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Chapter

Aromatic Rice of India: It's Types and Breeding Strategies

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Abstract

The coalescence of organoleptic traits viz., pleasant aroma, cooked rice texture, and taste make aromatic rice unique and distinguished from non-aromatic rice. Aromatic rice is cultivated in every rice growing country; with each country has its own indigenous collection. International trade of rice is dominated by *Indica* (long grained), *Japonica* (short grained), aromatic rice (Basmati and Jasmine) and glutinous rice; amidst which, Basmati types from India and Pakistan; and Jasmine types from Thailand have phenomenal demand. In India all types of aromatic rice are cultivated based on Kernel length; short, medium, long and very long grained. Basmati varieties own the major market, while other types of aromatic rice besides Basmati are popular in local market only. The country inherits rich diversity of aromatic rice germplasm; with more than 300 different types, each of the rice growing states of India has its own locally popular aromatic rice varieties. India a country where two third of its population consume rice as part of their daily food; aromatic rice always remain their favorite. Basmati, by virtue of its excellent qualities it dominates both national and international market. Every year, Basmati ranks first in respect of foreign exchange earned from the export of agricultural products from India (APEDA). The phenomenal demand and export figures have augmented Basmati Breeding program. However, only few aromatic varieties are cultivated depending on their demand, and their breeding program is also limited. In India, Basmati has overshadowed other types of aromatic rice in market and in plant breeding programs too. Breeding for Basmati varieties is undertaken by prime agricultural institutions of India. The country regulates quality standards and development of Basmati varieties with the help of *Export of Basmati Rice (Quality Control and Inspection) Rules 2003*; Agricultural and Processed Food Products Export Development Authority (APEDA); and Basmati Export Development Foundation (BEDF). However, no such initiatives have been taken to promote the development of other aromatic rice varieties of India besides Basmati.

Keywords: aromatic rice, types of aromatic rice in India, basmati rice, basmati breeding program

1. Introduction

Rice is an important crop as half of the world's population depends on it. The year 1966 was declared as Year of Rice by FAO and again in 2002, United Nations General

Assembly declared 2004 as International Year of Rice. Milled rice is the third most produced crop after wheat and maize in world. Rice cultivation is source of employment to billions of people in rice cultivating countries. The global rice consumption is dominated by the countries in the Asia-Pacific region, like China, India, Indonesia, Bangladesh, and Vietnam. There are different types of rice cultivated around the world, but if we talk about global rice trade, then there are four types: long grained *Indica* (80%), short grained *Japonica* (15%), aromatic rice *viz.*, Basmati and Jasmine (4%) [1] and glutinous rice (1%). Among different types of rice, aromatic rice occupies a very small group but they possess excellent quality traits of rice. However, the word aromatic literal meaning is pleasant or sweet smell, though the aromatic rice is more than aroma. They are known for soft cooked rice texture, sweet taste and tenderness which make them class apart and command premium price in comparison to non-aromatic type of rice. From Glaszmann [2] classification of rice types, aromatic rice falls under three groups; **Group I** (Jasmine, aromatic rice from South East Asia and China); **Group V** (Basmati); and **Group VI** (aromatic rice from Indonesia, Philippines, and China). Aromatic rice is cultivated in all rice growing countries; each having their own indigenous collection: like *Basmati* of India and Pakistan; *Dulhabhog* of Bangladesh; *Khao-Dawk-Mali (Jasmine)* from Thailand; *Azucena* and *Milfor* of Philippines; *Rodojolele* of Indonesia and *Sugandhi* of Myanmar [3] *Della* rice of USA. Major aromatic rice producing and exporting countries in the global market are India (Basmati types), Pakistan (Basmati types) and Thailand (Jasmine types). In this chapter we will learn about aromatic rice varieties of India its economic importance to India and breeding strategies used to develop these varieties.

