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Rice Biodiversity in Cold Hill Zones of Kashmir Himalayas and Conservation of Its Landraces

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Abstract

Jammu & Kashmir is an agri-horticulture state (in India) where a large population is economically dependent to agriculture and horticulture, directly or indirectly for livelihood, food and nutritional security. Rice, the staple food of majority population, is cultivated in diverse agro-ecological situations extending from subtropical area (<1000 m amsl) of Jammu, through temperate valley to cold high altitudes regions (1650–2400 m amsl) of Kashmir, and therefore rice biodiversity is rich. Some of the landraces fall into *indica* type and thrive well in temperate regions of valley, while others fall into *japonica* type and are prevalent in hilly areas. Cold tolerance is a special feature in most of these peculiar landraces, which are different from rest of the country. However, with the advent of High Yielding Varieties the local biodiversity got neglected and remained confined to seed banks. With new emerging challenges like climate change, population explosion, limited land and water resources, demand for organic products, local landraces have assumed tremendous importance, either for direct exploitation or indirect use. In this chapter, we attempt to bring out information about these landraces in a comprehensive manner and discuss the issues pertaining to their conservation, utilization, cultivation and revival through approaches like participatory plant breeding, participatory varietal selection or plant biotechnology.

Keywords: *Oryza sativa*, climate change, high yielding varieties, cold tolerance, characterization, India

1. Introduction

The state of Jammu and Kashmir comprises the extreme western part of the Himalayas (32.44°N and 74.54°E), with altitude ranging from 200 to 7000 m amsl. The valley of Kashmir

(temperate zone) is approximately 120 km long and 32 km wide with an altitude range of 1524–2286 m amsl. Annual precipitation varies from 700 to 1500 mm. The temperature remains generally low, varying from -10°C during winter to 30°C during summer, with a yearly average of around 13°C . Generally, soil in rice growing areas is clay loam with a neutral pH. The economy of Jammu and Kashmir is predominantly agrarian, rice being the staple food and the most important food crop occupying an area of almost 140 thousand hectares. There are many well-known landraces of rice in Kashmir, noted for their unique qualities, peculiar taste and texture after cooking, early maturity and cold tolerance. When Green Revolution made its impact in India, the state of Jammu and Kashmir did not lag behind. Some introductions from China like China-1039, China 1007 and locally bred varieties like K-39, Jhelum and Chenab spread to every nook and corner of the state through vigorous political and infra-structural support by way of different Govt. sponsored schemes. As a result, faster replacement of indigenous low yielding landraces by modern High Yielding Varieties (HYVs) took place in the sixties and the entire rice area of Kashmir valley got covered under a few varieties.

China 1039 and China 1007 were the most popular varieties during 60s and 70s; K39 was the dominant rice variety from 80s to mid-1990s; while Jhelum took over as the most popular variety for the decade beginning from mid 90s. This variety has an excellent cooking quality and is most preferred even today, but due to its susceptibility to blast there has been a decline in its area. In order to save farmer's interests a blast tolerant variety Shalimar Rice-1 was released in 2005 by the State Varietal Release Committee for the valley basin irrigated areas of Kashmir. This was followed by release of Shalimar Rice-2, Shalimar Rice-3, Shalimar Rice-4, all of which are blast tolerant and have good cooking quality (**Table 1**).

Variety and year of release	Cross combination	Salient feature
Plains (upto 1650 m amsl)		
China 1039 (1955)	Introduction	Yield potential 50–55 q/ha, cold tolerant, lodging and shattering susceptible, maturity 136–140 days (1650 m amsl). Moderately susceptible to blast, recommended for cultivation upto an altitude of 1650 m amsl
China 1007 (1956)	Introduction	Yield potential 50–60 q/ha, lodging and shattering resistant, cold tolerant at early stages of growth, maturity 145–147 days, special attribute: resistant to blast and suitable for low lying areas.
China 988 (1956)	Introduction	Lodging and shattering resistant, cold tolerant at early stages of growth, maturity 147–150 days, moderately tolerant to blast, suitable for low lying areas.
China 972 (1956)	Introduction	Lodging and shattering resistant, cold tolerant at early stages of growth, maturity 147–152 days, moderately tolerant to blast, suitable for low lying areas
K-60 (1962)	China 47/RIKUU-132	Resistant to shattering and lodging, resistant to cold, maturity 140–145 days, blast resistant
K-65 (1966)	NORIN-8/China-47	Easy threshability, lodging susceptible, low head rice recovery, maturity 140–145 days, suitable for low lying areas
K-39 (1978)	China 1039/IR-580	Yield potential 58–62 q/ha, high yielding, recommended upto 1650 m amsl, mod: susceptible to blast, resistant to lodging, maturity 140–145 days. High head rice recovery (%age)

