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# Coordinated Rice Improvement Project in India: Its Significant Achievements and Future prospects

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## ABSTRACT

*India is the second largest producer of rice in the world and it is the most important staple food grain. All India Coordinated Rice Improvement Project (AICRIP) was initiated with objective of conducting multi-location trials to identify suitable genotypes of high yield potential along with appropriate crop management practices. Since its inception AICRIP contributed significantly in meeting the growing demand both within and outside India. Significant progress has been achieved through AICRIP in terms of varietal release thereby increasing the crop productivity and also meeting the food and nutritional security. This paper makes a sincere effort in bringing out the significant achievements/milestones achieved under the AICRIP program and also gives a few directions for widening the areas under AICRIP.*

***Key words:*** *Rice, AICRIP, zones, varietal improvement, food and nutritional security*

## INTRODUCTION

Rice (*Oryza sativa* L.) is the staple food for millions of people across the globe. India leads in the area and is the second largest producer of rice. Rice is also the staple food for more than two thirds of population in India and contributes ~40% to the total food grain production. The crop is cultivated under diverse ecologies spread in about 44 million hectares (Mha) of area. In 2016-17 highest rice production of 109.7 million tonnes (Mt) from 43.19 Mha was recorded (Directorate of Economics & Statistics, Department of Agriculture, Cooperation and Farmers Welfare, Government of India). Area, production and yield of rice in India during 1950-51 to 2016-17 are presented in Table 1. The leading rice producing states are West Bengal, Uttar Pradesh, Punjab, Chhattisgarh, Bihar and Andhra Pradesh. About 40% of the rice area in India is rainfed and >70% is in eastern India. Out of the total rainfed area, 23% are rainfed upland and the rest is under rainfed lowland. The entire rainfed upland and 52% rainfed lowlands are drought prone. About 17% of rainfed lowlands are flood prone.

Rice is a tropical plant and usually requires high temperature and high humidity for healthy growth. The required mean monthly temperature is ~ 24°C. It should be 20°-22°C at the time of sowing, 23°-25°C during growth and 25°-30°C at harvesting time. The average annual rainfall required for rice is about 150 cm. Rice can be grown on a variety of soils with certain tolerance to both acidic as well as alkaline conditions. Loam and lighter soils and black soil is also suitable for rice cultivation. The burgeoning population across the globe requires increased production of rice to meet their food demands. It is projected that India should produce about 120 Mt of rice by the year 2025 *i.e.*, an additional production of about 1.5 Mt per year. This increased production has to necessarily come from increased productivity rather than increase in area under rice and that too under deteriorating soil, water and other natural resources. Food grain production in India has undergone rapid strides in producing the different crops output ensuring regular supply of food grains since the establishment of coordinated research carried out in multi-location and multi-disciplinary approach in different crops. The present paper articulates the salient

