers productions is always demand driven, creation of demand among farmers is one of the most important steps required towards promotion of biofertilizers. Research and development efforts by the government and research organizations have brought remarkable programmes in production and wide use of Biofertilizers in the country, its potential requirement exceeds the actual production (Parr et al., 1994). However, data revealed that the more than 50% production of biofertilizers is localized on southern part of Indian states and only 2% is produced by eastern states including Odisha (Fig. 1), which may not fulfill the requirement of farming community of Odisha. Moreover, 86% of total production of biofertilizers is produced by six states (Tamil Nadu, Karnataka, Kerala, Andhra Pradesh, Uttar Pradesh, Maharashtra, Gujarat, Madhya Pradesh) of India (Fig. 2), whereas negligible (0.8%)
amount of biofertilizers are produced by Odisha (NCOF, 2013) which is also an indicator of lack of interest towards biofertilizer by Odisha farming community.

To attain production targets, the Govt. of India implemented a central sector scheme called National Project on Development and use of Biofertilizers (NPDB) during the Ninth Plan for the production, distribution and promotion of biofertilizers. A National Biofertilizers Development Centre was established at Ghaziabad as a subordinate office of the Department of Agriculture and Cooperation with six regional centres (Ghosh, 2004), however, these units only partially fulfill the large distribution networks over larger areas. Public sector fertilizers giant IFFCO is located in Phulpur (Uttar Pradesh) and produces all strains of Biofertilizers and have distributed it in all states. However, IFFCO plant at Paradeep (Odisha) is producing biofertilizers which supplies only little part of Odisha and that too for non-rice crop. Recently, OUAT established a biofertilizer plant through RKVY grant for supplying Rhizobium inoculants for pulses but not for rice crop. Therefore, it is essential to establish a biofertilizer plant at ICAR-National Rice Research Institute, Cuttack (Odisha), not only to produce bioinoculants for rice and rice-based system but also making awareness about biofertilizer and its application in field by farming community (each year >2500 farmers visitors) of the eastern states including Odisha and also producing and supplying quality inoculants which is lacking in the most of the distribution system because biofertilizers are sold without strict control over quality production. ISI specifications are formulated already only for some biofertilizers and yet location-specific strains are to be developed. Facilities and regulatory acts for testing biofertilizers are meager and carrier material of long shelf life is not available. Low productivity, unpredictable climatic swings and low dosage of chemical fertilizers also characteristics of agriculture in dry lands (Tittabutr, 2012).

Based on nutrient requirements of rice crops, ICAR-National Rice Research Institute, Cuttack has developed many strains of nitrogen fixing, phosphate solubilizing and mobilizing microbial inoculat es especially for rice crop which can reduce the nitrogen and phosphorous requirement by 20 and 25%, respectively without declining the crop yield. Some of the microbial inoculants produced at NRRI, Cuttack are shown in Fig. 3.

In view of the above, there is urgently required to setting up of biofertilizer production unit for supplying of quality bioinoculants to farming community cultivated rice and rice-based crops in Odisha.
Fig. 3. Microbial bioinoculants especially for rice crop are available at NRRI, Cuttack such as (a) liquid bioinoculant of endophytic nitrogen fixing Azotobacter chroococcum strain AVi2 (MCC no. 3432; KP099933); (b) rhizospheric Azotobacter vinelandii strain SRIAz3 (JQ796077); (c) Soil-based sporocarp formulation of Azolla; (d) Arbuscular mycorrhiza; (e) 102 strains of Azolla germplasms maintained at microbiology nethouse of NRRI, Cuttack. In addition to these, we also have two liquid formulations of phosphate solubilizing bacteria and two exopolysachharide producing liquid bioinoculants especially for rice crop.

PROBLEMS TO BE ADDRESSED

Rice is the most important food crop of Odisha. Nearly 70% of the state’s population directly or indirectly depends upon rice cultivation. It is grown in an area of 41.8 lakh ha with productivity of 1821 kg/ha (rice) during 2013-14. To sustain the production and productivity of rice in Odisha, we must address following issues especially in nutrient prospective through biofertilizer (Table 1).