Variety and year of release	Cross combination	Salient feature
Chenab (1996)	K-21/IR-2053	Yield potential 60–65 q/ha, coarse grained, moderately tolerant to blast, cold tolerant, possess complete synchronous flowering recommended upto 1650 m amsl, better cooking quality, maturity 138–140 days.
Jehlum (1996)	JAKKOKU/IET-1444	Yield potential 60–65 q/ha, high yielding, better cooking quality, greater tolerance to cold, moderately susceptible to blast. Recommended upto 1650 m amsl, maturity 138–140 days.
Shalimar Rice-1 (2005)	China 1007/IET 1444	Yield potential 65–70 q/ha, high yielding, better cooking quality, greater tolerance to cold, highly resistant to blast. Recommended upto 1650 m amsl, maturity 142–145 days, medium bold grain size.
Shalimar Rice-2 (2012)	VL Dhan 221/K 39	High yielding (80–85 q/ha) moderately blast resistant <i>indica</i> rice variety having long panicle, more number of grains/panicles strong stem, resistant to lodging, high phenotypic acceptability takes 139–143 days to mature. Recommended for plains of the valley (upto 1650 m).
Shalimar Rice-3 (2012)	IR32429-47-3-2-2/K 438	High yielding (80–85 q/ha), early maturing, cold tolerant <i>indica</i> variety having moderate resistance to blast, erect plant type, easy thresh ability, erect flag leaf, recommended for cultivation in plains of the valley (upto 1650 m)
Shalimar Rice-4 (2016)	Jehlum/84017-IR745-12-1	High yielding (75–80 q/ha), early maturing, cold tolerant <i>indica</i> variety having resistance to blast, easy thresh ability, recommended for cultivation in plains of the valley (upto 1650 m)
Higher belts (upto 1800–2100 m amsl)		
Shenei (1967)	Introduction	Yield potential (30–35 q/ha), moderately tolerant to blast, cold tolerant, maturity 130–135 days, recommended ecology 1850–2200 m amsl
China 971 (1967)	Introduction	Yield potential (30–35 q/ha), moderately tolerant to blast, cold tolerant, maturity 130–135 days, recommended ecology 1850–2200 m amsl
Barkat (1974)	Shenei/China 971	Yield potential (38–40 q/ha), cold tolerant, high head rice recovery, susceptible to blast, maturity 140–145 days. Suitable for cultivation under mid altitude condition 1650–1850; universal donor for cold tolerance
K-332 (1982)	Shenei/Norin 11	Yield potential 40–45 q/ha, <i>japonica</i> type, cold tolerant, high head rice recovery, moderately resistant to blast, maturity 130–140 days.
Kohsar (2002)	Shenei/GINMASARI	Yield potential 45–50 q/ha, <i>japonica</i> type, cold tolerance particularly at seedling stage, high degree of resistance to blast, suitable for high hills of the valley (1800–2150 m). The variety has high head rice recovery, easy threshability, sticky type of grain, short bold grains, and matures in 138–140 days
Subtropical area (<1000 m amsl)		
Ranbir Basmati (1996)	Selection from Basmati 370	Suited to non-basmati growing areas, yield potential 20–30 q/ha; altitudinal tolerance upto 1000 m.

Table 1. The most popular rice varieties and their salient features.

Narrow genetic base increases the vulnerability of rice production system to biotic/abiotic stresses and has resulted in yield stagnation. Among the biotic stresses rice blast is the most damaging disease in Kashmir, while low temperature ranks first among the abiotic factors limiting rice production [1]. Further, climate change is also a potential threat to rice production owing to erratic rise/fall in temperature, and change in the dynamics of pests and diseases. These nutritional and food security related issues demand the immediate attention of rice breeders and biotechnologists. Locally available rice germplasm is a valuable repository of traits which could help address most of these concerns effectively. Novel gene pools could be generated from the characterized germplasm and donors for yield, quality and resistance to biotic and abiotic stresses identified. Besides, there are some quality rice varieties which when cultivated properly can boost the farm income substantially.

2. Collection, conservation and documentation of rice biodiversity - How and why?

The advent of Green Revolution had an overwhelming impact on rice production in Kashmir, as was elsewhere in the country. In 1966, the International Rice Research Institute (IRRI) released the first high yielding rice variety in the Philippines. In the subsequent decade Rice Breeders at Rice Research Station, Khudwani introduced Chinese high yielding varieties viz., China 1039, China 1007, China 988 and China 972 in selected pockets of Kashmir valley. However, in a matter of few years these varieties and the rice varieties developed by the station through crossing programme viz., K-60, K-65 and K-39 (most popular) almost completely replaced hundreds of the traditional rice landraces previously cultivated by the farmers [2]. The new rice varieties had a higher harvest index (grain/straw ratio), and the benefit of delivering significantly higher yields when combined with accompanying management practices, including irrigation, weedicide and fertilizer application. These high yielding varieties spread in favorable environments, where the natural and infrastructural setting allowed for such practices. In unfavorable environments, in which irrigation and mechanization were not possible or agrochemicals were not available, the cultivation of the traditional landraces persisted. These marginal areas (upland environments, high altitude belts, very cold areas, etc.) could serve as a repository of indigenous rice germplasm/landraces. One such niche area is the 'Sagam' belt of Anantnag district, which continues to grow aromatic landraces *Kamad* and *Mushk budji*.

