Rice Genetic Resources: Collection, Conservation, Maintenance and Utilization

BC Patra, BC Marndi, P Sanghamitra, S Samantaray, N Umakanta and JL Katara

SUMMARY

The increased demand for rice will have to be met from less land, less water, less labour and fewer chemicals under changing climate. Can we meet the challenges to rice productivity, stability and nutritional quality improvement by strategic use of the available germplasm resources? Can India, having more than 106,000 germplasm accessions in the National Gene Bank effectively make use of these huge resources? Past experience suggests that germplasm still holds the key to our food and nutritional security of future generation. It is well known that the traditional rice varieties and their wild relatives constitute an invaluable gene pool in terms of resistance/tolerance to biotic and abiotic stresses, which can be exploited for developing modern new generation rice varieties having enough resilience to sustain adverse climatic changes. All these issues have been dealt in this chapter under the ongoing Institute multi-disciplinary research project.

1. INTRODUCTION

The plant genetic resources (PGR) constitute the basic raw material for any crop improvement programme. It may consist of seed or vegetative propagules (tuber, sucker, rhizome, cutting, seedling etc.) of plants, which contains the functional units of heredity. They are generally referred to as germplasm or genetic resource material. In fact, Sir Otto Frankel coined the word 'Genetic Resources'. Rice (*Oryza sativa* L.) is one of the most important cereal food crops for more than one-half of the world population and provides 50–80% of daily calorie intake. Rice is grown in more than 115 countries. In India, it is cultivated under a wide range of growing conditions, such as below sea level farming in Kuttanad in Kerala to high altitude farming in the Himalayas. Because of its adaptation to such variable agro-ecosystems, fortunately a rich genetic diversity and variability is encountered which helps sustain the adverse alterations in temperature, precipitation as a result of climate change. There are varieties, which can withstand submergence during flood and there are others which can grow under moisture stress during drought condition and also at soil and water salinity. Therefore, it becomes imperative to conserve them for posterity. The search for superior genotypes regarding yielding ability, disease and pest resistance, abiotic stress tolerance or better nutritional quality is very hard, competitive and expensive. Evidently, there is a gap between available genetic resources and breeding activities. However, with the advent of modern genomic tools the scope for use of vast genetic resources has increased. Newer strategies must be designed, first for an elaborate evaluation, and subsequently for efficient utilization of the diverse germplasm resource so painstakingly collected and conserved in the gene banks. Accelerated genetic gains in rice improvement are needed to mitigate the effects of climate change and loss of arable land, as well as to ensure a stable global food supply. The enormous rice genetic diversity available in the gene banks will be the foundation of the genetic improvement of the crop through unraveling the new genes and traits that will help rice producing farmers who are facing the challenges brought about by climate change, pests and diseases, and other unfavourable conditions.

2. ORIGIN AND EVOLUTION OF CULTIVATED RICE

Rice is cultivated as far north (53°N) on the border between Russia and China, and as far south as central Argentina (40°S). It is grown in cool climates in the mountains of Nepal and India, and under irrigation in the hot deserts of Iran and Egypt. It is an upland crop in parts of Asia, Africa and Latin America. At the other environmental extremes are floating rice, which thrive in seasonally deeply flooded areas such as river deltas - the Mekong in Vietnam, the Irrawady in Myanmar and the Ganges-Brahmaputra in eastern India and Bangladesh.

The centre of origin and centers of diversity of two cultivated rice species i.e. *Oryza sativa* and *O. glaberrima* have been identified using genetic diversity, historical and archaeological evidences and geographical distribution. It is generally agreed that river valleys of Yangtze, Mekong Rivers could be the primary centre of origin of *Oryza sativa*. The foothills of the Himalayas, Chhattisgarh, Jeypore tract of Odisha, north eastern India, northern parts of Myanmar and Thailand, Yunnan Province of China are some of the secondary centers of diversity for Asian cultigens. There are 22 agro-biodiversity hotspots in India, out of which five hotspots fall in eastern region of the country, of which the Koraput region covering part of northern Eastern Ghats is of great concern as the upland short duration drought avoiding *aus* types have been originated here.

The Inner delta of Niger River and some areas around Guinean coast of the Africa are considered to be the centre of diversity for the African cultivated species of *O. glaberrima* (Chang 1976; Oka 1988). It is also assumed that the Asian annual wild species *O. nivara* has given rise to the Asian cultivated species *O. sativa* and the African annual wild species *O. barthii* to the African cultivated species *O. glaberrima*.

The diversity and variability within the Asian cultivated rice (*O. sativa*) is enormous. Some controversy exists over when and where rice was domesticated. It is fairly safe to say that rice was being cultivated at least 10,000 years ago and that it was domesticated from its wild ancestor *O. rufipogon* (Khush 1997). Two major sub groups of rice, *indica* and *japonica*, led rice genetic resources specialists to conclude that there were two centers of origin. One was thought to be in the tropical regions of South Asia where *indica* rice varieties dominated and the other near Central China where *japonica* rice dominated (Londo et al. 2006). It has generally been recognized that genetically the *japonica* (*sensu stricto*) is a fairly homogeneous group whereas the *indica* is highly heterogeneous group (Jennings 1966).

3. WILD RICE

Genus *Oryza* consists of 24 species, of which two are cultivated and rests are found wild in different parts of the world; all of them grow in the tropics only. There are two species that are close relatives of the cultivated rice and are believed to be the progenitor species of the cultivated ones. One of these, *Oryza rufipogon*, grows wild in India, China, Southeast Asia and South Asia. The other one, known as *O. barthii* (syn. *O. breviligulata*) grows wild in northern part of tropical Africa. These two wild species of rice attracted the attention of Neolithic man for their grains for his subsistence especially when he had not enough wild animals for hunting or wild fruits to gather. In fact, some of the aborigines still continue to collect seeds of wild rice in India, Southeast Asia and Africa. Recent study at this institute on morphological and molecular aspect confirms the validity of two wild rice species of same AA genome and there is distinct speciation between perennial *O. rufipogon* and annual *O. nivara* populations (Samal et al. 2018).