1. Odisha encountered a fertilizer deficit of 0.8 m tones annually and even it does not fulfill demand through biofertilizer because of very negligible amount (0.8%) of total biofertilizers are produced by Odisha compared to other states of India. Therefore, there is a need to establish a biofertilizer unit which may fulfill the requirement of rice farming community.
2. There is very rare rice-specific biofertilizers is available in Odisha. Hence, it is mandate to develop a rice-specific biofertilizer, which is presently available at NRRI, Cuttack (Table 1; Fig. 1).
3. Government is taking serious steps to bring down use of urea as nitrogen fertilizers for rice-based cropping system, because it acts as a slow poison to deteriorate soil health and also causes methane and nitrous oxide emission which are responsible for climate change. Hence, encouragement to use biofertilizers among farming community may solve this problem in some extent.
4. Some of the farmers are not having faith on use of biofertilizers because of lots of spurious bioproducts/biofertilizers available in market, which is not giving encouraging results; hence state government should take some initiative to supply quality products to the farming community. The present project proposal submitted by us may solve this problem.

5. Most of the farmers of the Odisha are not aware about importance of biofertilizer, hence, it is mandate to give a proper training, awareness programme, field demonstration trial, hands on training etc. In this regard, NRRI Cuttack plays a crucial role because around >5000 farmers annually visiting here across eastern states to acquire recent development in rice cultivation. NRRI also known for giving successful training on sustainable development of rice cultivation in eastern India.

6. Now we have to double the farm income by cutting down the input cost. Farmers are generally investing most of the money towards nutrient management. Hence, we have to identify cost-effective nutrient management practices and it will be fulfilled by biofertilizers (Table 2).

Table 1. Recommendation of bio-fertilizers for rice crop

<table>
<thead>
<tr>
<th>Inoculants</th>
<th>Recommendations</th>
<th>Nutrients supply to plants</th>
<th>Increase of grain yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>BGA</td>
<td>50-60 kg fresh wt/ha (or) 6-7 kg dry weight</td>
<td>20-25 kg/ha/season</td>
<td>10-20%</td>
</tr>
<tr>
<td>Azolla</td>
<td>10-15 t fresh wt/ha</td>
<td>20-40 kgN/ha/20-75 days</td>
<td>10-30%</td>
</tr>
<tr>
<td>Azotobacter</td>
<td>5-6 kg solid/500 ml liquid/ha</td>
<td>5-10 kg N/ha</td>
<td>5-15%</td>
</tr>
<tr>
<td>AM fungi</td>
<td>1 ton soil based inoculums/ha(Upland rice)</td>
<td>Supplemented 30% Phosphorus</td>
<td>15-25% (upland rice with crop rotation)</td>
</tr>
<tr>
<td>PSB</td>
<td>5-6 kg solid/500 ml liquid/ha</td>
<td>Supplemented 10-20% Phosphorus</td>
<td>5-15% (upland rice)</td>
</tr>
</tbody>
</table>

Table 2. Economic cost analysis of biofertilizers for rice crop

<table>
<thead>
<tr>
<th>Biofertilizer/crop</th>
<th>Quantity required lit/ha</th>
<th>Cost of application (Rs/ha)</th>
<th>Amount of nutrient mobilized kg/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Azotobacter</td>
<td>0.5 – 2.0 lit</td>
<td>80 - 400</td>
<td>20 - 25 kg N</td>
</tr>
<tr>
<td>Azoto + Azosp + PSB</td>
<td>0.5 – 2.0 lit</td>
<td>80 - 400</td>
<td>20 kg N + 12 kg P</td>
</tr>
<tr>
<td>Mixed inoculants</td>
<td>0.5 – 2.0 lit</td>
<td>80 - 400</td>
<td>25 kg N +15 kg P</td>
</tr>
<tr>
<td>Mycorrhiza</td>
<td>2.00 – 5.00 kg</td>
<td>200-500</td>
<td>20-25 kg P + micronutrients+ moisture</td>
</tr>
</tbody>
</table>
Career opportunities for candidates in Agricultural Social Sciences


Social Science Division,
ICAR-National Rice Research Institute, Cuttack-753006, India.

Introduction

Since the very beginning Social Science has played a very significant role in translating the research outputs and technologies into actionable practices and also assisted the top level policy making in using science for welfare of the nation. Globally, the agricultural sector is witnessing advancement in scientific knowledge; technological enhancement and new innovations. However, the newer challenges of resource depletion and degradation, climate change, varied biotic and abiotic stresses are also embracing agricultural sector world-wide. In this background, it is not only important to transfer the good agricultural practices (GAP) to the farmers, but it’s equally important to keep account of these detrimental changes to assist policy makers in addressing these challenges while exploiting the newer opportunities. Apart from it, if we consider agricultural sector as an industry and the research organizations as a firm, then the technologies produced by these organizations or any scientific knowledge provided by them would be a product. Under this school of thought, a social scientist has a very prominent role in accessing the attributes of demand from the end users and conveying the attributes to the firms for product improvement. Also, the forecasting of future trends based on past patterns is integral part of agricultural sciences. With scientific advancement in field of robotics, cloud computing, artificial intelligence, artificial neural network etc. data management, development of new algorithms and statistical models are gaining high attention. In such a vivid canvas, Social scientists/academicians have a crucial role to play. In this article specifically written for the agricultural graduates, we have provided some pathways for making their career in Social Sciences.