**Table 1.** All India area, production and yield of rice from 1950-51 to 2016-17.

| Year | Area | Production | Yield |
|---|---|---|---|
| 1950-51 | 30.81 | 20.58 | 668 |
| 1951-52 | 29.83 | 21.3 | 714 |
| 1952-53 | 29.97 | 22.9 | 764 |
| 1953-54 | 31.29 | 28.21 | 902 |
| 1954-55 | 30.77 | 25.22 | 820 |
| 1955-56 | 31.52 | 27.56 | 874 |
| 1956-57 | 32.28 | 29.04 | 900 |
| 1957-58 | 32.3 | 25.53 | 790 |
| 1958-59 | 33.17 | 30.85 | 930 |
| 1959-60 | 33.82 | 31.68 | 937 |
| 1960-61 | 34.13 | 34.58 | 1013 |
| 1961-62 | 34.69 | 35.66 | 1028 |
| 1962-63 | 35.69 | 33.21 | 931 |
| 1963-64 | 35.81 | 37 | 1033 |
| 1964-65 | 36.46 | 39.31 | 1078 |
| 1965-66 | 35.47 | 30.59 | 862 |
| 1966-67 | 35.25 | 30.44 | 864 |
| 1967-68 | 36.44 | 37.61 | 1032 |
| 1968-69 | 36.97 | 39.76 | 1075 |
| 1969-70 | 37.68 | 40.43 | 1073 |
| 1970-71 | 37.59 | 42.22 | 1123 |
| 1971-72 | 37.76 | 43.07 | 1141 |
| 1972-73 | 36.69 | 39.24 | 1070 |
| 1973-74 | 38.29 | 44.05 | 1150 |
| 1974-75 | 37.89 | 39.58 | 1045 |
| 1975-76 | 39.48 | 48.74 | 1235 |
| 1976-77 | 38.51 | 41.92 | 1089 |
| 1977-78 | 40.28 | 52.67 | 1308 |
| 1978-79 | 40.48 | 53.77 | 1328 |
| 1979-80 | 39.42 | 42.33 | 1074 |
| 1980-81 | 40.15 | 53.63 | 1336 |
| 1981-82 | 40.71 | 53.25 | 1308 |
| 1982-83 | 38.26 | 47.12 | 1232 |
| 1983-84 | 41.24 | 60.1 | 1457 |
| 1984-85 | 41.16 | 58.34 | 1417 |
| 1985-86 | 41.14 | 63.83 | 1552 |
| 1986-87 | 41.17 | 60.56 | 1471 |
| 1987-88 | 38.81 | 56.86 | 1465 |
| 1988-89 | 41.73 | 70.49 | 1689 |
| 1989-90 | 42.17 | 73.57 | 1745 |
| 1990-91 | 42.69 | 74.29 | 1740 |
| 1991-92 | 42.65 | 74.68 | 1751 |
| 1992-93 | 41.78 | 72.86 | 1744 |
| 1993-94 | 42.54 | 80.3 | 1888 |
| 1994-95 | 42.81 | 81.81 | 1911 |
| 1995-96 | 42.84 | 76.98 | 1797 |
| 1996-97 | 43.43 | 81.73 | 1882 |
| 1997-98 | 43.45 | 82.54 | 1900 |
| 1998-99 | 44.8 | 86.08 | 1921 |
| 1999-2000 | 45.16 | 89.68 | 1986 |
| 2000-01 | 44.71 | 84.98 | 1901 |
| 2001-02 | 44.9 | 93.34 | 2079 |
| 2002-03 | 41.18 | 71.82 | 1744 |
| 2003-04 | 42.59 | 88.53 | 2079 |
| 2004-05 | 41.91 | 83.13 | 1984 |
| 2005-06 | 43.66 | 91.79 | 2102 |
| 2006-07 | 43.81 | 93.36 | 2131 |
| 2007-08 | 43.91 | 96.69 | 2202 |
| 2008-09 | 45.54 | 99.18 | 2178 |
| 2009-10 | 41.92 | 89.09 | 2125 |
| 2010-11 | 42.86 | 95.98 | 2239 |
| 2011-12 | 44.01 | 105.3 | 2393 |
| 2012-13 | 42.75 | 105.24 | 2462 |
| 2013-14 | 44.13 | 106.65 | 2416 |
| 2014-15 | 44.11 | 105.48 | 2391 |
| 2015-16 | 43.49 | 104.41 | 2400 |
| 2016-17 | 43.19 | 109.70 | 2550 |

(Area - Million hectares, Production - Million tonnes, Yield - Kg/hectare) Source: Directorate of Economics & Statistics, Department of Agriculture, Cooperation and Farmers welfare, Government of India.

achievements of the All India Rice Coordinated Improvement Project (AICRIP) and its future prospects to cater the projected demand of rice and diverse interest of stakeholders associated with rice.

## Rice ecosystems in India

Rice is grown under highly diverse conditions in India with area spread between $79^0$ to $90^0$E longitude and $16^0$ to $28^0$ N latitude. It is cultivated mostly as a rainfed crop in areas with unpredictable rainfall pattern and distribution. It is also cultivated in submergence prone areas where water level could reach 2-3 m or more. Rice is cultivated from below sea level (as in Kuttanad district of Kerala) and at an altitude of 2000 msl (6600 ft) in Jammu and Kashmir. Further, it is also grown in areas where the temperatures of 4-45$^0$C are recorded and average annual rainfall is from 31-67 mm in Rajasthan to 2818 mm in Assam. A wide range of rainfall distribution pattern (drought, submergence, deep water) and distinct differences in soils (coastal and inland salinity, alkalinity, acidity), agro-climatic situations (high humidity) and seasons has resulted in the cultivation of thousands of varieties and one can see a standing rice crop at some parts of the country or the other in any time of the year. The above-mentioned diverse ecosystems are also the cause for low productivity of rice in India.

## Major ecologies of rice in India

The four major ecologies/systems of rice are described below:

♦ Irrigated rice eco-system: In India, total area under irrigated rice is about 22.0 Mha, which accounts

for about 50% of the total area under rice crop in the country and includes Punjab, Haryana, Uttar Pradesh, Jammu & Kashmir, Andhra Pradesh, Telangana, Tamil Nadu, Karnataka, Himachal Pradesh and Gujarat etc. Globally, irrigated system provides 75% of total rice production.

♦ Rainfed upland rice ecosystem: Total area under rainfed upland rice in the country is about 6.0 Mha, which accounts for 13.5% of total area under rice located mainly in eastern zone - Assam, Bihar, Eastern Uttar Pradesh, Madhya Pradesh, Odisha, West Bengal and NEH Region. The rainfed upland ecosystem is drought prone.

