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NEPALESE FINE AND AROMATIC RICE LANDRACES: A REVIEW

Kamana Rayamajhi [1,2,*] and Bishwas Malla Thakuri [1,3]

[1] Institute of Agriculture and Animal Science (IAAS), Tribhuvan University, Nepal.
[2] Nepal Agricultural Research Council (NARC), Nepal Seed and Fertilizer Project, Khumlatar, Lalitpur.
[3] Inland Norway University of Applied Sciences, Postboks 400, 2418 Elverum, Norway.

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*Correspondence:
kamana.rmj@gmail.com;
Tel.: +977 9840069424

ABSTRACT

With the recent issue of Geographical Indication (GI) tag claim by India on Basmati rice, Nepalese rice sector got an urgent call to conserve and promote fine and aromatic rice landraces. Fine, medium, coarse landraces were further classified into aromatic and non-aromatic. Some of the aromatic landraces popularized by their local dialect names as Basmati anadi, Basmati anpjhutte, Choti basmati, etc. were cultivated in diverse environment by local farmers but utilization in national rice improvement program is insufficient. Just handful of landraces were used as parental lines to develop improved varieties viz. Jarneli in Khumal-2, Pokhreli masino in Khumal 4, Khumal -5 and Palung 2, pureline of Jethobudho as Pokhreli jethobudho, pureline of Lalkabasmati as Lalkabasmati. With the prevailing trend of fast-track registration of the exotic improved lines, our grassroots level efforts to study the genetic makeup and unique attributes of our landraces are overshadowed. However, Jarneli, Kalo marshi, Kalo nuniya, Mansara, etc. were found to be popular for traits nutritious, medicinal, abiotic stress tolerance and resilience to low fertility soil. Furthermore, the modern tools of molecular characterization are yet to be utilized prominently to identify such valuable genes and understand their phylogenetic diversity rewarding for future rice breeding program.

1. INTRODUCTION

As the principle food grain of Nepal, rice (*Oryza sativa*) contributes 20% to the AGDP and 53% to the total cereal food production with the total area (14,58,195 ha), production (55,50,878 Mt) and productivity (3.804 Mt\ha) (MoALD, 2021). The aromatic rice comprises of group of varieties that emit aroma in cooking and consists of excellent eating (softness) qualities, fetching premium price in both national and international markets. The Basmati rice of Nepal is one of the most scented aromatic fine rices cultivated in lower belts of churiya range hills and some plains nearby Koshi river (Joshi *et al*., 2017). Basmati dhan is also known as 'Aghani' in mithila language and used as various socioeconomic purposes like making 'Acchata'and burning 'Diya' in a clay pot as a religious belief, 'Khuechha' and 'lawa' during marriage ceremony and 'Guchha','Jutti' and 'Samachakhewa'as decorative items made from panicles of Basmati rice (Mandal, 2021).

Nepal used to export about 200 metric tonnes of fine quality aromatic rice per annum earning 41 million rupees price in 1977 (Giri & Shahi, 1978). A total of 48 fine and aromatic rice varieties including both improved and local landraces are found to be grown in Nepal. Out of total area under rice cultivation, 16.9% (258855 ha) of area is covered by fine and aromatic rice of which the share of mountains, hills and terai are 5.92%, 44.20% and 49.88%, respectively (MOAD, 2015). The dietary pattern is changing over the years with change in living standard and economic status of the people. Nowadays, medium, and higher income groups prefer fine and aromatic rice over traditional coarse and sticky ones. The consumption of fine rice was 71.1 g per day and coarse rice was 245 grams per day (CBS, 2010/11). There is increasing demand of fine and aromatic rice in Nepal, but the demand is largely fulfilled by importing from open borders. The rice breeding program in Nepal is still dependent on foreign germplasm despite having 2500 rice landraces and 8,389 rice accessions recorded (Joshi, 2017).

Considering this scenario, the government of Nepal launched the first mission program on "Fine and

Aromatic Rice" in 20 districts in 2015, aimed at increasing area, production, and productivity of fine and aromatic rice for reducing imports in Nepal (CDD, 2015). With targets to cultivate fine and aromatic rice in 7500 ha and attain yield at 3 t/ha, the mission had major activities like 50% subsidies in foundation seed, 75% in commercial or improved seed, 100% in green manure (Sesbania aculeata) crop seed and provision of Zinc Sulphate for the reclamation of Zinc deficiency in rice field (MOAD, 2015).