Dilemma of choice

During the final year of his/her graduation in agriculture, the candidate faces dilemma of choice. It’s the dilemma of choosing employment or higher education. However, it finally depends on the candidate to opt any one of them, based on his socio-economic conditions, prevailing circumstances and state of mind. After completion of his/her graduation one can opt any one subject group from list of 20 major groups and any one discipline from among 97 disciplines based on his/her eligibility. Generally, it is being observed that in Agricultural disciplines those opting higher education and has a sound academic track choose core science group with the perception of higher opportunities in those groups. However, Social Science group provides equal opportunities in academic as well as employment. For the candidates with interest in Sociology, Mathematics, Statistics, Computer and having good analytical skills and logical reasoning Social Science is the right career choice.
Social Sciences and Statistical Sciences at a glance

Social Science group is an umbrella which encompasses disciplines like Agricultural Economics, Dairy Economics, Agricultural Extension, Dairy Extension etc. while statistical science encompasses Agricultural Statistics, Computer Application and Bioinformatics in it. Agricultural economics is not only a discipline to study and earn for empty stomach. But it is highly applicable in almost every sphere of life for everyone. It is impossible for anyone to escape from the purview of laws of economics for their rational money related decisions. No one can take their money related decisions rationally without applying principles of economics knowingly or unknowingly. Its range of application varies from a beggar to a business tycoon; illiterate to highly literate; from producer to consumer and from birth to death of an individual. Agricultural extension helps one to develop their communication skills; in understanding rural psychology and rural setting to develop sound and realistic model for the delivery of Govt. programmes and schemes for welfare of masses. Similarly agricultural statistics also helps in data management and data analysis for making evidence based policy decisions. Now a days, computer application, bio-informatics and related fields have also mushroomed up from agricultural statistics which have tremendous application in research organizations and institutes.

Career opportunities in Social Sciences and Statistical Sciences

Every year, many prestigious national and international organisations recruit social scientists with sound subject knowledge and sharp analytical skills. Thus, for a social scientist the career is quite bright. This article is written specially in keeping in view the students of agricultural stream in their graduation. The whole of the article is presented in a tree form for the easy understanding of the readers of this article.

Social Science offers employment in both private as well as public sectors. After completion of Bachelors in Science in Agriculture if one wants to opt for Social Science group for higher education, Indian Council of Agricultural Research’s Junior Research Fellowship (ICAR-JRF) exam opens the door in major subjects namely Agricultural Economics, Agricultural Extension, Dairy Economics, Dairy Extension for Social Science aspirants. Similarly Statistical Sciences opens avenues in Agricultural Statistics, Computer Application and Bioinformatics. If the aspirant has good academic track record and scores in merit in JRF exam, ICAR provides fellowships to such candidates for their higher education in form of Rs. 12640/- per month and the aspirants can get admission in any one of the 72 SAUs/ 4 Deemed to be Universities/ 2 Central Universities and 2 Central Universities with agriculture faculty.

After completion of post-graduation in any of above disciplines he/she is eligible to appear for PhD in the disciplines of his/her choice during post-graduation. Also, he/she can be picked up by Multi-National Companies (MNCs) and research organization for conducting research as a Senior Research Fellow (SRF). During Ph.D. one can avail very handsome fellowship from ICAR or University Grant Commission (UGC) or Department of Science and Technology (DST) or can avail the most prestigious Prime Ministers Fellowship.

Now a day with modification in eligibility for the scientist and lecturer, only PhD holders can only be eligible for being recruited as scientists in various scientific organizations and institutions and lecturers in various academic institutions. Also the candidate with good academic record can be eligible for various posts not only in national institutes located in the country but also in various international research institutes situated worldwide. Various highly reputed financial institutions like World Bank, RBI, NABARD,Scheduled Commercial Banks
and others also recruit enough numbers of economists, statisticians and extension experts at a very lucrative pay scale. Apart from these financial institutions various prestigious international research organization like FAO, CGIAR etc. also offers project positions to the such fellows with sound knowledge of the subject matter as well as excellent analytical skills. Thus, for a good social scientist many chairs are waiting at various high esteemed prestigious global as well as national institutions as well as Governmental organisations and non-governmental organisations.