4. WEEDY RICE: MYSTERY IN EVOLUTION

Weedy rice appears as hybrid swarms due to introgression of genes between wild and cultivated species in nature. In Asian rice, it is known as *Oryza spontanea* whereas in African context it is said as *O. stapfii.* It grows faster; produces more tillers, panicles and biomass; makes better use of available N; shatters earlier; has better resistance to adverse conditions; and possesses longer dormancy in soil. Because of its high competitive ability, it becomes a serious threat to rice growers worldwide. It is also called as red rice because of its red pericarp. One of the major constraints/bottlenecks to attain the potential yield target of the present improved rice cultivars is considered due to the contamination of weedy rice in the cultivated areas. Due to conspecific form of cultivated rice makes similarity of morphological and physiological appearance between weedy rice and cultivated rice in the field, it is very difficult to discriminate the weedy rice phenotypically from the cultivar/variety of rice at the vegetative stages. Therefore, chemical control measures to manage weedy rice in conventional rice cultivars are not advisable. Some weedy rice also have inherited traits linked to wild rice such as red pericarp, black hull, long awn, light seed weight, strong seed dormancy and easy seed shattering which leads to loss of grain during harvesting in the field. There is also very high level of genetic variability and plasticity found within and among weed populations (Green et al. 2001) as the growth of weedy rice varies considerably among different biotypes due to differences in plant height, tillering, or leaf-producing capacity. Since, evolution of the weedy rice is not completely understood, a preliminary study was conducted to evaluate the genetic diversity of weedy rice lines found in the state of Odisha which includes seventy five weedy rice collected from different locations of Odisha, India of which fifteen wild rice (six accessions of *Oryza rufipogon*, nine accessions of *Oryza nivara*), six cultivated rice including three each of landraces and high yielding cultivars (Ngangkham et al. 2016).

A set of SSR molecular markers from different chromosomes were used for diversity analysis in 96 weedy rice and found to be robust enough to be used for diversity analysis. The observed heterozygosity (Ho) in analysis was found low which might be due to autogamous nature of rice crop (Nachimuthu et al. 2015) and less segregation or selection of stable progenies in the present samples. The genetic diversity was found to be higher than the other weedy rice populations studied. The genetic similarity coefficient of the whole 96 samples varied from 0.60 to 1 and distributed in different clusters. This result suggests a complex and unclear evolutionary process of weedy rice in Odisha, India. Thus, the considerable higher level of genetic diversity in weedy rice lines of Odisha indicates a complicated type of origin of weedy rice in this region of India which might be due to either adoption of direct seeded rice growing technique in this region or reduced weed control practices owing to limited human labour input. The genetic similarity coefficient of the whole 96 samples varied from 0.60 to 1 and diversifying the whole weedy rice lines into distinct groups after their evolution. Thus, the present investigation revealed that the origin of some of the weedy rice of Odisha is probably through the hybridization between the wild rice and rice cultivars cultivated in the nearby areas by the farmers.

Recent changes in farming practices and cultivation methods along with less weed management may have promoted the re-emergence and divergence of weedy rice. The abundant genetic diversity of weedy rice populations accompanied by the changes of farming practices may complicate weedy rice control in future and consequently threaten rice production. Thus, effective methodologies for weed control and management must be developed to prevent weedy rice from extensive spreading and infestation.

5. NERICA RICE

West Africans domesticated *Oryza glaberrima* about 3,500 years ago. The Asian species *O. sativa* reached Africa about 450-600 years ago and slowly displaced the native rice because of low harvest. By the 1990s, native African rice was reduced to a few pockets on scattered farms. Then Sierra Leonean plant breeder Monty Jones and his colleagues found a way to create a fertile hybrid between African and Asian rice. Called "*Nerica*" (New Rice for Africa), it could yield a bumper harvest like its Asian parent, but it was as tough as its African side, resistant to drought, pests and diseases. Scientists have bred many varieties of *Nerica* and farmers have started growing them. This new rice, descended from an endangered species, is helping Africa to feed itself, yet this opportunity would have been lost if *O. glaberrima* had gone extinct.

6. EXPLORATION AND COLLECTION OF RICE GERMPLASM

In the past, the scientists involved with crop improvement programme at different research stations undertook the evaluation of germplasm and identified several donors. They were utilized for crop improvement program and 394 varieties were recommended for general cultivation, as pure line selections. In 1955, when Dr. N. Parthasarathy was Director, the NRRI undertook its first planned exploration and collection mission of rice germplasm in the erstwhile Jeypore tract (now Koraput district of Odisha). The collection programme continued for five years (1955-59) by a team of scientists led by