♦ Rainfed lowland rice ecosystem: In India, lowland rice area is about 14.0 Mha, which accounts for about 32% of the total area under rice in the country located mainly in eastern India and is characterized by poor soil quality. It is drought/flood prone due to erratic rains.

♦ Flood-prone rice ecosystem: It occupies about 2.5 Mha in eastern states of the country. Research programme on development of submergence tolerant rice varieties is crucial for improving productivity of such areas.

Besides, about 1.0-2.0 Mha area is affected by salinity. Thus, the different ecosystems under which rice is cultivated may be broadly classified as (i) irrigated, (ii) rainfed lowland, (iii) rainfed upland and (iv) deep water (Fig. 1). Among these, further sub-systems are usually identified to take location-specific variations such as 'favourable' or 'unfavourable' moisture, temperature; proneness to drought, submergence, both drought and submergence; growth duration (early, medium, late maturity groups) and low light intensity conditions. Depending on the patterns of rainfall distribution, rice is cultivated as rainfed upland crop in Jharkhand, Chhattisgarh and Western Odisha (Jeypore) and parts of West Bengal (Purulia and Bankura districts). It is also grown in shallow (up to 30 cm), semi-deep (30-100 cm) and deep-water (>100 cm) ecosystems in eastern Uttar Pradesh, Bihar, West Bengal, Assam and Odisha.

## Some important rice research events in India

♦ Indian Council of Agricultural Research (ICAR) was established in 1929 and initiation of rice research


**Fig. 1.** Different rice ecologies in India.

in several states that led to establishment of 82 research stations in 14 states by 1950.

♦ Introductions of rice varieties were done from other countries *viz*., Shinei, China 45, China 988 and China 1039 were successful introductions. These efforts led to the identification of 445 improved lines, mostly based on pure line selection.

♦ Establishment of CRRI (now NRRI) in 1946 at Cuttack, Odisha.

♦ Establishment of AICRP on Rice in 1965 at Hyderabad, Andhra Pradesh.

♦ Establishment of DRR (now IIRR) in 1974 at Hyderabad, Andhra Pradesh.

♦ A collaborative project of *japonica*/*indica* hybridization started in South-East Asian countries in 1952 by FAO.

♦ A parallel scheme with similar objectives was adopted by ICAR. These two projects used 192 improved indica varieties selected by the participating Asian countries and Indian states and produced a total of 710 *japonica*/*indica* hybrids. The $F_1$ seeds were distributed to the participating countries or states for growing the $F_2$ and subsequent generations and to breed

varieties suited to local conditions. The success was witnessed in the release of Malinja and Mashuri in Malaysia, ADT 27 in India and Circna in Australia.

♦ Another scheme was launched by the then Central Rice Research Institute (CRRI) in 1960 to breed high yielding fertilizer responsive hybrid varieties with *japonicas* in 11 states.

♦ Crosses were effected between indicas and bulus at CRRI, Cuttack CR 1014, a late maturing tall and non-lodging variety with medium slender grains and good cooking quality was developed from the cross T 90/Urang Urangan.

♦ The development of Taichung Native 1 from the semi-dwarf mutant Dee-Geo-Woo-Gen (DGWG), Taiwan and Tsai Yuan Chung of China was a major event in rice research in Asia.

♦ In 1966, scientists at IRRI developed IR8, while Indian scientists developed and released Jaya and Padma in 1967 and 1968, respectively. Both these varieties were semi-dwarf possessing sturdy stems, photo-insensitivity, fertilizer responsiveness and high yield and became quickly popular with farmers and ushered the green revolution in rice in Asia.

♦ ICAR institutes/AICRP (Rice) continued their concerted efforts to develop and release a number of high yielding varieties, which were widely adopted by farmers and played an important role in enhancing the rice production in the country. Some of these varieties are Jaya, Swarna, Samba Mahsuri, MTU 1010, NDR 359, Improved Samba Mashuri, Jyothi, Sarju 52, Pooja, Lalat, Ratna, Ranjit, Sahabhagi Dhan, PB1, PB 1509 and PB 1121.

## The All India Coordinated Research Project (AICRP) on Rice: An overview

The All India Coordinated Rice Improvement Project (AICRIP) was established at Hyderabad by ICAR in 1965. The mandate at that time was the development of an integrated national network of cooperative experimentation on all aspects of rice production to accelerate breeding efforts with semi dwarf varieties. The Rockefeller Foundation, IRRI and US Agency for International Development (USAID) extended personnel and financial support to AICRIP to enhance the pace of rice research in the country. With the responsibility to organize multi-disciplinary, multi-location testing and develop suitable varietal and production technologies, AICRIP capitalized upon the available research infrastructure in different states of India and successfully introduced a national perspective to rice research.