But, you should know it very clear that to be a good social scientist you must have sound grip on mathematics, statistics and computer. Along with these three basic needs you must have good analytical ability and you should be updated with latest socio-economic happenings of your country as well as of the world. After all you must have an enthusiasm to learn new things in the area and to apply your theoretical knowledge into practice. All these things would make you an eminent expert in field of Social Science.

All the interested and enthusiastic candidates with the zeal and interest to learn and apply principles of sociology in their life and to choose it as their career profession should know about the career pathways in Social Sciences. The following tree diagram shows the employment opportunities in social science after post-graduation and also briefs about the job opportunities just after graduation.
Fig. 1: Career pathway after B.Sc. Agriculture and post-graduation in Social and Statistical Sciences
Reference Books for the candidates in Social Science group

For the easy reference of candidates, we provide some of the standard reference books that would be useful for an aspirant to crack the competitive exams in Social Science group.

Table 1: List of reference books for ICAR- JRF Exams in Social Science group

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Books</th>
<th>Author</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Agricultural Economics</td>
<td>Subba Reddy and Bhavani Devi</td>
</tr>
<tr>
<td>2.</td>
<td>Agricultural Finance and Management</td>
<td>Subba Reddy and P. Raghuram</td>
</tr>
<tr>
<td>3.</td>
<td>Economics of farm production and management</td>
<td>V. T. Raju</td>
</tr>
<tr>
<td>4.</td>
<td>Fundamentals of farm business management</td>
<td>Johland Kapoor</td>
</tr>
<tr>
<td>5.</td>
<td>Advance Economic Theory</td>
<td>H.L. Ahuja</td>
</tr>
<tr>
<td>7.</td>
<td>Agricultural Marketing in India</td>
<td>Acharya and Agarwal</td>
</tr>
<tr>
<td>8.</td>
<td>An Introduction to Agricultural Social Sciences</td>
<td>Subhash Chandra (Must Read)</td>
</tr>
<tr>
<td>9.</td>
<td>Objective Agricultural Economics</td>
<td>K.N. Ravi Kumar</td>
</tr>
<tr>
<td>10.</td>
<td>Extension Education</td>
<td>Adivi Reddy</td>
</tr>
<tr>
<td>11.</td>
<td>Extension Communication and Management</td>
<td>G.L. Ray</td>
</tr>
<tr>
<td>12.</td>
<td>Objective Agricultural Extension</td>
<td>V.G. Sunil</td>
</tr>
<tr>
<td>13.</td>
<td>Objective Extension</td>
<td>Shruti</td>
</tr>
<tr>
<td>15.</td>
<td>Objective Statistics</td>
<td>B.L. Agarwal</td>
</tr>
</tbody>
</table>

“The economy depends about as much on economists as weather does on weather forecasters.”

- Anonymous
Choosing agricultural engineering for his/her B.Tech degree, the candidate has the option of opting either farm machinery, soil and water conservation engineering or agricultural process engineering for pursuing his higher studies. Selection of right subjects to build a future in agricultural engineering is a strenuous job. The easy path that the candidate opts is by asking his close friends or seniors but hiding his subject of interest because he is not confident enough to track his subject. However, there is a solution to every problem. Candidate showing interest in mathematics, designing and statistics can choose Agricultural process engineering/Agricultural Structures and Process Engineering/ Food Process engineering as one of his career options.

As known, food is one of the paramount factors that have made things alive on earth. Not a single human can survive without food, may it be a beggar or an aristocrat. Each and every person consumes food in one or the other form such as raw (fresh vegetables and fruits), minimally processed (fresh cut fruits), processed (chips, pizzas, biscuits) etc. These forms of food intake require different techniques for its preparation and processing which makes the food unique in taste, flavour and aroma. Building a future in a subject which is an integral part of human life always sounds interesting. Thus, for a beginner to enter into the field of food processing should have a sound knowledge of career opportunities before actually proceeding ahead blindly.

Each and every year, many prestigious national and international organisations (both govt. and private) recruit food experts with good knowledge of subject matter and sharp analytical skills. Hence forth, the career in process engineering is bright enough for a good student. This article is written specially in keeping in view the students of agricultural engineering stream in their graduation. The whole of the article is presented in a block form for the easy understanding of the readers of this article.