In context of unfulfilled demand of fine aromatic rice on one side and the loss of important landraces on the other side, there seems to have a potential gap somewhere. If we do not work out immediately, there is high chance of not knowing even the names of most of our landraces by our future generation. So, the review highlights the status of fine and aromatic rice varieties in Nepal including major activities done for identification and analysis of fine quality and aromatic rice genotypes in Nepal. The article collects evidence of presence of landraces with high aromatic quality preferred and named locally as various types of 'Basmati Dhan'.

1.1 Fine and aromatic landraces with preferred quality traits.

For milled rice the length of fine, medium, and coarse rice is > 6mm, 5.0-5.99mm and < 5mm, respectively (FAO, 2010). The diversity within and among fine and aromatic rice line is simply fascinating due to difference in size of the grains and varying degree of aroma (Table 1). And more specifically, special traits like earliness, drought tolerance, nutritious and medicinal value (Table 2). So, the differences in landraces are utilized according to consumer's preferences.

Table 1. Classification of landraces based upon their fine and aromatic trait.

S.N.	Groups	Description	Landraces
1.	Fine aromatic	Small size grain with aroma	Jorayal Basmati, Aachame masino, Bayarni, Biramphool, Gauria, Gurdi kalo, Gurdi seto, Khalte kholo, Mansara, Masino, Sisuwa panheli, Jethobudho, Panhele, Anpjhutte, Rato Basmati, Motisar, Kalo masino, Chobo masino, Manakote, battisara, Thapachini
2.	Fine nonaromatic	Small size grain without aroma	Andheri, Chhote, Gola, Gudura masino, Gurdi, Jerneli, Khusremni, Lamjunge, Manamuri, Panheli masino, Samundraphini, Tunde, Marshi, Jhinuwa, Mutmur, Anjani
3.	Medium aromatic	Medium size grain with aroma	Laji, Mahajogani, Aanga, Chiniya puri, indrabeli, Jhinuwa, Jhinuwa ghaiya, Jhinuwa Masino
4.	Medium nonaromatic	Medium size grain without aroma	Anjana, Kohile Jadhaniya
5.	Coarse aromatic	Large size grain with aroma	Anjana, Gudgudo, Gudura, Sali dhan, Anadi Basnadar, Dudhe marshi, Pakhe jhinuwa
6.	Coarse nonaromatic	Large size grain without aroma	Aanga, Aanpjhutte, Anadi rato, Bange jhinuwa, Budho thakale, Darmali, Dudhe juwari, Golaya tauli, Gorkhali, Anadi, Jadan, Germani, Pakhe jerneli, Jhaurijhutte juwari, Juwari, Jhinuwa, Kathe marsi, Kathe juwari, Naltumme, Naulo madhise, Sali dhan, Seto thakale, Silange pakhe, Thimaha, Tauli, Thulo masishe, mutmur, Jarneli

Source: Joshi, 2017; Rijal, 1998

The farmers are very selective towards growing Landraces with the unique traits that add onto extra value to our cultivated varieties like Jarneli, Kalo Marshi, Kalo nuniya, Mansara, Mutmur, Pakhe jhniwa, Sali Dhan, Samudraphij, Sotwa, Sukirato, etc. The Landraces with their important unique traits are listed in Table 2.

Table 2. Landraces with their unique traits.

	Lines	Trait
1.	Jarneli	Drought tolerance
2.	Kalo marshi	Tasty, easy milling, Andilo (giving energy for longer period)
3.	Kalo nuniya	Nutritious and sticky
4.	Mansara	Adapted to Low fertility rainfed marginal environment.
5.	Mutmur	Grows in poor, rainfed soils
6.	Pakhe jhinuwa	Early maturity and High Yield under low input.
7.	Sali dhan	Bold grain, scented upland
8.	Samudraphij	Suitable in swampy Land
9.	Sotwa	Medicinal Property
10.	Sukirato	Early maturity, red grain, good in low fertility

Source: Joshi, 2017

Most of the landraces in Table 2 are cultivated and preserved by local farmers for their distinct properties but there are no efforts for conservation through registration at national level.