2. Aromatic rice in India

India has nearly 300 indigenous collections of aromatic rice varieties. These varieties falls under different types based on kernel length: **Small grained (≤ 5.51 mm)**; **Medium grained (5.51–6.60 mm)**; **Long grained (6.61–7.51 mm)**; and **Very Long grained (>7.51 mm)**. Most of the aromatic rice of India are short to long grained only few of them are Very long grained (Basmati types). In general, there are two types of aromatic rice: Basmati and non-Basmati types [4]. This differentiation is done on the basis of kernel dimensions (Kernel length, Kernel breadth, ratios of length/breadth; before and after cooking) as mentioned in **Table 1**.

2.1 Non-Basmati type of aromatic rice of India

This group mainly constitutes of small, medium and long grained types of aromatic rice. The center of diversity of non-Basmati types of aromatic rice of India is located in Himalayan foothills; Indian states of Uttar Pradesh and Bihar; and

Kernel dimensions	Basmati type	Non-Basmati type
Kernel length	6.4–7.6 mm	5.2–5.4 mm
Kernel length/breadth ratio before cooking	3.5–4.2	3.3–3.5
Kernel length/breadth ratio after cooking	4.9–5.6	2.95–3.8
Elongation ratio of kernel length	1.7–1.83	1.4–1.57
Elongation ratio of kernel breadth	1.26–1.33	1.31–1.61

Table 1.
Differentiation of Basmati and non-Basmati types.

States of India	Small grained (≤ 5.51 mm)	Medium grained (5.51–6.60 mm)	Long grained (6.61–7.51 mm)
Andhra Pradesh	—	Jeeragasamba	—
Assam	<i>Joha rice</i>	—	—
Bihar	Badshah Bhog, Deobhog, <i>Katarni</i> , Tulsi-Manjari, Shyam, Jeevan, Kanak Jeera, Mircha, Bramobhusi, Ranijawain, Karina, Tulsi Pasand, Dewatabhog	Gopal Bhog, Champaran Basmati (Lal), Champaran Basmati (Kali), Champaran Basmati (Bhini), Bhilahi Basmati, Amod, Abdul, Kesar, Sonachur	Baikani
Himachal Pradesh	—	Achhu, Begru, Panarsa (local)	Baldhar Basmati, Madhumati, Mushkan, Seond Basmati
Kerala	<i>Jeeraksala, Gandhaksala</i>	—	—
Madhya Pradesh	Chinore, Dubrej, Kalimooch, Bishnubhog, Badshah Bhog, Tulsi-Manjari	Chatri, Modhuri, Vishnu Parag	Laloo
Maharashtra	Ambemohar, <i>Ajaraghansal</i>	Prabhavati	—
Manipur	—	<i>Chak Hao</i>	—
Uttar Pradesh	Adamchini, Badshah Pasand, Bindli, Bhartaphool, Dhania, Chhoti Chinnawar, Laungchoor, Jeerabattis, Kanak Jeeri, Yuvraj, Moongpholi, Rambhog, Ramjawain	Karmuhi, Kesar, Kesarparsom, Sonachur, Tilakchandani, Kalanamak, Vishnu Bhog	Type-3, Hansraj, Nagina-12, Safeda, Kalasukhdas, Tapovan Basmati, Type-9, Duniapat Dabraji
West Bengal	<i>Gobindbhog, Tulaipanji</i>	Kanakchur	—

Italicized and bold genotypes names indicate that they hold GI tag.

Table 2.
Indigenous aromatic varieties cultivated in different states of India.

Tarai region of Nepal [5]. Few famous and locally cultivated varieties of this group with respective kernel length are listed below (**Table 2**) along with their area of cultivation. There are a total of eight non-Basmati types of aromatic rice with GI tag in India; names of such varieties are mentioned in bold and italicized letters in the table (**Table 2**).

2.2 Basmati type of aromatic rice of India

This group includes slender and long to very long grained type of aromatic rice. It is indigenous to Himalayan foothills. The word Basmati is derived from Sanskrit word, *vas* (aroma) and *mayup* (ingrained or present from earlier). Morphologically Basmati rice is similar to *indica* type but differs from *indica* in phenol reaction and isoenzyme pattern [2]; opaque kernel appearance, intermediate amylose content and alkali spreading value. Consequently, Basmati is classified into intermediate group between *indica* and *japonica* [6].