Figure 1 gives a brief exposure to the readers about the career opportunities for a beginner in the area of Agricultural Process Engineering. This is just a window which on
opening shows how to proceed further in the arena of Agricultural Process Engineering. There is no dearth of job opportunities in agricultural engineering. The candidate can seek jobs in different NGOs, private companies like Jain irrigation, Mahindra, Nestle, etc. soon after completion of B. Tech degree with a handsome pay package. However, pursuing higher studies widens the opportunities of achieving higher positions such as Scientist or Assistant professor in reputed institutes/universities. While studying M.Tech and/or Ph.D. in the said discipline in India or abroad, the candidate gets national/ international fellowship as well as industrial visit to different food industries like Amul, Britannia, Yakult, etc. Though after completing M.Sc. and PhD in Process Engineering with good academic record, one can be eligible for various posts not only in national institutes located in the country but also in various international research institutes situated worldwide. Various highly reputed food safety regulators like FSSAI (Food Safety and Standards Authority of India), FAO (Food and Agricultural Organization), WHO (World Health Organization), FCI (Food Corporation of India), etc. also recruit enough numbers of the experts in food process engineering with a good pay package. Apart from these, the candidates can work in different projects of international institutes such as IRRI, FAO etc. or can come up with his own start-ups (as entrepreneur) with a strong base of the subject as well as excellent analytical skills. Thus, for a good food specialist, many chairs are waiting at various high esteemed prestigious global as well as national institutions as well as Governmental organisations and non- governmental organisations.
But, we all know that the path of success is always made of thorns. You must know your subject well and know the trend of the market, consumer acceptability of products so that you can come up with new ideas and do innovative research. You can also think of how to minimize both the food loss and food waste by acting on value addition. This subject is quite interesting because you always get an opportunity to work on what you eat.

In the scenario when the country incurs an annual loss of Rs. 92,651 crores due to agricultural losses, the role of agricultural process engineers is vital. So, it’s a wakeup call for all the interested and enthusiastic candidates with the zeal and interest to learn new techniques and methods in process engineering and come out with innovative ideas to mould the food we eat daily and to choose it as their career profession.
Rice (Oryza sativa) is one of the most important cereal crops and staple food for more than half of the world’s population mostly grown in developing countries of Asia, Africa, and Latin America and many other regions of the world. India is the second largest producer and consumer of rice in the world. The level of mechanization is directly related with the production and productivity. The estimated levels of mechanization of various farm operations in India are: 40% for tillage, 30% for seeding/planting, 37% for irrigation and 48% for threshing of wheat, 5% for threshing of rest of the crops and 35% for plant protection (CIAE, Bhopal). The productivity of rice in Punjab, Haryana and Western UP was more than other states because average farm power availability is more than 1.5 kW. In eastern states of India namely, West Bengal, Bihar Odisha and Jharkhand, the availability of farm power is 1.25, 0.80, 0.60 and 0.60 kW ha\(^{-1}\) respectively which is less than that of the average farm power availability of India (1.5 kW ha\(^{-1}\)) because of involvement of the draught animals and human muscle power as the major power sources for agriculture (http://farmech.dac.gov.in). The average farm power availability and productivity of Indian agriculture increased from 0.25 to 1.84 kW ha\(^{-1}\) and from 0.52 t ha\(^{-1}\) to 1.92 t ha\(^{-1}\), respectively over the years from 1951 to 2012.

There is shortage of farm labours and declining interest of youths in agriculture. With increase in wage rate of farm workers along with cost of other inputs, rice farming is gradually becoming less remunerative. Farm machinery and equipment provide a package of technology to (i) increase land productivity by improved timeliness of operations, reduced crop losses and improved quality of agro-produce; (ii) increase efficiency of inputs used through their efficient measurement and placement; (iii) increase labour productivity by using labour saving and drudgery reducing devices, and (iv) reduce cost of cultivation. Improved agricultural tools and equipment are estimated to contribute to the food and agricultural production in India by savings in seeds (15-20%), fertilizers (15-20%), time (20-30%), and labour (20-30%); and also by increase in cropping intensity (5-20%), and productivity (10-15%). International and national experiences have established the benefits of engineering inputs in terms of enhanced productivity by about 15% and reduction in cost of production by 20%, apart from increase in cropping intensity (20%), timeliness in farm operations and drudgery reduction (Mehta et al., 2014).