Dr. S. Govindaswami and supported by a scheme sanctioned by the ICAR. This mission was popularly known as Jeypore Botanical Survey (JBS) and was the first of its kind, ever organized in the world to collect rice germplasm (Chang 1989). The team explored about 27,000 km^2 and collected a total of 1,745 cultivated rice and 150 wild rice accessions (Govindaswami and Krishnamurty 1959). Recently in 2010, FAO recognized Koraput region as one of the Globally Important Agriculture Heritage Systems (GIAHS). Later when Dr. R.H. Richharia became Director of NRRI, he introduced 67 varieties from Taiwan, tested them, two or three cultures were dwarf types and one of them was identified as Taichung Native 1 (TN 1) which laid the foundation for Green Revolution in the country. Simultaneously, a PL-480 project on collection of rice germplasm was operative in North east during 1967-72 with Dr. M.S. Swaminathan and Dr. S.V.S. Shastry at IARI, New Delhi and was popularly known as Assam Rice Collection (ARC). During 1970-79, a special programme was undertaken to collect rice germplasm from all the rice growing districts of Madhya Pradesh by Dr. R.H. Richharia after he left NRRI in 1969. He explored 42 districts and collected a total of 19,226 accessions which formed the Raipur Collection. A special drive for upland paddy varieties under cultivation in Andhra Pradesh, Karnataka, Maharashtra, Madhya Pradesh, Uttar Pradesh, Odisha and West Bengal further resulted in collection of 1,938 cultivars. In 1975, a comprehensive exploration and collection programme was drawn for the whole country especially for the traditional rice growing areas of Karnataka, Maharashtra, Madhya Pradesh, Uttar Pradesh, Bihar, West Bengal and Odisha covering 30 districts of 7 states. This programme was popularly known as National Collection from States (NCS) and resulted in collection of 1,038 accessions. Increased interest in herbal medicines during last few decades has necessitated collection of rice germplasm with special emphasis on their medicinal value from Bastar region of Chhattisgarh and Kerala for the world famous 'njavara' rice. During recent evaluation, few landraces/farmers' varieties from Assam have been found to have high level of protein (14-15%). Traditional landraces like Bindli from Uttar Pradesh is now reported to have high Zn (>50 ppm) in brown rice apart from having strong aroma. Studies on the evolutionary changes in the traditional varieties grown in particular regions have been started to find out the reasons of disappearance/extinction of primitive varieties/landraces for the farmers' field (Chourasia et al. 2017).

7. COLLECTION OF TRAIT SPECIFIC GERMPLASM

7.1. Medicinal rice

The documentation of indigenous traditional knowledge on the medicinal and nutritional significance of red rice is another aspect which is gaining momentum due to recognition of *njavara* rice of Kerala as one of the regions of Geographical Indication (GI) of Goods Act 1999 under the Intellectual Property Right. This was the first time that a rice variety of Kerala received GI Registry in 2008. Studies found that *njavara* has increased level of protein and amino acid in the organically grown seeds; thus it should be developed as baby food and a health product to save this wonder rice from extinction. Seventy two accessions of rice germplasm were collected from Bastar region of Chhattisgarh in which some medicinal rice namely Gudmatia, Bhejari, Danwar, Baisur, Gathuwan were also reported.

7.2. Saline tolerant rice

Fifty one accessions of saline tolerant rice mostly from Pokkali region of Kerala (one of the potential regions for GI) were collected, characterized and evaluated for better utilization.

7.3. Basmati rice

Eighty eight accessions of long slender basmati rice germplasm were collected from eight districts of western Uttar Pradesh and six districts of Haryana state in collaboration with NBPGR during early 1990s.

7.4. Aromatic short grained rice

Sixty seven accessions of short grained scented rice 'Kalanamak' germplasm were collected from eastern Uttar Pradesh, which has been evaluated.

7.5. Boro rice

A total of 208 accessions of Boro rice germplasm were collected from Assam, north Bihar, north Bengal and eastern Uttar Pradesh during early 2000.

7.6. Bao rice

About 126 accessions of Bao rice germplasm were collected from deep water areas of Assam and Meghalaya, and evaluated for utilization in breeding programme.

7.7. Aman rice

A set of 69 accessions of Aman rice germplasm were collected from West Bengal.

7.8. Cold tolerant rice

A set of 116 accessions of cold tolerant rice germplasm were collected from hilly regions of Arunachal Pradesh.

7.9. Wild and weedy rice

About 495 accessions of wild rice germplasm (*O. nivara, O. rufipogon*, and *O. coarctata (Syn: Porteresia coarctata*) were collected in 12 exploration trips from Odisha and West Bengal under National Agricultural Technology Project (NATP). Apart from this about 223 accessions of weedy rice (*O. sativa f. spontanea*) have also been added to the gene pool.

7.10. Specialty rice

Attempts are on to collect aromatic rice, soft rice, wine rice, glutinous or waxy rice, colour rice (brown, green, black, red), beaten rice, pop rice, organic rice, nutritional rice etc.

8. GERMPLASM INTRODUCTION

When the International Rice Commission (IRC) recognized NRRI as a centre for the maintenance of world genetic stocks of rice, many varieties of south and Southeast

Asian countries were introduced to the country for their maintenance at NRRI, this provided an opportunity to Indian scientists to test and recommend few of them for general cultivation in the country. Since its inception in 1946 till 1977, Director, NRRI continued to remain in charge of overall supervision of the world genetic stock for multiplication and maintenance of the FAO designated germplasm being run at 5 countries i.e. India, Indonesia, Japan, Pakistan and USA. The world genetic stock was comprising of *japonicas, indicas, bulus* and floating types. Again, when NRRI was recognized as the main centre for the inter-racial hybridization programme between *japonicas* and *indicas* during 1950-1964, many exotic japonica rice germplasm were introduced into India. The participants of the southeast and south Asian countries came with their own rice varieties for hybridization. This further provided opportunity to Indian rice scientists to study the varieties of other countries. Some of the *japonicas* when tried in temperate hilly regions were found suitable for direct introduction. Many *japonica* varieties (Aikoku, Asahi, Fukoku, Gimbozu, Norin 1, Norin 6, Norin 8, Norin 17, Norin 18, Norin 20, Rikuu 132, Taichu 65) were crossed with the popular varieties of Odisha (T 90, T 812, T 1145, BAM 9) and the progenies were grown at the three Rice Research Stations (Bhubaneswar, Berhampur and Jeypore) for further selections. In all, 192 improved local varieties were selected and a total of 710 different *indica x japonica* crosses were made. The F_1 seeds were distributed to many countries for further crop improvement programme. Only four varieties were released; Malinja and Mahsuri released in Malaysia, ADT 27 in Tamil Nadu state of India and Circna in Australia.