1.2 History of fine and aromatic rice

Before 1980

1950: Initially, the rice varietal improvement in Nepal started as the selection of the local seeds (CDD, 2015; Rijal, 1998; Mallick, 1981) after which the exotic germplasm was introduced and tested in Agronomy farm, singhadurbar and parwanipur, Bara. However, none of them were found performing better than the popular local variety, thapachiniya with yield 2541 kg\ ha.

1972: The establishment of National Rice Research Program at Parwanipur, Bara, initiated the systematic research followed by release of some semi dwarf IRRI lines IR 20 and IR 22. Moreover, the other high yielding varieties were released like Mansuli, Durga, Janaki, Jaya, and Sabitri with average grain yield of 4-5 t\ha (CDD, 2015).

1970s to 1980s: The Mansuli which was of intermediate height and fine grain was widely accepted by farmers and popularized in late in the terai and inner terai regions of Nepal (CDD, 2015).

1981 to 2000

The increasing popularity of Mansuli in terai and inner terai region indicated that the farmers preferred traits like intermediate height, fine to medium grain size and acceptable cooking qualities. So, the focus was drawn to those traits to develop the varieties khumal 2, khumal 4 for midhills and palung 2 for palung and similar climatic areas of high hills. Despite of high popularity of Mansuli, the blast susceptibility decreased its demand and increased the search for blast resistant variety like Sabitri started in terai and inner terai regions. In the meantime, the varieties with intermediate to tall heights like Radha 7 and Radhakrishna 9 were developed by National Breeding Program for terai region (CDD, 2015; NNRP, 1997). The exotic germplasm Rampur mansuli was introduced (a blast resistant variety of Mansuli type) was released as a substitute of Mansuli variety in 1999 (CDD, 2015; Khatiwada & Upreti, 2008).

2001 Onwards

As alternative to Mansuli, Mithila and Ram dhan were released for irrigated and Loktantra was released for rainfed lowland and Radha 13 for low fertility and rainfed\partially irrigated lowlands. All these varieties were specifically selected for the mansuli type grain color. The popular aromatic rice Pokhreli jethobudo was released in 2006 for pokhara valley and its surroundings upto 600-900 masl, followed by exotic aromatic germplasm, Sunaulo sugandha with 3.8 mt per ha production was released in 2008 for terai and inner terai. In 2010, the release of Lalka basmati for main and inner terai region was done through Local selection method (CDD, 2015).

These varieties Pokhreli jesthobudo and Sunaulo sugandha were developed by the joint venture of Local Initiatives for Biodiveristy, Research and Development (LIBIRD) and Nepal Agricultural Research Council (NARC). The increasing involvement of private sector in recent period has initiated the hybrid rice research and use of markers assisted breeding (CDD, 2015; Joshi *et al*., 2009). Moreover, the popular high demanded varieties Jumli marshi, khumal 4 and mansuli were utilized in molecular breeding for development of blast resistant varieties (CDD, 2015).

2. UTILIZATION IN VARIETAL IMPROVEMENT PROGRAM

Despite having approximately 2500 rice Landraces growing under diversified environment, very few germplasms have chance to reach up to varietal development stage. Mostly, Pokhreli masino, Jarneli, Jumli marshi and Jethobudho are popularized in Nepalese market as well as utilized in the development of improved varieties. The details of parental lines used for developing varieties are listed in Table 3.

Table 3. List of fine and aromatic varieties developed from local landraces.

S.N.	Varieties	Parent Lines	Released Year
1.	Khumal-2	Jarneli/ Ku-16-361-BLK-2-8	1987
2.	Khumal-4	IR 28/ Pokhreli Masino	1987
3.	Palung -2	BG- 94-2/ Pokhreli Masino	1987
4.	Khumal -5	Pokhreli Masino/ KA-IB-361-BLK-2-6	1990
5.	Manjushree 2	Jumli Marsi/IR 9129-159-3\\kn-lb-361-1-8-6-3	
6.	Khumal-8	Jumli Marsi/ IR 36	2007
7.	Khumal-10	IR 36/ Khumal 5	2011
8.	Pokhreli jethobudo	Pureline selection from Jethobudho of Pokhara Valley.	2006
9.	Lalka basmati	Pureline selection from Lalka basmati of eastern terai.	2010

Source: Upreti, 2017

Most of the popular aromatic varieties, with high yield potential favoured by commercial farmers in Terai region viz. Mansuli, Sunaulo sugandha, Sugandhit dhan 1 were developed from exotic germplasm of Malaysia and India respectively and varieties with submergence tolerant gene like Swarna Sub-1 and Samba Mansuli Sub-1 were introduced through International Rice Research Institute (IRRI) as shown in Table 4.