Waking up to the loss of original indigenous varieties of agri-horticulture crops a 'National Agricultural Technology Project on Sustainable Management of Plant Biodiversity (1995–2005)' was undertaken by scientists of SKUAST-K. Under this project a total 1911 germplasm accessions, which were under cultivation before the introduction of improved or imported varieties, were collected. The collected biodiversity included 742 accessions in cereals, 38 in pseudo cereals, 28 in millets, 71 in oilseeds in pulses, 377 in vegetable crops, 21 in spices and condiments, 13 in fodder crops, 204 medicinal and aromatic plants, 55 in fruit crops and 4 in

others. The university deposited 1447 germplasm specimens with the National Gene Bank for storage and handed over 557 germplasm accessions to the Germplasm Handling Unit of the National Bureau of Plant Genetic Resources (NBPGR), New Delhi for long term storage. For collection of rice germplasm, expeditions were undertaken by a team of rice experts and scientists to collect the rare germplasm from different areas, among which Tral (Wagad, Shikargah), Pahalgam (Batekoot, Puhri-pajal, Khayar Hapath-nard), Shopian (Balpora, Ganapora, Shadimarg, Kalampora), Badgam (Khan sahab, Chadoora), Kupwara (Nagri malpora), Rajouri and Uri were the prominent ones. Nearly 100 existing landraces of rice were collected and assigned accession numbers, for conservation and maintenance in the seed bank at Rice Research & Regional Station, Khudwani.

Currently most of the rice fields in Jammu & Kashmir are occupied by merely a small number of high yielding rice varieties, of which K-39, Jehlum, Chenab, Shalimar Rice 1, Rambir Basmati are the prominent ones. This trend is no different than rest of India and other Asian regions. In India the most widely grown rice varieties are Swarna, Samba Mahsuri, Sona Masuri, Jaya, Ratna, etc. In Philippines almost half of the rice area is devoted to four of the most widespread HYVs, Cambodia one single IRRI variety (IR66) accounts for around 90% of the rice area, and in Pakistan only four HYVs are planted on 99% of the country's rice fields. This illustrates the immense 'genetic erosion' that has occurred in farmers' fields since the onset of the Green Revolution.

At present, 580 germplasm accessions, indigenous and exotic, are being maintained as three row material at Mountain Research Centre for Field Crops (erstwhile Rice Research & Regional Station), Khudwani. Almost all these accessions have been characterized for different agro-morphological traits, diseases resistance score (leaf blast, panicle blast) and aroma in a period of 5 years (2008–2013). A systematic and exhaustive morphological and molecular characterization of the 'speciality' rice types has revealed some interesting results [3]. DNA fingerprints of 16 pigmented and aromatic genotypes, mostly of Western Himalayan region (32° 44'–35° 2' N and 74° 28'–75° 48' E at altitude range of 1540–2200 mamsl in Kashmir; and 31° 17' N and 76° 51' E at an altitude of 1190 mamsl in Himachal Pradesh (India) have been developed and these were evaluated for genetic diversity using SSR markers. Various population parameters viz. range, mean, skewness and kurtosis from the data generated have shown wide range of variability (unpublished). This has enormous implications for future studies on gene/allele mining, as germplasm in Western Himalayas could serve as a vital resource of genetic repository for marginal areas.

The germplasm bank at MRCFC Khudwani maintains some well adapted exotic introductions (including *Goshigon*, *Chengshi*, *Koshihikari*, *Cheolwean 32*, *Kunusa rex*) and some indigenous introductions (like *Heera*, *Dullar*, *Bahrigu dhan*) from other rice growing regions of India. It also maintains some international blast differentials (like C101-LAC, C101-A51, C101-PKT, C105-TTP-4-1-23, RIL 10, RIL 29, NP 125, USEN, Tadukan, Shia-tai-tsau, HR 12, CO 39 etc.) which are being used in the development of blast tolerant rice genotypes [4] (Figure 1).



Figure 1. Biodiversity of rice, as depicted through a range in morphological variability.

3. Why are landraces important?

3.1. Genetic and agronomic value

The local varieties are a repository of diverse genes, some of which are of practical importance in the changing socio-economic as well as edaphic/climatic conditions. While all high yielding varieties in Kashmir are white, mostly with medium bold grains, local rice varieties often exhibit tremendous morphological diversity. The color of the outer layer (pericarp) can range from black/purple to red and brownish to white. The grain weight of landraces in Kashmir, as characterized by the thousand-kernel weight, varies between 15 and 32 g, while the HYVs varies only between 22 and 34 g. In fact, more than 90% out of 92 identified landraces cultivated in the area are no longer under cultivation (**Figure 2**).

The findings of a recent study, conducted somewhere else, are presented here to illustrate the importance of conserving and exploring the ‘genetic value’ of landraces. A major quantitative trait locus for phosphorus-deficiency tolerance, *Pup1*, was identified almost a decade back in the traditional *aus*-type Indian rice variety ‘Kasalath’ [5, 6]. The locus was sequenced and *Pup1*-specific protein kinase gene located, which was recently named as phosphorus-starvation tolerance 1 (*PSTOL1*) gene. It is important to emphasize that this gene is absent from the rice reference genome and other phosphorus-starvation-intolerant modern varieties. The overexpression of *PSTOL1* in such varieties significantly enhances early root growth and grain yield in phosphorus-deficient soil by enabling plants to acquire more phosphorus and other nutrients [7]. The absence of genes like *PSTOL1* and submergence-tolerance gene *SUB1A* from modern rice varieties underlines the value of traditional rice germplasm.