9. GERMPLASM CHARACTERIZATION, DOCUMENTATION AND SEED SUPPLY

Characterization is the description of plant germplasm, which involves determining the expression of highly heritable characters ranging from morphological or agronomical features to seed proteins or molecular markers. It results in better insight in the composition of the collection and the coverage of genetic diversity. Every year new germplasm accessions are collected and conserved in Gene bank of NRRI which is characterized for utilization in the breeding programme. So information on germplasm also helps to facilitate the exchange of materials and information among gene banks and help the users in experimenting with conserved germplasm.

10. STATUS OF RESEARCH

At National Rice Research Institute, all the germplasm collections including wild and weedy rice are characterized at appropriate stages of plant growth and maturity for agro-morphological traits based on the descriptors which include 19 qualitative and 11 quantitative characters. These materials after characterization are harvested, processed, packed and sent to National Gene Bank for long term storage (LTS) and also a set of it is conserved at ICAR-NRRI under medium term storage module. The details of germplasm characterized at NRRI during last five years are given in Table1.

Table 1. No. of germplasm characterized during last five years (2012-17).

Year	No. of accessions characterized	Type of germplasm
2012-13	2545	Released varieties and land races of India
2013-14	600	Landraces of India
2014-15	6406	Landraces, wild and weedy rice of India
2015-16	5800	Landraces, wild and weedy rice of India
2016-17	5800	Landraces, wild and weedy rice of India

With the aim of creating database, 14000 accessions of morphologically characterized rice germplasm were documented (Tables 2 & 3). The data revealed that majority of the accessions were with green basal leaf sheath, green leaf blade, well exserted panicle, intermediate type, long fully awned, intermediate threshing, white kernel colour, some aromatic, erect flag leaf and fast leaf senescence type (Fig. 1).

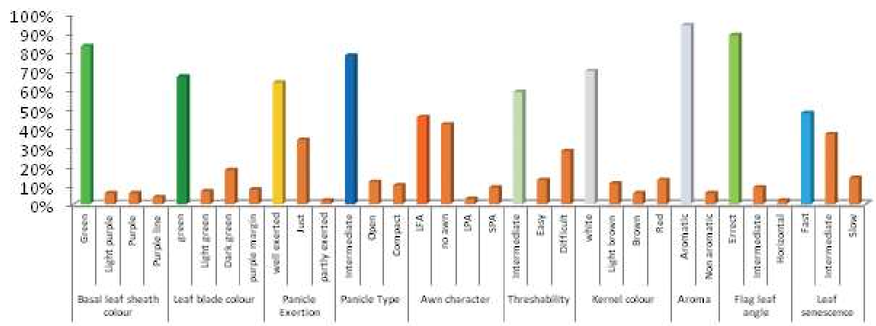

Fig. 1. Variations observed in qualitative characters of 14000 rice germplasm accessions

Table 2. Important donors identified against major diseases.

	Possible donor for resistance	
Diseases	Landraces	Improved Varieties
Blast (*Pyricularia oryzae*)	Tetep, Tadukan, Gampai, Peta, Sigadis, Dular, Kalamdani, Tarabali, Mugisali, Madrisali, Sollpona, Rongaahu, Manoharsali, Andrewsali, Gajepsali, Beganbisi 2, Rongagutia, Kolimekuri, Rikhojoi 2, ARC 7098, AC-55 (CH-55), AC-8368 (BJ-1), AC-8369 (S-67), SM-6, SM-8, SM-9, CP-6, AC-293 (AKP-8), AC-294 (AKP-9), AC-360 (PTB-10), AC-26904 (Tetep), Fukunishike CO-4, CO-29, Tadukan, Zenith, Carreon	ADT 29, ADT 25, CO 43, MTU 3626, MTU 6203, MTU 7014, MTU 9992, WGL 26889, WGL 47969, WGL 47970, MTU 993, BJ-1, NLR 145, PTB 10, NLR 36, CO 4, CO 25, CO 29, CO-30, MTU 9993, Saleem, Thikkana, Kotha Molagoli, Kulu-72, Pinakini, Swarna muli Dular, Vajram, Prahlad, Lacrose-Zenith-Nira, BJ1, Karjat,

Contd.....

	Possible donor for resistance	
Diseases	Landraces	Improved Varieties
Bacterial leaf blight (*Xanthomonas oryzae*)	Dholamula, Moinasail, Kartik kolma, Japorisali, Gajepsali, Jatiosali, Kola ahu, Ahusuri, ARC 5827, AC-33523 (Tarical), AC-33557 (Dulla karma), AC-33562 (Kangpui), AC-3094 (TKM-6), AC-8368 (BJ)-1, AC-26903 (DV-85), Chinsurah boro-II, Somera mangga, Wase Aikoku 3, Malagkit, Sung son	Pallavi, TKM 6, Sigadis, Pelita 1, MTU 15, MTU 16, ASD 5, T 1069, ARC 18562, MTU 4870, MTU 2400, MTU 3626, MTU 6203, MTU 7014, MTU 9992, Swarna, PLA 9180, BPT 3291, Mahsuri, RNR 10786, PNR 2736, RNR 4970, RNR 10208, AS 330.
Rice Tungro Virus (*Nephotettix malayanus*)	Kataribhog, Latisail, Sigadis, Ambemohar, Habiganj, ARC 14766	BJ 1, PTB 18, W 1263, Gampai 15, Pankhari 203, ARC-7125, ARC-7149, DW-8, AC-368 (PTB-18), AC-5079 (Kataribhog), Bhagirathi, Boitalpakhia, AC-34558 (Nalini), AC- 17933 (Kamod-153), AC- 34650 (Usha), AC-273 (ADT-20), AC- 297 (ASD-1), AC-304 (CO-1), AC-315 (CO-12), AC-351 (PTB-1), AC-360 (PTB-10) AC-3094 (TKM-6), AC-8396 (CB-1)
Helmintho sporium oryzae	Bhatta Dhan.	Ch 13, Ch 45, BAM 10, AC 2550, ADT 29, CO 29.
False smut (*Ustilaginoidea virens*)	Sugandha, Sabari, Karna, Deepa, Sona, ARC 5378, AC-26570 (ADT-33), AC- 40119 (PTB-23), AC-40124 (PTB-26), AC- 3070 (PTB-32)	Udaya, CO 9, IR 62, MNP 85, BR 16, IR 24, IR 29.
Stem rot (*Helminthosporium sigmoideum*)	--	Basmati 370, Bara 62
Ragged stunt virus	--	PTB 21, PTB 33
Grassy stunt virus		*Oryza nivara*
Sheath rot (*Sarocladium oryzae*)	Bhatta Dhan	AC- 26904 (Tetep), Ram Tulasi
Brown Spot	Katak tara, Bhut muri, BAM 10, SR-26B, CH-45, CO-20	