Basmati is aromatic rice, but all aromatic rice is not Basmati. A rice variety to be called as Basmati rice has to meet all the minimum standards of Basmati rice quality

traits. These minimum standards have been outlined by the recommendations of the *Central Sub Committee on Crops Standards, Notification and Release of Varieties for Agricultural Crops* constituted by the Central Seed Committee established under Section 3 of the Seeds Act, 1966 of India and *Export of Basmati Rice (Quality Control and Inspection) Rules, 2003*. These traits are mainly quality traits; and are summarized below.

Hence, any aromatic rice in India can be called as Basmati only when it meets the minimum standards given in aforementioned table (**Table 3**). Apart from, quality standards, there is another writ under *Export of Basmati Rice (Quality Control and Inspection) Rules, 2003* which defines which genotype of an aromatic rice can be called as Basmati. According to this rule; Basmati is of two types:

1. Traditional Basmati: these are pureline selection from the existed Basmati landraces which are six in number (**Table 4**).
2. Evolved Basmati: Evolved Basmati varieties are developed through hybridization or any other breeding methods in such way that at least one of the parents used to develop them was a Traditional Basmati Variety or pureline Basmati variety (**Table 4**).

Given the importance of Basmati; in year 2008 **APEDA**, an Indian government Organization has filed an application to obtain GI tag for Basmati. Basmati became a registered GI form 15th February 2016 under agricultural goods with its GI periphery confines to *seven* states of India; Jammu & Kashmir, Himachal Pradesh, Punjab, Haryana, Delhi, Uttrakhand, and Uttar Pradesh. Basmati Export Development Foundation (BEDF), is an organization founded by APEDA to promote Basmati export; regulate production of foundation and certified seeds; authorize centers for sample drawn by customs department; develop new DNA testing laboratories to monitor quality standards of newly notified Basmati rice in National Trials of India; and supervise registration of Basmati as GI product.

Traits	Value
Average pre-cooked milled rice length	>6.61 mm
Average pre-cooked milled rice breadth	<2 mm
Average length/breadth ratio of pre-cooked milled rice	>3.5
Average cooked rice length	>12 mm
Average pre-cooked rice length/pre-cooked rice length (elongation ratio)	>1.7
Average volume expansion ratio	>3.5
Amylose content range	20–25%
Alkali spreading value range	4–7
Minimum brown rice recovery	76%
Minimum milled rice recovery	65%
Minimum head rice recovery	45%
Aroma	Present
Texture of cooked grain (without surface bursting of cooked rice kernel), non-stickiness, tenderness, good taste and mouth feel	Present

Table 3.
Minimum standard of Basmati rice quality traits.

Traditional Basmati	Year of release	Pedigree
Basmati-217	1973	Pureline selection from local landraces of Punjab
Basmati-370	1976	Pureline selection from local landraces of Punjab (now in Pakistan)
Type-3	1978	Pureline selection from Dehraduni Basmati
Ranbir Basmati	1996	Pureline selection from Basmati-370
Taraori Basmati	1996	Pureline selection from Karnal local
Basmati-386	1997	Pureline selection from local landraces of Punjab
Evolved Basmati		Pedigree
Punjab Basmati-1	1984	Sona/Basmati370
Pusa Basmati-1	1989	Pusa150/Karnal Local
Kasturi	1989	Basmati370/CR 88-17-1-5
Haryana-1	1991	Sona/Basmati370
Mahi Sugandha	1995	BK-79/Basmati370
Improved Pusa Basmati-1	2007	Pusa Basmati-1
Pusa Basmati-1121	2008	Pusa 614-1-2/Pusa 614-2-4-3 (sister line of PB-1)
Vallabh Basmati-22	2009	—
Pusa Basmati-6	2010	PB-1/PB-1121
Punjab Basmati-2	2012	—
CSR-30	2012	Buraratha 4-10/Pak Basmati
HUBR10-9	2013	Taraori Basmati/Jaya
Vallabh Basmati-21	2013	—
Pusa Basmati-1509	2013	Pusa Basmati-1301/Pusa Basmati-1121
Basmati-564	2015	—
Vallabh Basmati-23	2015	—
Vallabh Basmati-24	2015	—
Pusa Basmati-1609	2015	PRR78/C101A51
Pant Basmati-1	2016	PB-1/IET-12603
Pant Basmati-2	2016	—
Punjab Basmati-3	2016	B-386/IET-17948/B-386
Pusa Basmati-1637	2016	MAS derived NIL from PB-1
Pusa Basmati-1728	2016	MAS derived NIL from PB-6
Pusa Basmati-1718	2019	PB 1121/SPS97//PB1121*IRBB59