3.2. Socio-economic and cultural value

Rice is not only the dominant staple food, but also an integral part of culture in rural Kashmir. Some landraces have a special cultural value, for example scented landraces *Mushk budji* and *Kamad* have traditionally been served on particular occasions like marriage ceremonies and festivals. These varieties used to be sold as ‘food for the royal families’ in the local markets of



Figure 2. Local biodiversity of rice as depicted by the difference of panicle type, grain type, grain color, awn type etc.

Srinagar during the times of Maharajas, which could only be afforded by the affluent and rich families owing to their 4–5 times higher market price. These landraces are highly valued even in present times and are served to distinguished visitors and dignitaries. Some red rice types called ‘Zag’ are used for the preparation of snacks like ‘Vazul bate’ for pregnant ladies owing to their higher nutritive value, while some are preferred for preparation of munchies like ‘Bate laaye’, ‘Mur-murei’ and ‘Chewrei’. The varieties’ names in the local language often reflect the rice’s appearance (*Kaw kreer*, *Laer beoul*, *Nika katwor*, *Shala kew*), smell (*Mushk budji*, *Mushkandi*), color (*Zag*, *Safed Khuch*, *Bari safed*, *Kaw kreer*, *Khuch*, *Sig safed*, *Safeed braz*, *Safed cheena*), cultivator’s name (*Aziz beoul*, *Begum*, *Qadir baig*, *Rehman bhatti*, *Noormiree*), etc. Many varieties are characterized by a very specific taste, and their seeds are exchanged among neighbors/relatives, or are gifted for eating purposes in the form of roasted rice, locally called ‘*Bayel tamul*’. The long-grained basmati type varieties are cooked as ‘*Kashmiri pulao*’ and served along with dry fruit and raisins in the famous Kashmiri cuisine locally called as ‘*Wazwan*’. The loss of biodiversity therefore would also imply a fading rural culture (**Figure 3**).

3.3. Health value

The taste, texture and organoleptic value of rice depend on many factors. Rice is a starchy staple food which provides almost 90% of dietary energy to an average Kashmiri. It is a part of their culture, and even in parties, conventions, get-togethers rice is an indispensable component of their dishes. No party can ever be even imagined without ‘*bate*’ (cooked rice)! Starch properties of the traditional varieties are therefore an important factor determining the choice of varieties for different occasions. Varieties differ widely in the proportion of starch composition/fractions of amylose (consisting of linearly linked glucose molecules) and amylopectin (composed of glucose molecules with branched links). The waxy rice varieties consist of amylopectin only, and have a sticky texture because these absorb less water upon cooking. On the other hand, rice landraces with more than 25% amylose content absorb more water and have a fluffy texture after cooking. Higher proportion of amylose is further associated with low glycemic index (slow starch digestion) and longer feeling of satiation after ingestion. On the other hand fast



Figure 3. Agricultural biodiversity shapes food culture (a) Kashmiri salted rice *Taeher*, generally served at *Sufi dargahs* (b) Sweet *Kashmiri pulao* served with *Wazwan* (c) *Bate laaye* sold by local vendors as snacks for children (d) Cooked pigmented rice by a *Gujjar* family.

digestion can cause a sensation of hunger shortly after the ingestion of waxy rice and is considered unfavorable because its long term consumption can induce type II diabetes (i.e. non-insulin dependent diabetes) in adults. There is a prompt and pronounced increase of the blood glucose level (= high glycemic index) after the ingestion of rice (especially waxy rice), similar to that caused by white bread or pure glucose. Therefore in some parts of Jammu & Kashmir such waxy varieties are used for the preparation of sweet/salty snacks (*Meethay chaval*, *Taeher*) by cooking them and then cooling before consumption. Some varieties are preferred for the preparation of bread (*Tomul tschot*). Cooling after cooking has been shown to substantially slow down starch digestion due to physiochemical changes in the starch structure (retrogradation) [8]. Besides starch composition many other factors specific to these varieties viz., physiochemical starch structure or the size of the starch granules, also contribute to delayed starch digestion.

3.4. Grain nutritional value

Another aspect that makes rice landraces attractive is the wide range in palatability, texture, and nutritional value depending upon their genetic makeup. With the advent of high yielding varieties and large scale adoption of the rice milling technology the spread of vitamin