Over these years there was rapid shift in farm power uses from animal power to mechanical power. Mechanical power helps in timely farm operations with low labour and cost, but reduction in animal uses on farms increases the problem of crop biomass burning, especially paddy straw in northern India. Mechanization of traditional rice farming practices can overcome this crisis and help in drudgery reduction. NRRI has significant role in developing improved rice machinery. Here information about these machines/implements is discussed in details as follows:
1. Bullock drawn tillage implements:
Bullock drawn harrows were developed for use by small and medium land holding farmers to prepare the field after initial ploughing operation. NRRI two gang notch type disc harrow is developed for puddling the field. It has two gang with 2 notch type disc mounted over each hollow drum. It has provision for adding weight (sand) inside the drum to get better penetration in the soil. The two gangs are coupled in such way that it, can be pulled by a pair of bullock. Disc harrow is made by using Angle iron, MS sheet, notch discs etc. Its field capacity is 0.35 ha h⁻¹. This equipment can be used in light as well as heavy soils by increasing and decreasing the weight. On similar working principle NRRI drum type disc harrow with 3 plane disc mounted over each hollow drum was developed.

2. Sowing implements
Sowing implements have the most important role to mechanize the rice cultivation by replacing the traditional method of broadcasting in dry soil and manual transplanting in puddled soil condition. NRRI developed plenty of machines to mechanize the sowing operation. For dry direct sowing of rice row seeding is the most efficient means to sow the crops with optimum seed rate and also with maintained row to row spacing. Row seeding also promotes maximum tillering and better sunlight penetration to rice plants. Weeding cost is also reduced by using line sowing method.

2.1 Manual drawn sowing implements for dry sowing
2.1.1 Single row, two row & three row manual seed drill
To mechanize small land size farms these implements were developed. Provision of fluted roller metering mechanism was given to adjusted the seed rate as per required by the operator. Field capacity for these implements varies from 0.01 ha h⁻¹ to 0.04 ha h⁻¹. The machine saved seeds and labours in sowing of crops along the rows that helped in weeding and inter-culture operation
Single row, two row & three row manual seed drill

2.2 Power operated sowing implements for dry sowing
Manual operated machine requires higher human efforts and gives lower output. Time is constraint in sowing operation. It this operation delayed than possibly it affects the yield of the crop. If the field is prepared for dry sowing than timely sowing before monsoon is necessary for smooth operation of power operated machinery. So to handle all kind of land situations and get optimum seed rate for sowing here details about some improved machinery particularly for rice sowing are given:

2.2.1 Three row self-propelled hill seeder
For precise sowing of rice seeds in hills this machine is developed. Cup feed type metering mechanism (plastic wheels with grooves on its periphery)is provided in this machine. It has 3.5 HP petrol start kerosene driven engine as a source of power. The seed rate is controlled by varying the positioning of seed box. It is made by using Angle Iron, MS Flat, GI Sheet, Plastic wheels, Chain & sprocket etc. Its field capacity is 0.1 ha h⁻¹. It is suitable for dry hill seeding of rice with uniform hill spacing.

2.2.2 Power tiller operated multicrop seed drill
NRRI Five row power tiller operated seed drill was used for dry sowing of crop like rice, wheat, green gram, and black gram etc. It is mounted on the back side of power tiller. Machine is consists of seed box, flutted roller type seed metering mechanism, Frame, Furrow openers, ground wheel, power transmission system, ground wheel lifting mechanism, transport wheels and hitching mechanism. Seed rate adjusting lever is provided on the back side of seed box. Different seed rate for different crop can be adjusted by shifting the position of this lever. Its field capacity is 0.15 ha h⁻¹. There was no damage to rice seed in fluted roller when flaps were kept in down ward position.

2.3 Sowing implements for pre germinated seeds
However the dry sowing of rice needs less field preparation and less water as compare to puddling and transplanting but due to severe weed growth in dry sowing this technology is not that popular among farmers. Weeds are the main problem in adoption of dry sowing of rice. To improve farmers practice (Broadcast Biasi) efforts have been made by NRRI to develop some implements for line sowing in puddled soil conditions. Pre-germinated paddy seeding has
economical and operational advantages over traditional planting methods because it eliminates nursery raising, transportation and physical damage to the seedlings. It reduce the human drudgery in transplanting of paddy and reduce cost of cultivation. Here details of these implements are given:

2.3.1 Three row manual puddle seeder

It has float on the front to avoid sinkage of the machine. Metering device consists of plastic wheels having grooves on its periphery. The seed rate is controlled by varying the positioning of seed box. The seed rate is controlled by varying the positioning of seed box. It is made by using G.I. sheet, MS flat, Angle iron, MS Pipe, plastic wheels etc. Its field capacity is 0.15 ha h\(^{-1}\).