In 1965, AICRIP was started with its headquarters at Rajendranagar, Hyderabad. The core staff at the headquarters and participating centers was provided by ICAR. Since inception until seventies, AICRIP was supported by the Rockefeller Foundation, the USAID and the Ford Foundation by way of financial assistance and technical support through strengthening of the research activities and by providing scientists in specific disciplines on a complimentary basis. The construction of green houses through financial support from the Ford foundation provided facilities for year round screening for resistance to insect pests and diseases under controlled conditions. In course of time, the foreign assistance was gradually phased out.

Release of a miracle variety, IR 8, from Peta and Dee-geo-woo-gen in 1966 from IRRI revolutionized the rice yields. At the same time, semi-dwarf high yielding variety 'Jaya' was released by AICRIP in 1968 ushering in green revolution. This transformed the country into a state of self-sufficiency by mid-eighties and stalled rice imports, while beginning an era of exporting rice, earning high foreign exchange for the country by early nineties.

To begin with, AICRIP work was carried out in seven zones each under the responsibility of a zonal coordinator. The zonal headquarters were Khudwani, Jorhat, Faizabad, Patna, Hyderabad, Cuttack and Coimbatore. Twelve regional stations *viz.*, Palampur, Pantnagar, Kapurthala, Chinsurah, Sambalpur, Raipur, Maruteru, Karjat, Nawagam, Mandya, Aduthurai and Pattambi were established in the major rice growing states of the Country. Upper shilling, Kalimpong and Imphal were identified as testing centers. Thus, there were 22 centers. Considering the progress and future challenges, during fifth five year plan (1974-79), ICAR provided 23 additional centers, thus raising the number to 45. These centers were classified into single cropped (24) and double cropped units (21). Centers at Imphal, Upper shilling, Agartala, Pondicherry, Kohima and Varanasi were fully financed by ICAR. Cuttack center

was a part of Central Rice Research Institute (CRRI). The rest were financed on a 75:25 with State

**Table 2.** Zones, area covered, funded and voluntary centres of AICRIP.

| Region / State | Locations | |
|---|---|---|
| | Funded | Voluntary |
| | *ZONE I - HILLY AREAS* | |
| North Western Hills | | |
| Jammu & Kashmir | Khudwani (1) | Rajouri, Wadura, Bandipore, Pombay (5) |
| Himachal Pradesh | Malan (1) | Palampur, Dhaulakhan (2) |
| Uttarakhand | | Almora, Bageshwar, (2) |
| North Eastern Hills | | |
| Manipur | | Imphal-CAU (1) |
| Nagaland | Kohima | |
| Meghalaya | Upper Shillong (1) | ICAR-Umiam, CAU-Umiam (2) |
| West Bengal | | Kalimpong (1) |
| Southern Hills | | |
| Karnataka | | Sirsi (1) |
| | *ZONE II - NORTHERN* | |
| New Delhi | | IARI- New Delhi (1) |
| Uttarakhand | Pantnagar (1) | |
| Punjab | Ludhiana (1) | Gurdaspur, Kapurthala, Rauni (3) |
| Haryana | Kaul (1) | Karnal (CSSRI), Jind, Rohtak, Kurukshetra, , Panipat (5) |
| Uttar Pradesh | Nagina, Kanpur (2) | |
| Jammu & Kashmir | Chatha (R.S. Pura) (1) | |
| Rajasthan | Kota (1) | Banswara (1) |
| | *ZONE III - EASTERN* | |
| Odisha | Jeypore, Chiplima (2) | Bhubaneswar, NRRI (Cuttack), (2) |
| Bihar | Patna, Pusa (2) | Patna- ICAR, Sabour(2) |
| Jharkhand | Ranchi (1) | Hazaribagh, Gharkatanga (2) |
| West Bengal (5) | Bankura, Chinsurah (2) | Canning, Pundibari, Chakdha, Hathwara, Kolkata |
| Uttar Pradesh | Masodha ,Ghaghraghat, Varanasi (3) | Lucknow, Modipuram, Gautam Budha Nagar (3) |
| | *ZONE IV - NORTH EASTERN* | |
| Assam | Titabar (1) | Gerua, Karimganj, North Lakhimpur (3) |
| Manipur | Wangbal (1) | Lamphalpat, (1) |
| Tripura | Arundhutinagar (1) | Lembucherra (1) |
| | *ZONE V - CENTRAL* | |
| Madhya Pradesh | Rewa (1) | Waraseoni, Jabalpur (2) |
| Chhattisgarh | Raipur, Jagadalpur (2) | Bilaspur, Ambikapur (2) |
| Maharashtra | Sakoli (1) | Sindewahi (1) |
| | *ZONE VI - WESTERN* | |
| Maharashtra | Karjat, Tuljapur (2) | Panvel, Radhanagari, Shirgaon, Phondaghat, Vadagaon, Parbhani, Palghar (7), |
| Gujarat | Nawagam, Navsari (2) | Derol, Vyra, Danti, Dabhoi, (4) |
| Goa | | Goa (1) |
| | *ZONE VII - SOUTHERN* | |
| Andaman & Nicobar | | Port Blair (1) |
| Andhra Pradesh | Maruteru (1) | Ragolu, Bapatla, Machilipatnam, Nellore, (4) |
| Telangana | Rajendranagar, Warangal (2) | IIRR, Jagtial, Kunaram, Rudrur, Kampasagar (4) |
| Tamil Nadu | Aduthurai, Coimbatore (2) | Trichy, Annamalainagar, Tirur (3) |
| Kerala | Moncompu, Pattambi (2) | Vyttila (1) |
| Karnataka | Mandya, Mugad, Ponnampet, | Brahmavar, Gangavati (5) Sirsi, Kathalgere, Malagi, Kumta (4) |
| Puducherry | Kurumbapet (1) | Karaikal (1) |
| Total locations | 45 | 78 |