B-deficiency (*beri-beri*) has become more common, due to the loss of vitamins through the disposal of rice bran. Earlier farmers used to process their rice manually and remove only the fibrous hull. Rice was then consumed as 'brown rice' that included the bran layer. The 'nutritional diversity' of rice bran added value to the rice bowl, because bran is more diverse in its composition and contains protein, lipids, fiber, vitamins, and minerals. The major vitamins present in the rice bran are vitamin E (α -tocopherol) and the B-vitamins (thiamin, riboflavin, and niacin) while the major minerals are phosphorus, potassium, and magnesium. It is a general practice nowadays to process rice grain by additionally removing the bran layer from the endosperm to obtain milled rice. This is done due to the consumers' preferences but it takes away the nutritive 'value' from nutritionally rich landraces, making them at par with other landraces or varieties. A study on Philippine rice landraces has suggested that their average lipid content is significantly higher than that of the HYVs collected from the same area. The lipid content of HYVs (brown rice) ranged between 2.0 and 2.1%, while its average value for the landraces was 2.3%, with some individual varieties having 3.2% lipid content. Similar study was undertaken on landraces of Kashmir [9]. A highly aromatic landrace of Kashmir Himalayas 'Mushk budji', which is grown in mid altitude cold regions, showed maximum total protein (8.86%) content as well as highest fiber content (3.31%). However, it recorded the lowest starch content of 70.45% while a popular high yielding variety grown in the plains of Kashmir valley 'Shalimar rice-1' recorded the highest (79.36%) starch content as well as maximum amylose percentage (24.34%). Total Phenol content showed a wide range from 4.87 to 1.02 mg/g, with maximum in a pigmented rice genotype 'Purple rice' while lowest in 'Jhelum', a popular high yielding rice variety. Besides, purple rice also had maximum total anthocyanin (9995.34 $\mu\text{g/g}$) content, while lowest (5943.14 $\mu\text{g/g}$) was recorded in Jhelum. Similarly, total carotenoids too varied in a wide range, with 'Khuch' recording almost 10 times (0.022 $\mu\text{g/g}$) than the lowest (0.002 $\mu\text{g/g}$) in Shalimar Rice-1 and Jhelum. These results indicate that scented and pigmented rice genotypes of Kashmir Himalayan region are of better nutritional quality than the conventional high yielding varieties and could be promoted as 'Specialty' rice for better economic returns to the farmers [9].

Similarly, higher levels of β -carotene are generally found in pigmented (colored) rice varieties [10]. Such landraces of Kashmir with colored pericarp viz., brown (*Zag*, *Khuch*, *Khuch niver*, *Mir zag*, *Niver*, *Mir sagi*, *GS 10*, *GS 44*, *GS 51*, *GS 52*, *GS 80*, *GS 83*, *GS 224*, *GS 268*, *GS 289*, *GS 484*, *GS 501*), purple (*Purple rice*), black (*Zager*, *Kaw kreer*) are only cultivated in remote areas maintaining a higher diversity of rice genotypes. Carotenoids being fat soluble, such varieties generally possess higher lipid content too. From a nutritional point of view this is favorable because it ensures the supply of unsaturated fatty acids necessary for the transformation of β -carotene into vitamin A. As with vitamins, minerals like iron and zinc are chiefly located in the bran of the rice grain. Generally, iron and zinc contents tend to be higher in aromatic and colored (red and black) rice varieties than in colorless varieties and ordinary HYVs [11, 12] (**Figure 4**).

3.5. Disease management value

Magnaporthe grisea, the causal agent of blast disease, is a serious pathogen of graminaceous species and is best known as the causal agent of the rice blast disease. The disease is a serious



Figure 4. Pigmented rice types (a) *Purple rice* (b) *Niver* (c) *Zag* (d) *Zager*

production constraint for rice in the northwestern Himalayan region of India, comprising the states of Jammu and Kashmir, Uttaranchal and Himachal Pradesh [13]. The disease is endemic to most rice growing areas of Jammu and Kashmir due to prevailing blast-conducive environmental conditions during the crop season. Although, chemical control of the disease is available, it is economically expensive for resource poor farmers and is environmentally undesirable. Since host resistance offers cost effective and eco-friendly method for disease management, a study in China has demonstrated how diversification of rice varieties is able to significantly reduce rice blast infestation [14]. Genetic diversity is a defense against diseases and pests owing to the presence of diverse genes and genetic components, which give selective advantage to these varieties under heavy selection pressure imposed by diseases. The rice blast disease is one of the major diseases in Kashmir, which exists as a combination of pathogenic races. Therefore, rice resistance genes often remain effective only for a few years of agricultural production, before succumbing to new pathogenic races. In the Chinese study diversification as a pest management strategy was so successful that farmers were able to abandon the use of fungicides in just 2 years. Similar results were obtained in Philippines, where more than 50 rice landraces were cultivated in two upland municipalities, and there were no reports of any rice pest infestation, except rats and birds [10]. A preliminary study with this purpose was conducted at MRCFC, Khudwani wherein rice germplasm was screened for blast tolerance under temperate conditions of Kashmir valley. Evaluation was



Figure 5. Popular landraces of rice in Kashmir (central two are scented, and outer two are red rice types).

made by the IRRI's standard evaluation system of rice on 0–9 scale. The promising test entries with tolerance to blast can increase prospects of producing rice organically.

4. Initiatives in biodiversity management of rice

4.1. Purification of scented local landraces

Kashmir is well known for the cultivation of some local scented landraces grown in different agroecological niches and maintained by farmers since time immemorial. Of the aromatic cultigens, *Mushk budji* and *Kamad* are in great demand due to their excellent cooking and eating qualities [15, 16]. Earlier, in absence of blast infestation these varieties would yield grain of 3.0–3.5 t/ha in farmers field. However, the yields declined drastically due to their