Table 3. Important donors identified against major insect pests.

Insect	Donors: Land races	Donors: Improved Varieties
Brown Plant Hopper (BPH) (*Nilaparvata lugens*)	Dhoiya Bankoi, Sahiba, Salkathi, ARC-6650 (Gomiri bora), AC-34969 (Baidya raj), AC-34993(Ghusuri), AC-34997(Jhupjhupa), AC-35014 (Nal dhan), AC-371 (PTB-21), AC-40634 (PTB-33), AC-30300 (MR-1523), AC-35184 (Dhoba numberi), AC-35228 (Jalakanthi), AC-35066 (Banspati), AC-35070 (Panidubi), AC-35108 (China bali), AC-17912 (Ganga sagar), AC-20363 (Kalachudi), Tarapith, Haldi ganthi ARC 7080, ARC 14766, NCS 91, NCS 131, NCS 707, Milyang-55, PTB 43, PTB 21, ARC 6248, ARC 6605, ARC 6619, ARC 5757, ARC 6158, ARC 6102, ARC-6650 (Gomiri bora), AC-34969(Baidya raj), AC-34993(Ghusuri)	Leb Mue Nahng, Udaya, CR 1009, PTB 18, Vajram, Pratibha, Nandi, Chaitanya, Krishna veni
Gall Midge (*Orseolia oryzae*)	ARC 5984, ARC 10660, ARC 6605, Leuang 152, ARC 5959, ARC 13516, ARC 14787. HR 13, HR 14, Ratnachudi, Eswarakora, HR 12, HR 42, HR 63, AC-35(Ningar small), AC-39 (CNAB white rice), AC-210(Bhadas-79), AC-391(Bikiri sannam), ARC-5984 (Suto syamara), ARC-10660, ARC-12508(Khauji), ARC-12586 (Vale matse), ARC-12588 (Amamma matse), ARC-12670(Nien sah), ARC-13166 (Jaksa), ARC-13210(Yangbelok), ARC-14915 (Maich dol), ARC-14967(Galong), AC- 352 (PTB-2), AC- 362 (PTB-12), AC- 371 (PTB-21), PTB-24, AC-26704 (Phalguna) and Leaung-152	Eswarakora, Siam 29, OB 677, CR 94-1512-6, Shakti, PTB 18, W 1263, Surekha, Orumundakam, Velluthicheera, W 1263, WGL 20471, WGL 47970, Pothana, Phalguna, RP 140, ORS 677, CR157-212, CR157-303, Kakatiya, Divya
White Backed Plant Hopper (*Sogatella furcifera*)	ARC 5803, ARC 6064, ARC 7138, ARC 7318, ARC 10340	IET 6288
Stem Borer *(Chilo suppressalis)*	ARC 6158, ARC 10386, ARC 10443, NCS 266, NCS 336, NCS 464, ARC 5500, W 1263, AC-3094 (TKM-6), AC-392, AC-267 (ADT-14), AC-8396 (CB-1), AC-344 (MTU-15), AC-20006 (JBS-1638), Tepa-1	TKM 6, CB I, CB II, Manoharsali

	Donors	
Insect	Land races	Improved Varieties
Green Leaf Hopper (GLH) *(Nephotettix* spp.)	ARC 6606	PTB 2, PTB 21, ADT 14, Vijaya, ADR 52
Leaf Folder (*Cnaphalocrocis medinalis)*	ARC 1129, Gorsa, Darukasali, AC-33849 (Bundei), AC-35034 (Hari sankar), AC-33831 (Sunakathi), AC-33832 (Surjana), Juli, AC-35338 (Saru chinamali)	PTB 12
Yellow Stem borer	AC-33515, AC-33526, AC-33538, AC-33563, ARC-5984, AC-30300 (MR-1523) and AC-30349 (Aganni)	
Nematode	AC-26594 (TKM-6), AC-40083 (MTU-17), AC-467 (Lalnakanda-41), Hasma, Bahagia, AC-40509 (Manoharsali), Amla, AC-17134 (Sathia), AC-22899 (Anang), AC-23652 (Kalakeri), Kanyakaprashant	

10.1. Sharing of germplasm for Rice improvement programme

Supply or distribution of rice germplasm is an important mandate of the institute for the utilization in crop improvement programmes of the country. Germplasm are supplied to various institutes/organizations through proper signing of Material Transfer Agreement (MTA). Total germplasm supplied to various institutes/ organizations during last five years is detailed in Table 4.

Table 4. No. of rice germplasm accessions distributed within and outside institute.