Underline: ICAR institutions

Agricultural Universities (SAUs - 25%) or 50:50 per cent basis with State Departments of Agriculture (SDAs - 50%). In August 1975, AICRIP was elevated to the status of Directorate of Rice Research (DRR) wherein lead research targeting mainly the irrigated ecosystem was included in the mandate. During VI plan period (1980-85), 8 more sub centers were sanctioned raising the total to 53. There were a total of 61 centers including 8 subject related special centers. In the VII plan period (1985-86 to 1989-90) the number of centers was reduced to 50 (18 main and 32 sub centers). During the VIII plan (1992-97), there were 51 approved centers of which six centers were withdrawn and Karnal center was merged with Kaul in the IX plan period (1997-2002). The total number of centers during X plan (2002-2007) increased to 46 with the approval of Kanpur and Nagina centers and to 47 during XI plan (2007-2012) with addition of Navsari in southern Gujarat in western India. During the ongoing XII plan (2012 - 2017), two centers *viz*., Karimganj and Sabour have been withdrawn. So, currently there are 45 funded centers under AICRIP (Table 2). In addition to these funded centers, there are more than 90 voluntary centers where trials were conducted on voluntary basis in each discipline.

The Directorate of Rice Research (DRR) was upgraded to national institute status and renamed as 'Indian Institute of Rice Research (IIRR)' during the golden jubilee year, from 15th December 2014. Over the years, the institute has strengthened its infrastructure and human resources and is well prepared to face the domestic and global challenges. It is committed to maintain its leadership and is responsive to the needs of its stakeholders. The institute activities are aimed at accomplishing the vision, mission and mandate of IIRR keeping in view the "Farmer First" motive of ICAR. The major mandate of the institute is to coordinate the rice research programme in the country (All India Coordinated Rice Improvement Project AICRIP), basic and strategic research for enhancing rice productivity under irrigated ecosystem, coordination of multi-location testing to develop location specific varieties and technologies for various ecosystems and dissemination of technologies, capacity building and establishing linkages. A novel feature of this programme is that ICAR research institutes including IIRR as well as state agricultural universities, state departments of agriculture and private seed industry work together as a team to resolve research problems of rice cultivation at national level. It is worth mentioning that the Indian-origin system of multi-location testing of improved genotypes through AICRP has become a role model for the initiation of similar institutional frameworks in other countries of Asia and Africa.

## Thrust areas of the All India Coordinated Rice Improvement Project (AICRIP)

♦ Three-tier varietal and hybrid evaluation system through multi-location testing for different agro-ecological zones and specific target regions/areas to develop location specific varieties and technologies for various ecosystems.

♦ Multi-location screening of genotypes for pest and disease resistance.

♦ Germplasm exchange and evaluation through national and international nurseries/trials.

♦ Multi-location agronomic studies on integrated nutrient management.

♦ Multi-location physiological studies.

♦ Coordinating and monitoring the seed production program.

♦ Dissemination of different technologies to the farmers through FLDs.

♦ Capacity building and establishing linkages with national, international and private organizations.

## Activities of All India Coordinated Rice Improvement Project (AICRIP)

The All India Coordinated Rice Improvement Project (AICRIP) comprises of eight major units *viz*., varietal improvement including hybrid rice, crop production (agronomy, soil science, plant physiology), crop protection (entomology, plant pathology) and social sciences. At the nodal centre, ~60 researchers and at the funded centers ~500 researchers comprising scientists, technical, administrative and supporting have been working for rice improvement. Realizing the limitations imposed by the ecosystem complexities, insect pest and disease problems as well as grain quality requirements of different rices consumed, AICRIP evolved to address these requirements. During the first decade, emphasis was given to achieve higher yields

through improved plant type largely for irrigated areas. This led to the development of short statured high yielding varieties (HYVs), which heralded the process of "Green Revolution" in India. During 80s, yield stability and quality improvement received major attention. This led to the development of varieties possessing major biotic stress tolerance and desirable quality to develop semi-dwarf basmati rice varieties. Nineties witnessed efforts in developing suitable hybrid rice technology and multi location testing to validate their superiority over varietal checks at least by 10%, non basmati quality trials targeting the export markets. During 2000s emphasis was on soil stress trials for problem areas, aerobic trials laying emphasis on developing genotypes for water limited environments and hill trials for incorporating cold tolerance. In recent times, emphasis has been on the near isogenic line (NILs) development for quick evaluation of marker assisted selection (MAS) derived products introgressed with genes for biotic and abiotic stresses. Additionally nutritional security is stressed by enriching the grain with micronutrients such as zinc, iron along with protein.