Source: APEDA and <http://drdpat.bih.nic.in>.

Table 4.
 Notified Basmati varieties of India.

2.3 Economic importance of aromatic rice in India

World trade of aromatic rice mostly includes Basmati and Jasmine types of varieties and India is leading exporter of Basmati in International market. In year 2019–2020, India has exported 4.45 million MT of Basmati to Iran, Saudi Arab, Iraq, UAE, Kuwait (major countries which import Basmati from India), US, UK,

Singapore and Malaysia; earning 4,330.68 million USD. Major export of Basmati from India is headed to Asian countries (Middle East) followed by Western Europe [7]. Besides, milled Basmati, parboiled Basmati called as Sella Basmati rice in India and Middle East; and Cooked Basmati in United Kingdom [8] is also exported from India. Nearly half of the exported Basmati to Gulf countries (Saudi Arabia, Kuwait, and UAE) as well as UK and USA, includes Sella types of Basmati [7]. Earlier, Traditional Basmati viz., Basmati-370 and Taraori Basmati dominated the export of Basmati from India. In early 1990s, an evolved Basmati variety PB-1 replaced them and ruled Basmati export. Currently, PB1121 is the major Basmati variety exported from India; which has an exceptional kernel length (approximately 9 mm) and elongation ratio of 2.7 [9]. Cooked kernels of PB1121 attain a maximum length of 21.0 mm to 21.5 mm which maximum known in any rice germplasm [9]. It occupies 47% of Basmati growing area, followed by PB 1509 (26%), PB-6 (9%) and PB-1 (8%); (APEDA, [10], Basmati Survey Report, *Kharif*, Volume 2).

3. Plant breeding methods used to develop aromatic varieties in India

In India, the systematic rice breeding program started with the establishment of agricultural organizations like ICAR (Indian Council of Agricultural Research, Delhi) in 1929; NRRI (National Rice Research Institute, Orissa) in 1946; Directorate of Rice Research; and Agricultural universities [3]. Aromatic rice breeding program was initiated at research stations: *Kala Shah Kaku* (Punjab state, now in Pakistan) and *Nagina* (Uttar Pradesh, India) [3] in 1920s. Further a separate program namely Basmati Variety Development Program was started at different research stations in India at Kaul, Kapurthala, Pantnagar and New Delhi, to develop new Basmati varieties by applying pureline selection in available germplasm, using dwarfening genes and hybridization techniques. These initiations, and diligence of plant breeders led to the development of few short, medium, and long grained aromatic varieties and a total of 30 notified Basmati varieties. PB-1718 is latest addition to this list; notified as Basmati variety in 2019 (APEDA [10], Basmati Crop Survey Report, *Kharif*, Volume 2).