Table 4. List of fine aromatic varieties developed from exotic germplasm.

S.N.	Variety	Parentage	Origin
1.	Mansuli	Mayang ebos 80*2/ Taichung 65	Malaysia, 1973
2.	Sunaulo sugandha	Selection of Pusa basmati1 treated by y rays*Unknown Parent	India, 2008
3.	Sugandhit dhan 1	Pusa basmati/ IET 12603	India, 2016
4.	Swarna sub-1	Swarna/ IR49830-7-1-2-3//2*Swarna (Swarna/ IR49830-7-1-2-3)	IRRI, 2011
5.	Samba mansuli Sub-1	Samba mahsuri/ IR49830-7-1-2-3//2* Samba Mahsuri (Samba mansuli / IR49830-7-1-2-3)	IRRI, 2011

Source: SQCC, 2021

3. STATUS (DIVERSITY AND DISTRIBUTION PATTERN) OF FINE AND AROMATIC LANDRACES

The need for preservation of landraces arises for their specific preferred traits, various socio-economic and cultural values, and better local adaptation. For fine and aromatic traits, landraces like Lalka basmati, Kariyakamod, Kanakjira in Bara, Kalonuniya in Jhapa, Jethobudho, Jhinuwa and Panhele in Kaski, Gudgudo in Gulmi and Gudo (kalo and seto) in Dailekh were conserved in cultivation.

The glory of mid western mountains is that, our landraces viz. Basmati, Jumli marshi\Kali marshi can be grown at the highest altitude while the mountains at central regions have evidences of growing Pokhreli masino, Anadi, Marsi and Anpjhutte. The landraces grown in the western hills (Jethobudho, Jarneli, Jhinuwa, Anadi, Gauriya, Gurdi, Anpjhutte, Mansara), mid western hills (Danda mansuli, Basmati, Marshi, Pokhreli masino, Paran pyuli, Pyuthani seto) far western hills (Thapachini, Jorayal basmati, Shyamjira, Marsi, Jaulo, Ratodhan, Dudhe) and Central hills (Pokhreli masino, Basmati, Manbhog, Mansara, Bhogati) have their own locally preference whose genetic similarities and distinctiveness are yet to be studied at genomic level.

Table 5. Distribution pattern of locally preferred landraces.