ICAR-IIRR adopted a unique model that facilitates joint programme planning and implementation of multi-location testing along with exchange of breeding and germplasm material. This "National Evaluation system" follows a three tier system and assigns a number to every nominated entry developed by different cooperating centers known as Initial Evaluation Trail Number (IET No.). Normally, it takes a minimum of three to four years to identify a promising variety. The first level of testing involves one year Initial Varietal Trial (IVT) followed by two years of Advance Varietal Trials (AVT-1 and AVT-2). These trials help in the identification of elite breeding lines with consistently superior performance over the best checks. Simultaneously, these nominated lines will be screened for resistance to major insect pests and diseases at hot spot locations as well as controlled conditions under well defined disease and insect pressure. Additionally grain quality and agronomic performance will also be assessed for all the promising entries.

Finally, after three years of testing, the details of best performing elite lines possessing desirable characters and required level of resistance will be submitted by the concerned breeder in a proforma along with all the supplementary data and relevant information for consideration of the variety identification to the variety identification committee (VIC) during the annually held all India rice group meeting. Thus the superior test entries identified in the crop workshop/ group meeting will be later approved by the central sub-committee on crop standards, notification and release of varieties (CSCS & NRV) and state variety release committees (SVRC) and those approved cultures would be named and released for general cultivation as Central or as State releases.

## Major achievements of All India Coordinated Rice Improvement Project (AICRIP)

### *A. Varieties and hybrids released in India*

From 1966 to 2018, a total of 28088 elite lines developed by different cooperating centres were tested in multi-location trials across the country under the umbrella of AICRP-rice at funded, voluntary centres and in partnership with private sector for hybrid rice. The dynamic time tested multi-location three-tier testing programme involving one year of initial varietal trial (IVT) and two years of advance varietal trial (AVT-1 and AVT-2) as well as screening of elite breeding lines at hotspot locations for generating information on their pest/disease resistance/tolerance, grain quality attributes and agronomic performance has led to release of varieties including hybrids suitable for all the ecosystems.

Advanced breeding lines are screened extensively through 'National Screening Nurseries' *viz*., NSN-1, NSN-2, NSN for hills and national hybrid screening nursery (NHSN), under both artificial and natural infestation regimes at hot spot locations led to release of varieties resistant to major insect pests. In the last decade, about 180 entries have been identified as promising donors for resistance to multiple insect pests along with more than 80 multiple disease resistant lines.

AICRIP was instrumental in release of 1333 varieties including 107 hybrids till May 2019. A total of 282 varieties including 70 hybrids released by Central Sub-Committee on Crop Standards, Notification and Release of Varieties (CSCS & NRV) and 1051 varieties including 37 hybrids released through state variety release committees (SVRC) (Fig. 2). Having realized the scope and potential of quality rice for export, special