Breeding for aromatic rice varieties is a complex task which is attributed to its quality traits. In a study Khush and Juliano [11] gave three reasons which adversely affect the aromatic rice breeding programs, 1) number of breeding objectives are more; 2) lack of equipment to measure grain quality and; 3) selection indices are not well defined. In present time the second problem has been overcome due to development of different equipments, software etc. to measure to the quality attributes of aromatic rice. Still breeding for aromatic rice is a complicated task, attributed to reasons outlined in the following paragraph; after reviewing work of famous scientists on aromatic rice:

1. Rice is staple food to half of world population, and in scenario of increasing population; increasing yield become the prime objective of any varietal development program; accordingly less emphasis is made on quality rice (aromatic rice).
2. Aromatic rice and *Indica* varieties belong to two different groups; hybridization between them is incompatible resulting into hybrid sterility [12].
3. Aromatic rice yield poor [6, 13–15]; photoperiod sensitive [14].
4. Environmental factors viz., climate, soil, temperature; and cultural practices affect the grain quality of aromatic rice [6, 15].
5. Aromatic rice grow and express quality traits best in their indigenous area only [6].

Some of the most common breeding methods practiced to develop aromatic rice varieties in India are listed below:

3.1 Pureline selection

Pureline selection is oldest breeding method used in development of new aromatic rice varieties. Breeding for Basmati rice started with pureline selection in 1920's at two research stations; Kala Shah Kaku (Punjab state, now in Pakistan) and Nagina (Uttar Pradesh, India) [3]. The very first Basmati variety Basmati-370 was developed through pureline selection in 1933, at Kala Shah Kaku Research station by Late Sardar Mohammad. Few other Basmati varieties developed at these two research station were Basmati-217, Type-3, Type-23, N-10-B, N-12, Muskan, Begumi and Hansraj [8]. Among these, Basmati-217, Type-3 and Basmati-370 are still recognized as Basmati variety in India. A list of aromatic varieties (other than Basmati) developed through pureline selection is given below (Table 5).

3.2 Hybridization

It is a very common breeding method utilized in development of a crop variety. Hybridization is a process in which crosses are made between two varieties of same species (inter-varietal hybridization); between two different species of same genus (inter-specific); between two different genera of same family (inter-generic). For self pollinated crop like rice, hybridization program is followed via Pedigree selection, Bulk Method, and Convergent Breeding to develop new varieties. Introduction of dwarfing gene and development of hybridization techniques in 1960s, augmented the Basmati development program Siddiq et al. [7] and other aromatic varieties too. Short, medium and long grained aromatic rice were developed at

New variety developed	From	Traits improved	State of India
3 new genotypes	Jeeraksala	Improved agronomic and yield potential	Kerala
14 new genotypes	Kalanamak	Improved agronomic and yield potential	Uttar Pradesh
C435	Jeerege Sanna	Early maturing	Karnataka
K441	Kakasali	Early maturing	Karnataka
DP33	Krishna Pasangi	Early maturing	Karnataka
Madhuri Selection A	Madhuri	Perform well in delayed planting conditions	Madhya Pradesh
N-10B	Hansraj	Better quality and high yielding	Uttar Pradesh
N-12	Safeda	Better quality and high yielding	Uttar Pradesh
Type-9	Dimnepet	Better quality and high yielding	Uttar Pradesh
Type-1	Ramjeevan	Better quality and high yielding	Uttar Pradesh
Type-23	Kalasukhdas	Better quality and high yielding	Uttar Pradesh
Sugandha	Pureline selection from local Basmati		Bihar

Source: <http://drdpat.bih.nic.in>.

Table 5.
Aromatic varieties developed through pureline selection.

Variety name	Kernel type	Parents
Kusuma (LS)	Long	TN-1/Basmati-370
PAU 29-295	Very long	Basmati-370/Hamsa
GR101	Very long	IR8/Pankhali 203
PNR-546	Long	PNR-125-2/PNR130-2
Narendra Sugandha Dhan NDR-6093	Long	NDR 637/Type-3
Ketkijoha	Medium	Savitri/Badsh abhog
Nua kalajeera	Short	Pureline selection for Kalajeera
Nua Dhusara	Medium	Pureline selection for Dhusara
Nua Chinikamini	Short	
CR Dhan 907	Medium	Dubraj/Pusa 44
CR Sugandh Dhan 908	Medium	Swarna/Geetanjali
CR Sugandh Dhan 909	Medium	Pankaj/Podum oni
CR Sugandh Dhan 910	Medium	Swarna/Geetanjali
Gangawati Ageti	Long	Gaurav x Kalinga III
HUBR-2-1	Long	HBR92/Pusa Basmati/Kasturi

Source: <http://drdpat.bih.nic.in>.