2.3.2 Six row manual drum seeder

Three drums each seed drum has two rows can be assembled to form 6 rows of seed drum. Wheels are provided at both ends. These wheels are made up of Light iron rods and adjustable floats are provided for easy operation under puddle field condition. GI sheet, MS flat, MS rod, MS pipe etc. material was used for manufacturing the implement. Its field capacity is 0.04 ha h\(^{-1}\). One human can easily pull this machine.

2.3.3 Eight row self-propelled seeder

It is an eight row, engine operated paddy seeder. It is suitable for sowing of sprouted paddy seed in puddled field. It is suitable for direct seeding of high yielding rice varieties. The machine comprised of a light weight diesel engine, power transmission system, seed drum, main frame, float, ground wheel and tail wheel. The self-propelled system reduces the human drudgery in transplanting of paddy and reduce cost of cultivation. This machine is made by using GI sheet, MS flat, MS rod, MS pipe, angle iron, power system of VST tiller 8 row transplanter and speed reduction gear box etc. Its field capacity is 0.24 ha h\(^{-1}\). It is suitable for sowing of sprouted paddy seed in puddled field.
3. **Four row manual rice transplanter**

The four row manual transplanter (NRRI design) was comprised of floats, a main frame assembly made of MS pipe that supported the seeding tray made of G.I sheet, pushing lever tray indexing mechanism, picker bar assembly and handle. Manual rice transplanter can be used for timely operation and reduced cost of cultivation with better crop yield. Its field capacity is 0.03 ha/h. It is suitable for transplanting of 20-25 days old mat type rice seedlings. It saves about 30-40% labour requirement and 40 % cost in transplanting operation.

4. **Weeding equipment’s**

Weeding is most laborious job in rice farming. By using some improved weeders farmers can minimize the time requirement and cost for the weeding.

4.1 **Finger weeder**

It can be used for upland as well as lowland rice. Operator moves the handle forward and backward so that the weeds get uprooted by both direction motion. The fingers of weeder can work between the rows and between the plants. The fingers have been suitably spaced so that there is no clogging during operation. One labour can operate this weeder. Its field capacity is 0.02 ha/h. It is low cost hand tool which reduced labour requirement by 35-40% and was found to be ergonomically suitable for farm women.

4.2 **Star-Cono-Weeder**
It is suitable for weed cutting, churning and mulching in wet land. The stars and conical drums cut the weeds and churn them into the soil. Float controls working depth and does not allow rotor assembly to sink in the puddle. It is operated by pushing-pulling action. The orientation of rotors create a back and forth movement in the top 3 to 5 cm of soil and helps in uprooting the weeds. The weeder is make by the use of MS flat, GI sheet, MS Pipe etc. It field capacity is 0.017 ha h⁻¹. It reduces labour requirement by 50-75 % and was found ergonomically suitable for local labour.

Finger weeder&star-cono-weeder

4.3 Single row self-propelled power weeder
Suitable for intercultural operations in upland rice. It consists of a petrol start kerosene run 1.03 kW engine, an engine mounting frame, the main frame, transmission system, jaw type clutch assembly, clutch control lever, handle, two transport wheels, rotary tine assembly, a support wheel and a rubber flap. Power from engine pulley was transmitted to clutch, shaft through belt & pulley to the rotary blade unit through a belt. Engine speed of 3600 rpm is reduced to 470 rpm at rotary blade. Power can be cut off to the rotary unit by operating the clutch control lever. Power operated weeder reduced the drudgery involved in weeding operation. It field capacity is 0.025 ha h⁻¹ and weeding efficiency is 65 % with no crop damage.

5. Harvesting equipment’s
5.1 Power operated paddy thresher
This thresher has wire loop type threshing drum. Rotational power to threshing drum is given by 1.0 hp single phase electric motor through belt and pulley. The machine consists of a basic
frame, threshing cylinder, prime mover, and power transmission unit. Two persons are required to undertake the threshing operation. It is economical and suitable for threshing of paddy to small and marginal farmer. Threshing capacity 0.3-0.4 t h\(^{-1}\) and threshing efficiency is 98.5%.

6. Post-Harvest machinery
6.1 Power operated rice winnower cum cleaner
It is a power operated machine to clean threshed paddy crop. The machine is made of mild steel and consists of a blower, an electric motor (1 hp), hopper, vibratory feeding tray, discharge chute with two screens (top scalping and bottom grading screen) and supporting frame with trolley wheels. The blower is of centrifugal type with long axis and straight blades. The length of the axis is equal to the width of the feeding tray. The two suction ends are provided with adjustable shutters to control the inflow of air. The delivery end opens just below the lower end of the feeding tray. Power is transmitted from the motor to the blower shaft and eccentric drive shaft through ‘V’ belts and pulleys. The eccentric drive is connected with the vibrating tray. The blower shaft and eccentric drive shaft rotate at around 700 rpm and 350 rpm respectively. With this, airflow and vibration of the tray are optimum for cleaning operation.