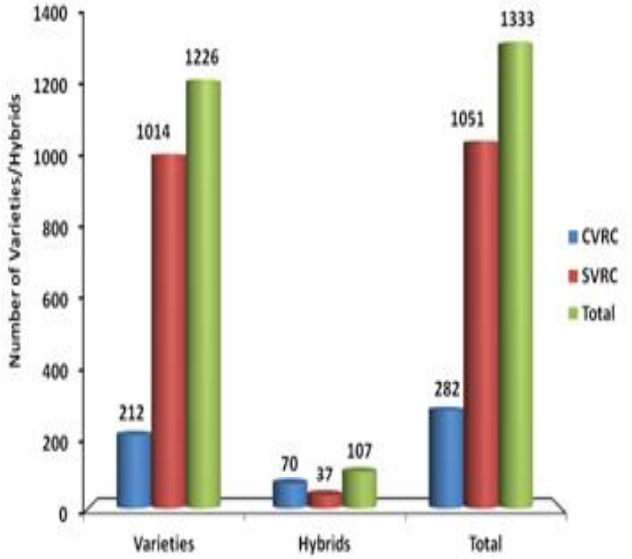


**Fig. 2.** Release of rice varieties and hybrids since the AICRIP.

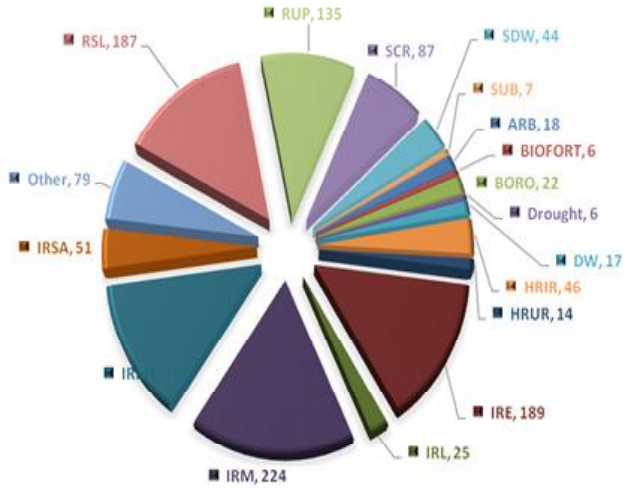


**Fig. 3.** Ecosystem wise release of rice varieties and hybrids.

thrust was given for genetic enhancement of quality rice in the country which lead to the release of around 30 export quality basmati and short grain rice varieties. Many of these varieties possess tolerance/resistance to major pest and diseases.

In the last decade effective deployment of biotechnological tools such as molecular marker assisted breeding has resulted in development of land mark varieties such as improved Samba Mahsuri and improved Pusa Basmati 1 which involved introgressing BLB resistant genes into the genetic background of Samba Mahsuri, the most sought after rice variety for its grain and cooking quality and Pusa Basmati 1, the important long grain Basmati variety which has a major share in export markets. The two landmark varieties are developed by IIRR, Hyderabad and IARI, New Delhi, respectively, tested and released through AICRIP as central releases. Similarly, efforts made at different institutes to introgress the major QTL 'Sub 1', for inducing submergence tolerance into popular varieties such as Swarna, Ranjith, Bahadur, CR 1009, Samba etc which were tested in the NIL-Submergence trials of AICRP and released in different states. High Zn lines: IETs 23825, 22624, 23830, 23824, 23833, 23834, 23831, 23829, 23832 of which IET 23832 has been identified in the states of Tamil Nadu, Karnataka, and Andhra Pradesh. The rice varieties and hybrids released for various ecosystems in India are presented in Fig. 3.

### *B. Ensuring food and nutritional security*

High yielding varieties of rice developed and released through AICRIP have benefited millions of farmers and are cultivated under different agro-ecologies. The high yielding varieties, particularly stress tolerant varieties help farmers to increase their production levels thereby providing them with the much required food and livelihood security. Development and wide adoption of HYVs and appropriate crop management practices have contributed significantly in enhancing the rice production, which crossed the 109 Mt mark during 2016-17.

Different institutes working on rice, along with increasing the productivity of crops, have also given emphasis on improving the nutritional quality of rice varieties and developed varieties with improved quality attributes (high protein-CR Dhan 310; high zinc - DRR Dhan 45, DRR Dhan 48, DRR Dhan 49, Chhattisgarh Zinc Rice 1; low glycemic index-Improved Sambha Mahsuri) in rice to provide nutritional security to the population depending on rice for staple diet.

Technological improvement in rice and favorable government policies have helped in increasing rice production in India during the last 65 years and made India not only self sufficient in rice production but also the largest exporter in the world. The production has increased by 89.12 Mt *i.e.*, by 533 percent (21.58

Mt during 1950-51 to 109.70 Mt during 2016-17). The growth in production is due to growth in productivity and expansion in area. While productivity increase of rice has contributed 381 percent (0.66 t/ha during 1950-51 to 2.55 t/ha during 2016-17), the area expansion has contributed 140 percent to production growth during the period (1950-51 to 2016-17).

### *C. Contribution to rice export*

India contributes ~22% of global rice production. About 42 Mt of rice is traded through international market. Leading rice exporting countries are India, Thailand, Vietnam, USA and Pakistan. During 2012, India surpassed Thailand to become the first among the rice exporting countries with the export of more than 10 Mt. A growing middle-class, rice consuming population will increase the demand for high-quality rice in domestic as well as international markets. This creates great opportunities for India to earn foreign currency by exporting basmati and high-quality non-basmati rice.

Among the wide array of rice cultivated in India, Basmati rice, the scented pearl also known as "Queen of Rice" is being cultivated since centuries in the Himalayan region. Basmati rice has combination of specific kernel dimensions, appealing aroma, texture of cooked rice, high volume expansion after cooking owing to its linear kernel elongation with minimum breadth-wise swelling, fluffiness, palatability, easy digestibility and longer shelf-life. Cooked Basmati rice is characteristically free-flowing and can be identified by its unique fragrance. It is primarily grown in the Indo-Gangetic Plains of north-western India comprising the regions of Punjab, Haryana, Himachal Pradesh, Delhi, Uttarakhand, Jammu and Kathua districts of Jammu and Kashmir and 27 districts of Western Uttar Pradesh. The area under Basmati rice cultivation increased from 0.78 Mha during 2004 to 2.12 Mha during 2016. Production of Basmati rice was 6.16 Mt during *kharif* 2016. India is the largest cultivator and exporter of Basmati rice, followed by Pakistan. Basmati rice from the Indian subcontinent is highly priced in the international market for its unique quality.