Year	Within institute	Outside organizations	Total
2012-13	2261	1929	4190
2013-14	1466	362	1828
2014-15	4821	458	5279
2015-16	5245	237	5482
2016-17	4937	254	5191
2017-18	3075	177	3252
Total	19544	1488	21032

10.2. Germplasm evaluation and utilization

The genetic erosion has been very fast in recent years due to rapid modernization of the society and genetic diversity has been replaced by introduction of few high yielding varieties. Farmers are leaving their own traditional varieties and growing the improved cultures thereby many of the landraces have become extinct. The need for both *in situ* and *ex situ* conservation is now felt as the paddy cultivation in the country is largely affected by extreme natural calamities after rapid climate change, through an erratic monsoon. Earlier the biggest challenge was flood, but subsequently other factors like salinity after frequent cyclones and sea water surge, temperature rise and drought like situation in many parts of the country have put the challenge before rice researchers to incorporate these genetic factors in the plant.

The importance of genetic resources is widely recognized. Activities in germplasm banks demand qualified researchers in several areas of knowledge. Besides, the conservation of genetic variability for the future, the actual utilization of available accessions is another important goal. The main factors responsible for the low utilization of plant genetic resources are lack of documentation and adequate description of collections, accessions with restricted adaptability, insufficient plant breeders particularly in developing countries and lack of systematic evaluation of the collections. Low seed availability due to inadequate seed regeneration programs is another barrier to their use (Dowswell et al. 1996). Furthermore, breeder-to-breeder exchange materials are very common and constitute a reasonable alternative to extend genetic variability in breeding programs.

Besides biotic stresses, rice crop frequently faces problems of drought, low temperature, submergence, water-logging, salinity/alkalinity etc. These abiotic stress situations cause drastic reduction in yield and thus varieties with in-built resistance to such stresses are desirable. The germplasm having resistance to such stress situations have been identified (Table 5). The All India Coordinated Rice Improvement Project (AICRIP) was launched in the year 1965 and thereafter, more systematic evaluation against major biotic stress situations was undertaken with multi-location field screening followed by greenhouse evaluation.

After repeated screening of thousands of rice germplasm in simulated condition for different abiotic stresses, some landraces were identified as tolerant to complete submergence. They are Khoda, Khadara, Kusuma, Gangasiuli, Atiranga, Ande Karma, Nahng tip, Kalaputia and so on. In some areas crop suffers from floods when it is submerged under water for up to 10 days. Rice cultivars cannot survive such prolonged submergence. Few rice cultivars have been identified which survive submergence up to 80 cm water depth, for 10 to 12 days at early vegetative stage of the crop. Genetic analysis of one such cultivar, FR 13A revealed that tolerance to submergence is controlled by one major gene. Using FR 13A as a donor, improved rice cultivar, Swarna Sub 1 has been developed and released in India which is gaining popularity among the farmers.

Direct seeding is common in rainfed lowlands. In eastern India sometimes early rain causes water stagnation in the field just after sowing which results in poor crop establishment. Two cultivars namely Panikekoa, AC 1631 and T 1471 have been identified as anaerobic seeding tolerant germplasm. The anaerobic seeding establishes the crop under water, reduces cost of cultivation, saves crops from birds and rat damage, reduces weed growth and thereby herbicide application accounting all these towards organic farming. Similarly, several new donors were identified for salinity tolerance at seedling stage and they are Pokkali, Orumundakan, Rahaspanjar, Bhaluki, Kamini, Matchal, Ravana, Gitanjali and Talmugur apart from the most popular variety

Table 5. Important donors identified against abiotic stresses.

Stress	Donors: Land races	Donors: Improved Varieties
Drought tolerance	Mahulata, Brahman nakhi, Zingsaingma (AC-9387, MNP-387, IC0593953), Sathchali, Nepalikalam, Kodibudama, NC 487, Dagaranga, Mettamolagolukulu, NC 488, ARC 10372, NC 492, AS 180, Hasakumra, Maibi, Koijapori, Bairing, Ahu joha, ARC 10372, Noga ahu, Soraituni, Lakhi, Pera vanga, Bodat Mayang, Prabhabati, *O. nivara* (BCPW-30, AC-100476, IC-330611) and *O. nivara* (SRD 01-17 , AC-100374, IC-330470), AC-254, AC-263, AC-304, AC-511, AC-2298, AC-3035, AC-3111, AC-3577, AC-9066, AC-9387, ARC-7063, AC-45 (CH-45), AC-40083 (MTU-17), W-691, AC-467 (Lalnakanda-41), AC-35207 (Dular), AC-37077 (Dhan gora), AC-37127 (Black gora), AC-37291 (Kalakeri), AC-8205 (Surjamukhi), AC-34440 (Salumpikit), AC- 34256 (Kabiraj Sal), AC- 34296 (Bombay murgi), AC-34992 (Sal kain), AC-35021 (Kalon dani), AC-35038 (Godhi akhi), AC-35046 (Nadi tikar), AC-35059, (Phutki bari), AC-35060 (Bhuska), AC- 35143 (Baihunda), AC-35452 (Karama)	CR 143-2-2, N 22, MTU 17, Kalakeri, Janaki, AS 313/11, AS 47, Aditya, Tulsi
Cold Tolerance	AC 540, Siga, Rajai, CB 1,Dholiboro, Dunghansali, Raja Sanula	Boro 33, IRGC 100081, 10114, 10028, Barkat, Kalinga 2, Tella Hamsa, Satya, Gavinda
Submergence Tolerance	Bhundi (JRS-9, AC 42091, IC575277), Atirang, Kalaputia, Kusuma, Gangasiuli, Solpona, Sail badal, Dhola badal, Kolasali, Boga bordhan, Rongasali, Khajara, Dhusara, Nali Baunsagaja, FR 13A, FR 43B, Chakia 59, CN 540, S 22, Madhukar, AC-24682 (FR-13A), AC-35741(Telgri), AC-35323(Chaula pakhia), AC-35675(Biesik), AC-36107(SL276), AC-36470(Khoda), Khadara, AC-26670(Janki), AC-40844 (Manasarovar), Sarumuli, AC-40916 (Jalamagna), AC-40604 (Jaladhi-1), Kanawar	--
Deep water	Nagari bao, Kekoa bao, HBJ 1, Jalamagna, Jaladhi 1, Jaladhi 2	--
Coastal Saline/ Alkaline	Cherayi Pokkali (AC 39416, IC413644, NC/03-98), Paloi (AC 42169,JRS-100), Rupsal (AC 42465,PSS-74), Talmugur (AC 43228), SR-26B, AC-8532 (Pokkali), Pateni-2, AC-41360 (Nonabokra), AC-35255 (Rahaspanjar), Canning 7, Ravana	SR 26B, Getu, Dasal, Patnai 23, Pokkali, Hamilton, CSR 10, CSR 13, CSR 18, Vikas, Co 43
Water- logging	Tilakkachari, NC 496, Kalakher sail	Jhingasail, Patnai 23