vulnerability to virulent races of rice blast pathogen (*Magnaporthe grisea*). Therefore, these varieties were thrown out of cultivation, except in some small isolated pockets where these varieties are being grown as complex mixtures. These varieties fetch 5–6 times higher price in local markets than the commonly grown high yielding varieties. In view of this an attempt was made at MRCFC, Khudwani to purify the farmers bulks and identify superior pure lines of *Mushk budji* and *Kamad* with good quality and agronomic attributes to boost the income of farmers. Fifty-five single plant selections of *Mushk budji* and 64 single plant selections of *Kamad* were chosen from the farmers' fields in *kharif* 2008 and threshed separately to raise the head to row progeny during *kharif* 2009. Based on yield, disease and quality traits, 18 promising progenies of *Mushk budji* and *Kamad* were selected for further evaluation during *kharif* 2010. Out of 16 *Mushk budji* pure line selections made from 55 single plant selections collected from different areas of Kashmir valley, three selections were finally found to be at par with each other in terms of grain yield and aroma and were chosen for seed multiplication, while one *Kamad* line was selected for its seed multiplication. During *kharif* 2011 these lines were multiplied to produce nucleus seed, and evaluated for agro-physiological characters and distinguishing morphological descriptors. During *kharif* 2012 these were being multiplied for distribution among farmers. The *Mushk budji* seed was distributed at MRCFC Khudwani among the farmers of Sagam, Kokernag, and Batengu; while in districts of Budgam, Kulgam, and Pulwama it was distributed to farmers through the respective Krishi Vigyan Kendras (KVKs). However, not much success could be achieved in identifying blast tolerant genotypes among these accessions and blast resistance remained a challenge. A programme on Marker Assisted introgression of blast resistance genes (*pita*, *pi54*) in *Mushk budji* was introduced recently (2014) with some progress already achieved (personal communication).

4.2. Identification and evaluation of local red rice type land races

As discussed earlier, a fruitful outcome of germplasm characterization was that some of the promising nutritive red rice types having colored pericarp were identified for evaluation, molecular intervention and biofortification. Preliminary evaluation of the 13 major red rice types viz., *Zag*, *Kupwara Zag*, *Uri Zag*, *Mir Zag*, *Khuch*, *Mir Sagi* and some other accessions (GS 51, GS 80, GS 83, GS 224, GS 268, GS 289, GS 484) was also completed for yield and agronomic traits (2011–2012). The biochemical and mineral contents (Iron & Zinc) of these landraces are being determined using modern techniques (Figures 5 and 6).



Figure 6. Evaluation, purification and selection of best genotype from *Zag*, *Mushk budji* and *Kamad* at MRCFC, Khudwani.

5. The way forward: What do we need to do?

Rice is cultivated in different agro-ecological regions of J&K, comprising sub-tropical area >1000 m amsl of Jammu region; mid altitude areas (1000 to <1650 m amsl) of Poonch, Rajouri and Doda districts; temperate or valley basin area (1650 to 1900 m amsl) and cold high altitude areas (>1950 to 2400 m amsl) of mountainous terrain of Kashmir. Nearly 10–12% of total rice cultivated area of the valley falls in the higher altitude region. The population of this region lives in harsher climate and difficult hilly/mountainous terrain. The farmers in this region still grow old non-descript varieties/cultivars which have poor yield potential and are susceptible to Paddy blast. Low temperature and very short summer months reduce yield and affect nutrient availability/mobilization rate from the soil. These are a big impediment to the introduction of varieties from mainland India, most of which thrive well under subtropical conditions [17]. Attempts were made in the past to develop high yielding cold tolerant rice varieties like Barkat, K332, Kohsar etc. [1, 15, 16]. Similarly, an innovative programme on development of a hybrid rice was started at SKUAST (K), Khudwani, after procuring cytoplasmic male sterile (CMS) lines and their maintainers from various institutions such as the International Rice Research Institute (Philippines), Directorate of Rice Research (Hyderabad), Central Rice Research Institute (Cuttack), and Punjab Agricultural University (Ludhiana). Studies on the performance of these CMS and maintainer lines (of tropical and subtropical regions) for various agro-morphological traits under temperate conditions of Kashmir revealed that these lines, because of poor phenotypic acceptability, cannot be used to develop experimental hybrids [18]. In addition, a good number of hybrids released in India were also evaluated along with their parental lines under temperate conditions and were found to be not suitable for cultivation in such an environment [19]. Thus, efforts were made to develop new CMS lines in the background of agronomically adapted and popular varieties of the region in order to fully exploit this technology. This led to the development of two cold-tolerant CMS lines suitable for Kashmir Himalayas [19]. These CMS lines were then successfully employed for development of medium-bold rice hybrids with good grain quality for Kashmir Himalayas [20].

The challenges to nutritional and food security need to be addressed. At the same time weightage of an equal measure needs to be given towards the conservation and utilization of rice genetic diversity. This can be done using a multi-pronged strategy involving the following:

5.1. Conservation and rejuvenation

Most of locally adapted aromatic and non-aromatic rice genotypes have evolved as a consequence of natural and human selection, and are highly adapted to specific ecological niches carrying the genes for adaptability, early maturity and cold tolerance. These genotypes, having evolved under specific ecological niches of Kashmir carry combined adaptive traits for such difficult ecological regime, and are not much amenable to high input agriculture. Therefore, these need to be conserved/maintained, and periodically cultivated for evaluation under resource poor and marginal conditions of far flung areas.