Basmati rice improvement project at ICAR-Indian Agricultural Research Institute, New Delhi has led not only improved the yield but also led to significant jump in forex earning's. Pusa Basmati 1 released by IARI, New Delhi in 1989 became very popular among the farmers of India and it covered around 75% of the total Basmati rice area within five years of its release. The higher productivity of Basmati rice complimented by rice mills with superior processing technology, the foreign exchange earnings from export of Basmati rice saw a phenomenal rise from Rs. 317 crores in 1987-88 to Rs. 865 crores in 1994-95 and thereafter it continued to increase reaching its highest up to Rs. 29292 Crores in 2013-14 and present foreign exchange earnings of basmati is Rs. 21513 and non basmati is Rs. 16930 Crores in 2016-17 (Fig. 4).

Pusa Basmati 1121, an improved Basmati rice variety possessing the longest cooked kernel length created a revolution in Basmati rice improvement. This variety became very popular among the farmers in the Basmati growing states of India and is very popular both with the Basmati rice farming community as well as exporters. Because of its superior grain and cooking quality attributes, and wide spread adoption coupled with high demand among the consumers has resulted in quantum jump in basmati exports from Rs. 2,824 crores in 2004-05 to Rs. 22,718 crores in 2015-16, out of which Pusa Basmati 1121 alone contributed Rs. 16,888 crores. The cumulative foreign exchange earnings from the export of Pusa Basmati 1121 from 2008 to 2016 has been estimated to be 1.17 lakh crores with an additional earning of Rs. 0.33 lakh crores from the domestic sale of PB 1121, making it to a total of Rs. 1.5 lakh crores from this Basmati rice variety alone.


**Fig. 4.** Forex earnings from basmati and non basmati rice exports from India.

### *D. Frontline demonstrations (FLD) programme*

Totally 27,172 FLDs were organized across India through which the production potential of varieties, hybrids, management practices and implements were demonstrated. This program has directly benefitted 67,930 farmers from across the country and directly/ indirectly helped thousands of farmers in getting access to new rice technologies. This program resulted in large scale adoption of 78 HYV and hybrids over a period of last ten years. FLDs resulted in yield advantages and income enhancement by almost 15% on an average. This is an unparallel effort in the recent rice extension programs in Asia. Spin off impacts of FLDs are many and are well documented.

## Future directions to enhance the productivity of rice

Multiple challenges like burgeoning population, changed dietary patterns, deteriorating soil health, increasing biotic and abiotic stresses and changing climate necessitates an increased rice production. The outcome and output of the AICRP is expected to meet the set production target of 137 million tons of rice on 37 million ha of land in 2050 compared with the current production of 109 million tons of rice on 43 million ha. The target can be achieved by utilizing the developments in science and technology with a prime focus on the following under the AICRP on Rice:

♦ Increasing yield potential of rice varieties through conventional and innovative approaches.

♦ Yieldthrough resistance breeding.

♦ Strengthening breeding strategies to develop new plant types in rice having moderate tillering habit, robust stiff culm, long panicles with large number of high-density grains, resistance to biotic stresses and their suitability for environmentally challenged ecologies.

♦ Development of super rice hybrids and inter-sub-specific (*Indica*/*Japonica*) hybrids for quantum jump in yield potential, stress tolerance and quality parameters.

♦ Identification of promising genotypes adapted to low light.

♦ Identification of new alternate areas for hybrid seed production to ensure the quality seed in view of weather uncertainties owing to climate change.

♦ Introduction and promotion of hybrid rice in potential areas of rice production especially shallow lowlands and irrigated medium lands during boro/ summer season.

♦ Development and promotion of new/improved resource conservation technologies in rice such as system of rice intensification (SRI), integrated crop management (ICM), aerobic rice, leaf color chart (LCC) based N application, direct seeding with drum seeder for achieving higher productivity levels.

♦ Development of ecosystem based bio-intensive IPM package for major insect pests and diseases of rice including the hybrids with emphasis on global warming.

♦ Refinement and economization of seed production technologies including hybrid rice.

♦ Genomic research to accelerate the varietal development.

♦ Development of $C_4$ rice with the objective to double the rice productivity

♦ Hybrid rice breeding.

♦ Capacity building in the frontier areas (genomic research, double haploids etc.) of rice research.

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