S N.	Rice cultivars	Distribution
1.	Achhame masino	200-800masl (Chitwan, Jhapa, Makwanpur, Morang)
2.	Anadi dhan	< 700 masl (Arghakhanchi, Rupandehi, Kailali, Siraha)
3.	Basmati	200-100masl (Bara, Bajura, Dadeldhura, Darchula, Dhanusa, Doti, Humla, Jhapa, Kapilvastu, Kanchanpur, Kathmandu, Lalitpur, Mahottari, Morang, Parsa, Pyuthan, Ramechhap, Rautahat, Rupendehi, Sarlahi, Siraha, Sidhupalchowk, Taplejung, Udayapur)
4.	Basmati anadi	<300masl (Bara)
5.	Basmati anpjhutte	<800masl (Dolakha)
6.	Chhoti basmati	<800masl (Jhapa,Morang,Sunsari)
7.	Danda basmati	1530 (Dadeldhura)
8.	Gola basmati	<500masl (Sunsari)
9.	Jetho budo	600-1250 (Kaski, Myagdi, Syanga, Tanahu, Parbat, Sunsari)
10.	Jhinuwa	<600masl (Baglung, Doti, Gorkha, Kaski, Lamjung, Kailali, Kanchanpur, Kathmandu, Myagdi, Nuwakot, Parbat, Sankhuwasbha, Sidhupalchowk, Sunsari, Syanga, tanahu)
11.	Jirasari	<600masl (Jhapa, Morang, Panchthar, Ramechhap, Sunsari)
12.	Jorayal basmati	<800masl (Doti)
13.	Jorpal basmati	<1200masl (Jhapa, Morang, Sunsari)
14.	Kalo basmati	<1200masl (Dhankuta, Kathmandu, Jhapa, Morang,Sunsari)
15.	Kalo nuniya	60-300masl (Jhapa, Morang, Sunsari)
16.	Kalo nuniya thulo	60-300masl (Jhapa, Morang, Sunsari)
17.	Kalo tunde basmati	<300masl (Jhapa, Morang, Sunsari)
18.	Kanak jira	<600masl (Bara, Bardiya, Chitwan, Jhapa, Morang, Sunsari, Kailali, Kanchanpur, Kapilvastu, salyan, sunsari, syanja)
19.	Kanak jira basmati	<300masl (Jhapa, Morang, Sunsari)
20.	Kasturi	<500masl (Bara, Kailali, Parsa)
21.	Krishnabhog	<1400masl (Achham, Dhankuta, Kanchanpur, Ramechhap)
22.	Lalka basmati	60-300 masl (Bara, Dhanusa, Kailali, Rautahat)
23.	Masino basmati	900masl (Dhading, Khotang)
24.	Pahade basmati	<1000masl (Ilam)
25.	Rato basmati	60-300 masl (Jhapa, Morang, Sunsari)
26.	Rato basmati sano	60-300 masl (Bara, Parsa, Mahottari, Siraha Jhapa, Morang, Sunsari)
27.	Ratotunde basmati	<300 masl (Jhapa, Morang, Sunsari)
28.	Seto basmati	60-300 masl (Bara, Parsa, Jhapa, Morang, Sunsari)
29.	Shyamjira	60-300 masl (Banke, Doti, Kailai, Kanchanpur, Jhapa, Morang, Sunsari)
30.	Thapachini	200-1400masl (Achham,Bajhang, bajura, Kailali, Deldeldhura, lamjung, tehrathum)
31.	Tulsiprasad	200-1400masl (Nawalparasi, Bara, Dhanusa)
32.	Tulsiphool	60-300 masl (Dhanusa, Morang, Siraha, Sapatari, Sindhuli, Sunsari, Udayapur, Mahottari)
33.	Ujarka basmati	60-300 masl (Bara, Parsa, Rautahat)

Source: Upadhyay & Joshi, 2003

Table 5. shows that most of the Basmati rice viz. Ujarka, Ratotunde, Rato basmati, kalo tunde basmati, Basmati anadi, Kanak jira, etc. are grown at less than 300 masl and some of them like Basmati anpjhutte, Choti, Gola, Jorayal basmati, Kasturi etc are better grown at 600-800masl.

While Landarces like Jetho budo, Masino, Kalo basmati, Jorpal basmati, Pahade and Masino basmati can also be grown above 800masl up to 1250masl. This provides a good opportunity for famers of hills and mountains for growing fine aromatic rice at higher altitudes as well.

4. VALUE OF OUR FINE AND AROMATIC RICE LANDRACES AND MAJOR ISSUES

With the major storage protein called glutelin i.e., oryzenin (Kulp & Ponte, 2000), rice has highest protein and energy digestibility among the cereals due to its low dietary fibre and tannin content (FAO, 2021). Additionally, it is good source of thiamine, riboflavin, niacin, and highest level of selenium among cereals (10-13 mg/100 gm). The long white grain rice is

relatively good source of carbohydrates, calcium, iron, thiamine, pantothenic acid, folate, and vitamin E than other cereals. Though, long grain varieties have higher chances of breakage during milling than short grain, it is assumed that higher the length-breadth ratio, higher will be quality (Bhattacharya, 1969).

Dhungana, 2017 evaluated the grain quality of ten aromatic landraces and found the highest hulling percentage (83.24 %) in jhinuwa and that of lowest in indrabeli (75.03%) both of which have capacity of strong aromatic emission. The highest Length to Breadth ratio was obtained in Jorayal Basmati (3.8) whereas the lowest was found in gudgudo (1.6). Based upon the L\B ratio, the studied varieties were classified as Bold (Anjana, Gudgudo, Gudura), Medium (Aanga, Chiniya puri, indrabeli, Jhinuwa, Jhinuwa ghaiya, Jhinuwa masino) and Slender (Jorayal basmati). In a comparative study of four types of Basmati rice varieties, Red, white, Black and Pokhareli, the highest protein content was found in red basmati rice 7.74%. The highest hulling percentage (72.02%) and head rice recovery (67.46%) was found in pokhareli basmati. Red Basmati was found to have better cooking quality due to highest kernel elongation and volume expansion ratios 1.62 and 2.85 respectively, minimum water uptake ratio (2.18) and gruelling loss (1.05%) and highest starch iodine value of 0.21(Ojha *et al*., 2018).