Conservation should aim to preserve all of the genetic variation that is available in a population, and is best insured by seed rejuvenation in an environment as similar as the native habitat of the population. On the contrary, evaluation should aim at the identification and isolation of obviously useful genotypes, involving selection and purification in the process. Splitting of original stocks into pure lines, and repeated seed increase cycles, are adjuncts of evaluation and utilization. Conservation maintains the germplasm inputs, while evaluation and utilization make these conservation efforts worthwhile. The dynamics of any crop needs to be understood prior to initiating any on-farm conservation and utilization programme. The conventional approach so far has been to transfer technologies generated elsewhere to the farmers. But such an approach has not only been less efficient in the adoption of the technologies by the farmers, but has also led to replacement or erosion of local genetic resources. This raises the question of how to generate relevant and farmer preferred technologies, while attempting to conserve, manage and utilize the rice diversity at community level.

Can participatory plant breeding be a guiding principle for redesigning/revitalizing the landraces to suit modern times? And can participatory varietal selection help in conserving the landraces in pure form wherever they fit farmers' criteria and consumers' preferences.

5.2. Participatory plant breeding and participatory varietal selection

There is a serious concern among the farmers, scientists, policymakers and environmentalists regarding continuous erosion of genetic biodiversity. When uniformity becomes the cause of genetic vulnerability, genetic diversity is the only insurance against it. In the era of climate change complex biotic and abiotic stresses shall cause the high yielding varieties succumb and lose their comparative economic advantage. The crisis is further expected to deepen in scope as well as intensity, when pressure due to population increase and urbanization causes shrinkage in rice area, as well as shift in rice cultivation towards newer areas with untested soil types, different climatic patterns, and new pathogenic interactions. Under these circumstances, can local landraces be a part of the solution?

Although many landraces are preserved by breeders in seed banks, farmers do not have access to these for cultivation. Moreover, preservation in seed banks does not allow these landraces to adapt to changing environmental settings and changing agricultural practices. In order to address both these issues and meet the challenges (discussed in above paragraph), systematic screening of the desired rice types by local farmers of an area, through participatory varietal selection (PVS), can lead to useful site-specific introductions [21]. In this perspective it may be renamed as participatory varietal dispersal (PVD), and can lead to high seed replacement rate. PVS will also generate wealth of information about the (a) farmer preferred traits, and (b) trade-off between traits, which can then be followed by participatory plant breeding (PPB) for incorporating such useful traits/genes into the existing varieties and landraces. This would ensure genetic diversity on ground, and guarantee sustained levels of high productivity (**Figure 7**).



Figure 7. Participatory varietal selection (PVS) could be a good strategy for evaluation, dispersion and distribution of local landraces.

5.3. Value addition and promotion of domestic/international trade

Many landraces, mostly of *japonica* background, are known for their superior agro-morphological and quality traits like taste, aroma, texture, colored aleurone, early maturity and cold tolerance. Notable among them are *Mushk budji*, *Kamad*, *Nun beoul*, *Laer beoul*, *Zag* and *Khuch*. While their collection, characterization and conservation in hot spots of the valley is important from genetic point of view, their purification and commercialization is of special importance from the farmers' perspective of livelihood security. Therefore, there is an urgent need to add value to these landraces by enriching them with minerals and micronutrients like iron, zinc etc., and promote their commercialization as 'speciality rices'.

Further, scientific studies on aromatic rice of Kashmir have not given ample attention to their domestic trade in the past, despite the fact that scented rice varieties have competitive international price and the state can earn foreign exchange from them. However, in the present decade Ministry of Agriculture, Government of J&K has keenly supported the promotion and revival of these varieties. The Ministry of Commerce, Government of India, has permitted export of *Sarveshwar* Basmati of Jammu & Kashmir to USA, Jordan and Saudi Arabia so that the farmers of the state could get benefited [2]. In order to further the cause it is important for the farmers, scientists, policymakers and environmentalists to understand the pattern of domestic trade of aromatic rices at the micro level to address the basic issues of promoting their cultivation, production and export. The marketing and price-spread patterns of aromatic rices of Jammu and Kashmir like *Mushk budji*, *Kamad*, *Ranbir basmati* have to be examined and policy interventions suggested with regard to their production and trade in the state. A beginning in this direction was made in the year 2012 by setting up demonstrative plots of *Mushk budji* and *Kamad* on an area of 0.8 ha in Sagam, and cultivated by local farmers under the guidance of SKUAST-K. The revival programme was a huge success. The landrace *Mushk budji* was released by Hon'ble Governor J&K at 3rd Agricultural Science Congress of J&K (2014) under Public Private partnership mode by SKUAST-K and Sarveshwar Overseas Ltd. The farmers that were involved in the programme bagged the Plant Genome Savior Community Award (2016) from Protection of Plant Varieties and Farmers Rights Authority, Ministry of Agriculture & Farmers Welfare, Govt. of India (**Figure 8**).

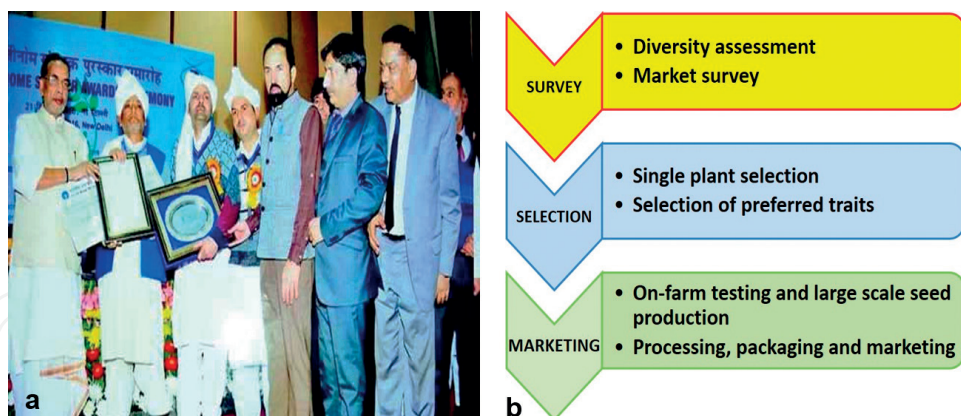


Figure 8. a) Award ceremony; b) Flow chart showing strategy for enhancing market 'value' of local landraces.