SR 26B. Drought is another major abiotic stress that adversely affects the crop leading to low productivity. While screening repeatedly over the years, few landraces have been identified as tolerant to vegetative stress drought and they are Mahulata, Sunamani, Naliakhura, Ranganatha Bao, Bhuta, Bibhisal, Brahman Nakhi, Salkain, Gauranga, Karinagin and Kiaketi. Some of such unique germplasm have been registered (Table 6) with NBPGR for special attention and utilization in rice improvement programme across the country.

Table 6. Registration of Unique Rice Germplasm with ICAR-NBPGR.

Sl. No.	Name of germplasm	Year of registration	Registration no.	Important trait
1.	Khoda (PD -27)	2004	INGR No. 04001	Tolerance to complete submergence
2.	T-1471(Kodiyan)	2005	INGR No.05001	Tolerance to anaerobic seeding
3.	Khadara (PD33)	2008	INGR No.08108	Tolerance to complete submergence
4.	Atiranga (RM5/232)	2008	INGR No.08109	Tolerance to complete submergence
5.	Kalaputia (PCP-01)	2008	INGR No.08110	Tolerance to complete submergence
6.	Gangasiuli(PB-265)	2008	INGR No. 08111	Tolerance to complete submergence
7.	Kusuma (PD-75)	2008	INGR No.08113	Tolerance to complete submergence
8.	Mahulata (PB-294)	2008	INGR No.08112	Tolerance to vegetative stage drought
9.	Medinapore (RM5/AK-225; IC-0258990)	2010	INGR No. 10147	Tolerance to complete submergence
10.	Andekarma (JBS-420; IC-0256801)-	2010	INGR No.10148	Tolerance to complete submergence
11.	Champakali (IC-0258830)-	2010	INGR No.10149	Tolerance to complete submergence

Contd.....

Sl. No.	Name of germplasm	Year of registration	Registration no.	Important trait
12.	Brahman Nakhi (DPS-3)	2010	INGR No.10150	Tolerance to vegetative stage drought stress
13.	Sal kaiin (PB-78;IC-0256590)	2010	INGR No.08112	Tolerance to vegetative stage drought stress
14.	Bhundi (JRS-9; IC0575277; AC42091)-	2014	INGR 14025	Tolerance to complete submergence and having shoot elongation ability
15.	Kalaketki (JRS-4; IC0575273; AC42087)-	2014	INGR 14026	Tolerance to 20 days complete submergence
16.	CR 143-2-2 (IC0513420)	2017	INGR 17019	Tolerance to both vegetative and reproductive stage drought stress
17	Salkathi (AC-35181; PB-289)	2018	INGR17069	Resistance to brown plant hopper (BPH)

10.3. Conservation of Rice Germplasm

Due to the danger of genetic erosion, the effort of developing a cold storage system for rice germplasm was initiated at NRRI in 1984. Meanwhile, during 1986, it was decided to conserve all the germplasm of NRRI at the National Gene Bank. Since then, more than 30,000 rice germplasm accessions have been deposited in the long term storage (LTS) of NBPGR. Under the aegis of the Indo-USAID collaborative project, a cold module was gifted to NRRI. The facility became operative in 1998 with a controlled temperature of 4±2 °C and 33±5% RH and found to be rather dependable and is meant for medium term storage (MTS) and the seeds are kept viable for 6-8 years. When accessions in the MTS working collection drops below 50 g after seed supply to indentor or if seed viability falls below 85%, then the accession is rejuvenated. The *japonica* varieties are monitored more frequently than *indica* rice as they have an inherently shorter storage life than *indica* varieties.

The seeds of each of the accessions are dried for reducing the moisture content up to 10-12% and kept in 3-layered aluminum foil pouches for medium term storage. The outer layer of the pouch is polyester of 12 micron; intermediate layer is aluminum of 12 micron and the innermost layer is polythene of 250 gauges. These aluminum foil pouches are stored in cold module at a regulated temperature of 4 ºC and 33% relative humidity (RH).

There are about 106,000 accessions of rice germplasm conserved in NGB at -18 ºC and with 3-4% RH. After thorough evaluation and screening thousands of germplasm lines over the years, the NRRI has identified several donors resistant/tolerant to different biotic and abiotic stresses as shown in Tables. Utilising these donors in the breeding programme, the Institute has so far released 128 varieties for different rice ecosystems. In the past, NRRI was supplying the germplasm even to the foreign agencies, but in the context of IPR regime, the sharing of germplasm has been restricted to the researchers within the country.