In molecular characterization of aroma in Jethobudo, seven enhanced jethobudo populations were evaluated for aroma with three known aromatic varieties: (Azucena japonica cultivar from IRRI, Pusa Basmati-1: a popular indian aromatic rice, Rato basmati: local aromatic rice of Nepal) and one nonaromatic modern variety IR 36 (Kandel & Shrestha, 2018). The seven SRR primers associated with aromatic quality were used to characterize the jethobudo populations using biomolecular technique (McCouch *et al*., 1997).

Panta et.al., 2012 found out the relative abundance of rice landraces and varieties in farmers field as 31-40% Basmati, 21-30% Sona mansuli and Anadi, 10-20% Jethobudho and less than 10% Rato anadi, seto anadi gurdi, jhinuwa, Jarneli, Mansara, Masula, Biramful etc. Furthermore, over 30 % of the farmers were growing Basmati rice and the varieties like Basmati, Sona mansuli and anadi were the most popular ones. So, the authors concluded that the value of the aromatic trait of Basmati or other local landraces can be about one-fourth of the value of rice produced. That implies the aromatic traits of rice have values of about NPR 11 billion ($148.6m) and tasty traits over NPR 2 billion ($27m) per annum (Panta *et al*., 2012).

The aroma was perceived as a relative term by the local farmers who believed that the degree of the aroma decreases if consumed on a regular basis. The application of chemical fertilizers would also decrease the pure aromatic taste, the degree of aroma decreases with storage time and aroma depends on the milling process i.e., rice milled with local Dhiki is more aromatic as compared to milled in a rice huller (Rijal *et al*., 1998). Moreover, the farmers realized the quality of rice was superior when grown on irrigated low land as compared to swampy lands. Thus, it was well accepted fact that the aroma is not only characteristic to the varietal genetic property, rather a collective result of well executed production practice.

According to a study conducted by Local Initiatives for Biodiversity, Research and Development (LIBIRD) and International Development Research Centre (IDRC) on the 'Inventory of Indigenous Rainfed and Aromatic Landraces in Seti River Valley, Pokhara, Nepal' the local landraces grown widely by farmers for their quality traits have been reported to have low yield potential, susceptible to insect-pests and prone to lodging. These were Jetho Budo, Gurdi, Anadi, Panhele, Gauria, Biramphool, Ramani, Mansara, Aanpjhutte, Jerneli, Khalte kholo. Though, the introduction of improved varieties could have replaced these landrances by farmers for their low Yield potential, the varieties Jetho budo, Anadi and Panhele were hardly replaced (Joshi *et al*., 1996).

5. CONCLUSION

To fulfil the demand of increasing population and substitute the cereals import with export in this changing global environment, the systematic development and deployment of high yielding and climate resilient varieties is the only option. This has drastically increased the trend of registering exotic improved varieties leading to increased rate of replacement of traditional rice varieties. However, this scenario i.e., pressure to feed the increasing population is leading to loss of authenticity in rice improvement program in Nepal as evident in any other sectors.

Despite of unceasing efforts of our dedicated researchers and local farmers in the conservation and promotion of fine quality rice landraces, these issues could be well addressed only through efficient utilization of preferred quality traits in rice breeding programs. The various

types of Basmati dhan, Sona mansuli, Anadi, Pokhreli

ethobudo, Mansara, Jhinuwa, Masula, Jarneli etc. are in the phase of gradual extinction despite of having quality traits viz., drought tolerance, growth in adverse environment, good aroma, medicinal value. Such varieties must be characterized at agro morphological and evaluated at molecular level for their valuable genes to be identified and utilized substantially in breeding programs. The easy way of fast-tracking registration of improved varieties via private sectors should not overshadow the value of our local landraces. Rather, the present rice research must be willing to deliver conscious efforts on evaluating our native germplasm and incorporate their valuable genes through modern breeding techniques in rice varietal improvement program.

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