The hopper is truncated trapezoidal in shape opening on to the vibrating tray. An adjustable gate at the bottom opening of the hopper controls the feed rate of impure grain. The vibrating tray is hinged with the main frame at slight inclination. Thick wire strips are welded like teeth of a comb at the lower end of the tray.

The rectangular shaped discharge chute is fixed with the vibrating feeding tray below its lower end. One top scalping screen having slotted holes (2.8x19 mm) and one bottom grading screen having round holes (1.8 mm) are provided in this discharge chute for cleaning operation. A damper is provided along the chute to obstruct the airflow to prevent good grains blowing away with chaffs. The whole unit is mounted on trolley wheels along with a handle to make it movable. Cleaning capacity of power winnower cum cleaner is 0.5 t h\(^{-1}\)
Rice winnower cum cleaner

6.2 Mini Paddy Parboiling Unit
It is a small size parboiling unit to produce quality parboiled rice by employing improved process. The unit is cylindrical in shape and is made of 20 gauge mild steel sheet. The prototype however makes use of an empty oil barrel of 200 liters capacity to minimize its manufacturing cost. It comprises two chambers separated by a perforated partition at a lower level to enable both soaking and steaming in the same unit. A central G.I. pipe with perforated laterals is provided for uniform distribution of steam. A tap is provided just below the partition to drain out water. A watertight outlet is provided for discharging parboiled paddy.

The process involves soaking of paddy at 75\(^0\) C for 3.5 h followed by open steaming for 30-45 minutes. The process ensures uniform parboiling, without any bad smell and produces light coloured rice with better consumer preference. It takes 5-6 hours to parboil 75 kg of paddy in one batch.
6.3 Chaff and husk stove

It is a low cost technology with possible high benefits. The stove uses rice husk and chaff to provide heat energy for cooking. It works on the principle of gasification and induced natural air draft. It burns the husk or chaff without producing smoke. Sustainability rating of this technology is very high; it uses the available rice husk in the rural places. It consumes 1.5-2.0 kg husk in one batch and burns for 45 min –1 hr.

Reference
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<thead>
<tr>
<th>Sr. No.</th>
<th>Name</th>
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<tbody>
<tr>
<td>1</td>
<td>Sumit Suman</td>
<td>Vill-Hawaspur P.O.+P.S.- Mansurchak Dist- Begusarai, Bihar PIN- 851128</td>
</tr>
<tr>
<td>2</td>
<td>Suman Kumar</td>
<td>Laheri mohalla Biharsharif Dist- Nalanda PIN-803101</td>
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<tr>
<td>3</td>
<td>Prabeen Kumar Sahu</td>
<td>c/o-Dr. Prasant Kumar Sahu, Ward no.5, Belama street, Kotpad Dist.- Koraput Odisha PIN -764058</td>
</tr>
<tr>
<td>4</td>
<td>Mandeep Kumar Diwakar</td>
<td>House no. 79, Naini thana, Allahabad PIN - 211008</td>
</tr>
<tr>
<td>5</td>
<td>Naveen Kumar</td>
<td>Vill-rasidpur P.O/P.S – Sheohar Dist.- Sheohar Bihar PIN - 843329</td>
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<td>6</td>
<td>Unique Rishab</td>
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<td>Ravesh Choungad</td>
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<td>At-Baktarpur, PO - Matia, Dist-Kendrapara, Odisha, PIN-54215</td>
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<td>Dibyalochan Das</td>
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<td>Nidhish Kumar</td>
<td>Kali Asthan Tenduni PO – Bikramganj Dist- Rohtas Bihar PIN -802212</td>
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<td>Prashant Kumar</td>
<td>Vijyanagar, Rukanpura PO- B.V. College Dist. – Patna Bihar PIN -800014</td>
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<td>16</td>
<td>Navleen Kaur</td>
<td>R.K College Road, Kishori Lal Chowk, Madhubani, Bihar District- Madhubani PIN - 847211</td>
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<td>Hansa Mohanty</td>
<td>79, Bara Supervisor Flat, Sidhgora, Jamshedpur, Jharkhand PIN - 831009</td>
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<td>Debasis Das</td>
<td>At- Samalpur, Po- Balia, Via- Kuruda, PS - Industrial Area, Dist- Balasore, Odisha, 756056</td>
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