Table 6.
Aromatic varieties developed through hybridization in India.

different agricultural research Institution in India (**Table 6**). PB1 is the first, high yielding, and semi-dwarf Basmati variety, developed through convergent breeding method in 1989 [9].

Outstanding achievements of Hybrid rice breeding in China encouraged Indian plant breeders to employ hybrid breeding in aromatic rice too. In India, hybrid breeding in aromatic rice was initiated first in Basmati germplasm. CMS lines like: **Pusa 3A** and **Pusa 4A**, were developed at IARI (Indian Agriculture Research Institute, New Delhi) from PB-1. Several high yielding varieties viz., Pusa Sugandha-2, Pusa Sugandha-3, and Pusa Sugandha-5 were developed using crosses of Pusa 3A and Haryana Basmati-1 [7]. Sugandha is a Hindi word meaning “Scented”. In 2001, IARI developed first *hybrid aromatic* rice (PRH10) in world. PRH-10 was developed by crossing Pusa Sugandha with Pusa 6A (CMS line).

3.3 Mutation breeding

Mutation breeding is a useful method to produce genetic variability in crop. In mutation breeding, whole plant/plant part/seed are subjected to mutagen (physical or chemical). This method has been widely applied in developing new varieties in different crops including rice. In aromatic rice, mutation breeding is used to bring desirable change in quality traits. Many mutants line have been developed from several aromatic rice genotypes including Basmati (especially Basmati-370) but only few of them are cultivated. In India mutant lines have been developed in genotypes viz., Kalimoonch-6, Bindli, Kamal Local, Type-9, NP-49, T412, Kalanamak, Gobindbhog, Badshapasand and Basmati-370. Mutants showing certain desirable trait (dwarf stature, lodging resistance, early maturing) are conserved to be used in future breeding program. One such institute is NRRI, Cuttack, India which is maintaining more than 100 mutant lines having certain desirable traits of aromatic rice. Geetanjali and ADT 41 aromatic rice varieties

were developed at NRRRI; these are mutant lines of Basmati-370. A-201 aromatic variety of USA was developed by using PI457920 mutant; this mutant was developed from Basmati-370 of Pakistan.

3.4 Molecular breeding

In recent years, application of molecular breeding techniques has increased in field of plant breeding. Biotechnological tools viz., NGS, GWAS, MAS, and QTL mapping etc. have been utilized at larger scale in studies related to plant breeding. In India, only two aromatic varieties (Basmati type) have been developed by using molecular breeding method. **ImprovedPB-1** has been developed which is resistant to bacterial blight (*Xanthomonas oryzae* pv. *oryzae*). Two bacterial blight gene (Xa13 and Xa 21) has been introgressed in PB-1 through Marker Assisted Backcross Breeding from donor parent IRBB55 [16]. PB-1718 is developed through MAS from NIL of PB-1121; the variety posses bacterial blight resistance gene Xa13. However, genetic mapping [17], QTL mapping [18], whole genome wide SNP marker analysis [19] have been used to study aroma genes of aromatic rice and other quality traits too.

4. Conclusion

Aromatic rice is not only special food in India, but they are culturally auspicious too. Indian consumers prefer aromatic rice over non-aromatic rice. Basmati is premium quality of aromatic rice of India and it is mainly cultivated for export purposes. There is a huge demand of Basmati in International market, but in India, demand of aromatic rice is not limited only to Basmati; rather many non-Basmati indigenous varieties are cultivated, and are very popular among locals. A major portion of non-Basmati types of aromatic varieties had been gradually lost in course of time due to aftermath of Green Revolution in India. Unfortunately, those lost aromatic germplasm inherited enriched quality traits on par with traditional Basmati types. In context of present scenario of aromatic rice in India, there is a need to emphasize on the under-utilized non-Basmati varieties rather only aiming to develop more and more of Basmati types.

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