Several categories of germplasm are conserved for different purposes. They are as follows-

a) Working collection: A collection of germplasm maintained and used by a breeder or other scientist for their own breeding or research, without taking any specific measures to conserve. The collection may have a short life span and the composition of the collection may vary greatly during its lifetime.

b) Active collection: A collection maintained by a gene bank and used as the source of seeds for active use, including distribution, characterization and regeneration. It is usually conserved under short- or medium-term storage conditions.

c) Base collection: A collection of seed ideally prepared and held in prescribed conditions for long-term conservation. The seed should be conserved and never used except for

    i. periodic germination tests

    ii. regeneration of samples conserved in long-term storage when their viability decreases below threshold

    iii. regeneration to replace stocks in an active collection after accumulating 3-successive generations of regeneration from active collection and

    iv. as the primary point of rescue when the accession is accidentally lost from all active collections.

d) Seed file: A small sample of original seed, set aside when a seed sample first arrives at the gene bank, to serve as the definitive reference sample. The seed file should be maintained under dry conditions preventing disease or pest damage, although not necessarily alive. Other seed samples of the same accession, *e.g.* for every new harvest, should be visually cross-checked with the seed file.

e) Safety back-up: Duplicate samples of the base collection, stored in a different gene bank, preferably in a different continent. The storage conditions in the safety back-up should be at least as good as those in the corresponding long-term collection. The holder of the safety back-up has no rights to use or distribute the seed in any way or to monitor seed health or viability. Additional duplication of the base collection to the Svalbard Global Seed Vault provides definitive safety back-up in case of large scale loss of crop diversity. Svalbard Global Seed Vault (SGSV) commissioned at Arctic island of Svalbard near Norway in North Pole in 2008 conserves about 0.8 million germplasm. It is managed by Norway's Department of Agriculture and the Global Crop Diversity Trust (GCDT) under the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA) and supported by Bill & Melinda Gates Foundation. Recently, India has deposited 25 accessions of pigeon pea in April, 2014 as the 59th Nation.

11. KNOWLEDGE GAPS

Though many rice germplasm are conserved in the gene bank but information on germplasm is not complete. Germplasm without characterization and evaluation data cannot be utilized for crop improvement programme. Hence a systematic characterization, evaluation and documentation of important traits against each germplasm required to be done for its better utilization by the breeder.

12. RESEARCH AND DEVELOPMENT NEEDS

i. Activities related to genetic resources are characterized by high cost and long term return. Introduction and germplasm exchange, collection, characterization, evaluation, documentation and conservation are essential steps that cannot be overemphasized.
ii. A database on agro-morphological traits of all germplasm conserved in gene bank need to be prepared.
iii. Also a National/central rice data-base can be prepared in collaboration with the research centers working in rice along with NBPGR.
iv. Research work should be oriented towards developing a core collection for better management and utilization of the germplasm. Work in this line has been initiated at this institute (Jambhulkar et al. 2017).
v. Human resource development by imparting training to persons engaged in PGR activities is required for proper maintenance and conservation of germplasm.

13. WAY FORWARD

i. Germplasm is basic to crop improvement programs for sustainable agriculture. A road map depicting collection sites need to be prepared so that areas which are not covered in the map will be explored and germplasm will be collected and conserved. Future collections should also aim at trait specific collection of germplasm.

ii. Wild and primitive populations are the reserves of cryptic variability and hence their capacity for adaptive response is high. Such genetic variation is as important as prevalent varietal diversity for genetic conservation. It is, therefore, important to collect and conserve the wild and weedy rice germplasm.

iii. It has been estimated that even 5% of rice germplasm conserved in different gene banks have not been utilized. Our research should be oriented towards developing a core collection which represents the diversity of entire collection and removes duplicate accessions that will enhance the use of germplasm by identifying diverse source of parents and also will ease in evaluating the germplasm against biotic and abiotic stresses.

iv. Identifying trait-specific genetically diverse parents i.e., salt tolerance, cold tolerance, drought tolerance, early/late heading, low chilling, tolerance/resistance to particular pests/diseases, adaptability to water logged habitats, tillering capacity, root system, leafiness, etc., apart from quality characteristics are the primary need of the plant breeder for trait enhancement. So identification of new diverse sources will help in better utilization of germplasm in the breeding programmes, aimed at producing agronomically superior cultivars with broad genetic base.

v. A rice seed file depicting photograph of individual germplasm may be prepared for identification of germplasm and avoiding misrepresentation of germplasm.

vi. Future works should aim at characterizing the gene bank materials and creating a data base for better utilization in breeding programme. Morphological and molecular characterization of a core/minicore and trait specific subsets will further enhance the usefulness of the germplasm accessions.

vii. Realizing the importance of genetic diversity, Jeypore tract of Odisha, the Palakkad area of Kerala and Apatani valley of Arunachal Pradesh should be protected as on farm *in situ* conservation sites.

14. CONCLUSION

The importance of genetic resources is widely recognized. Activities related to genetic resources like germplasm introduction, exchange, collection, characterization, evaluation, documentation and conservation are characterized by high cost and long term return. Until recent past, conservation of rice germplasm was synonymous with repeated rejuvenation in the field. This process of maintenance subjected the germplasm to a threat of losing their identity because of random and non-random processes due to sampling. Also loss due to unforeseen natural calamity of the type of super-cyclone and flood devastating the native germplasm cannot be ruled out so far on farm *ex situ* conservation is concerned.

In this chapter we tried to throw light on origin of rice and discussed about wild, weedy and Nerica rice. Various PGR activities like exploration, collection, conservation, characterization, evaluation, documentation, its status at ICAR-NRRI have been elaborately discussed. This chapter emphasizes collection of trait specific germplasm for its utilization in the breeding programme. The development of improved varieties through introduction and evaluation of germplasm in this institute are also highlighted. Future research work in creating a core/minicore collection and creating data base for better utilization of germplasm are emphasized.

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