5.4. Production of organic rice

The continuous cultivation of only a few select rice varieties has led to the loss of genetic diversity of landraces. Although many landraces are preserved in seed banks these are not accessible to the farmers. Ensuring genetic diversity requires that rice landraces are cultivated continuously, and not simply stored in seed banks. In view of a preferred shift towards organic cultivation, and consumers' readiness to pay higher price for organically cultivated rice, the scope of traditional rice landraces has increased tremendously. Earlier HYVs enjoyed a distinct advantage, owing to their being fertilizer responsive, but under organic cultivation these are bound to lose the yield advantage. Therefore on-farm cultivation of landraces organically shall not only be a profitable economic enterprise for the farmer but would also lead to their conservation and adaptation. This process would be dynamic, i.e. the landraces would get subjected to continuous selection by the farmers, and would thus be allowed to develop and evolve.

The challenges in production of organic rice would however be in the form of 'paddy blast' and 'weed growth', both of which are currently controlled by chemical intervention.

5.5. Promotion of brown rice

As rice bran contains up to 20% lipids, this makes brown rice susceptible to rancidity. In earlier times, rancidity due to these rice lipids was prevented by removing the hull shortly before its consumption, and thus protecting it from oxidation. Rice (with bran) could then be stored for about 1 year, without leading to rancidity. Rice bran is characterized by high nutritional value. It contains high proportion (nearly 80%) of unsaturated fatty acids, which are known to have blood cholesterol lowering effects. The major unsaturated fatty acids in rice are oleic acid (a monounsaturated acid) and linoleic acid (an essential polyunsaturated fatty acid), and these are not synthesized in humans and therefore need to be taken from outside. These lipids play important roles in cell membrane function and functioning of the nervous system. The consumers' preference for milled rice has further reduced the availability of iron and zinc substantially in their diet. The variability in mineral content among different rice landraces of

Kashmir is quite pronounced, with zinc content ranging between 30 and 80 mg/kg and iron content between 16 and 55 mg/kg.

The current prevalence of milled rice on the market reduces the rice's nutritional value and essentially turns it into a simple carbohydrate food. Therefore, in addition to developing more nutritious varieties, awareness of the benefits of eating brown rice should be raised among rice consumers. Such a combined approach would ultimately result in a sustainable enhancement of the essential nutrient supply in rice-based diets.

5.6. Gene mining using genomics and biotechnological approaches

Rice is a diverse crop that grows in different ecosystems. Genomics-based strategies for gene discovery, coupled with the validation of transgenes by genetic transformation, have accelerated the identification of candidate genes from this broad genetic diversity. It is therefore important to explore landraces as well as wild rice species, and characterize their genes for further use rather than storing them in gene banks. Current gene revolution has broadened the scope for the application of biotechnology in rice, across ecosystems and genetic barriers. In order to prevent biopiracy policymakers should look into the potential use of biotechnology in safeguarding intellectual property rights of rice farmers and scientists by promotion of finger-printing technologies for molecular characterization of rice germplasm.

With accumulation of genes from a few elite parental lines in the current generation rice varieties, the genetic base has plateaued leading to comparatively lower genetic gains over the existing high yielding varieties. The primary attention of converging genes for yield and yield component traits needs to be diversified. Grain quality and physiological traits like cold tolerance, thermosensitivity, source-sink relationship and harvest index, lodging resistance, better nutrient absorption, efficient number of productive tillers per hill, etc. have not been explored biotechnologically to generate meaningful results for higher and sustainable crop yields in rice under Kashmir conditions.

5.7. Combining high yields with high nutritional value through molecular breeding and biotechnology

The immense genetic diversity in rice landraces is reflected by their multiplicity of nutritional characteristics. Suitable rice varieties exist for enhancing the supply of various nutrients, including protein, essential lipids, certain minerals, and to some extent β -carotene also. The diversity of such favorable nutritional characteristics is not represented in most of the widespread HYVs currently prevailing in Kashmir. These HYVs have been developed mainly to optimize the quantitative yields, and not the nutritional value. The high nutritional quality of rice landraces can form a solid base for changing priorities in rice breeding, putting more emphasis on the grain nutritional value. In order to meet the targets of nutritional security and food security, biotechnology and molecular breeding techniques, like marker-assisted selection, marker-assisted backcrossing, and genetic transformation need to be employed for accelerating the development of more nutritious rice varieties. Combining high yields and high grain nutritional value thus appears to be possible through these molecular interventions.

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Author contributions

AMH has contributed ideas, conceived, structured and written the whole chapter including preparation of figures; while SNR has contributed in preparation of **Table 1**, **Figures 4** and **8**).

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