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Advances in quality breeding of rice *(Oryza* Sativa *L.)*

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Abstract
Rice (Oryzasativa.L.) is the staple food for more than half of the world population. Over 3 billion people in Asia alone derive 80% of their energy needs from rice. In addition to yield enhancement, quality improvement has now become the primary consideration in breeding programmes. Rice is the only cereal that is eaten as whole grain and human selection down the ages has given high preference to quality to cater to the needs of diverse rice based preparations. Grain quality in rice is difficult to define with precision as preference for quality varies from country to country and within the country from region to region and between ethnic groups. The concept of quality varies according to the preparations for which the varieties are used. Although, some of the quality characteristics desired by grower, miller and consumer may be the same, yet each may place different emphasis on various quality characteristics.

Keywords: Advances, Quality, Breeding, Rice

Introduction
The top six countries in the share of basmati exports during 2014-15 include United Arab Emirates, Saudi Arabia, Qatar, United Kingdom, Iraq, Kuwait, and Yemen Republic. With a small beginning in 1978-79, India exported 67,000 tonnes of basmati rice earning a modest foreign exchange of Rs.32 crores. The upward trend continued steadily with the quantum of basmati export raising to 3.70 million tonnes and the value realized being Rs. 27597 crores in 2014-2015. In the export markets still the traditional tall basmati variety Taroari Basmati followed by Basmati 370 and Type 3 (Dehradun) have supremacy over other varieties due to their exclusive quality features. However, among evolved basmati varieties, Pusa Basmati 1121 due to its extra long slender grains along with Pusa Basmati 1 have made their deep rooted niche in the international market. In marketing, appearance is of foremost importance as a quality characteristic; producers and millers emphasize on milling quality; food manufacturers insist on processing quality, dietitians require nutritional quality and consumers demand a widely divergent array of cooking and eating qualities. Thus good quality or poor quality is greatly influenced by preference and when preferences differ, the same rice judged as good by one can be rated as poor by another. Rice has many different uses so that the quality characteristics desired vary considerably being ultimately related to final consumer acceptance of each rice product. Essentially, rice is used as food for human consumption. The other uses include parboiled rice, quick cooking rice, dry breakfast cereals, value added rice products, canned rice, soups, baby foods, frozen dishes, rice flour, snack items, confections and brewing. The genetic makeup of the grain is a major factor influencing quality in rice. Characteristics influencing qualities in rice include hull and pericarp colour; grain size, shape, weight, uniformity and general appearance; milling outturn; kernel chalkiness, translucency and colour; cooking, eating and processing characteristics and cleanliness, soundness and purity. Since rice is consumed and processed mainly in whole kernel form, its physical appearance is particularly important.

Traits of Physical Quality
The length and width of a rice grain are important attributes that determine the class of the rice. There are three main classes of rice, based on grain length: short, medium and long. The ratio of the length and the width is used internationally to describe the shape and class of the variety. The other important aspect of length and width is uniformity – all the grains in one sample must look the same.
Grain weight provides information about the size and density of the grain. Grains of different density mill differently, and are likely to retain moisture differently and cook differently.

Uniform grain weight is important for consistent grain quality. The whiteness and translucence of rice is important.
Head Rice Yield is the weight of whole white rice grains remaining after milling, as a percentage of the total weight of the paddy. Breakage of grain during milling reduces % whole grain and it can be due to a number of factors. Chalky grains are softer than translucent grains and are more likely to break during milling.

Cooking and eating characteristics of rice: Cooking and eating characteristics of rice are determined by a combination of objective and subjective methods. The cooking and eating characteristics of rice are

- Amylose content
- Gelatinisation temperature
- Viscosity
- Texture of cooked rice
- Flavour and aroma

Amylose content strongly influences the cooking and eating characteristics of rice. Rice with a high amylose content (25-30%) tends to cook firm and dry, whereas rice with a intermediate amylose content (20-25%) tends to be softer and stickier and rice with a low amylose content (<20%) is generally quite soft and sticky. Waxy rice has a zero amylose content and is often referred to as sticky rice. Japonica rice tends to be low amylose, tropical japonica tends to be intermediate or high and indica rices fall into all the amylose classes.
Gelatinisation temperature is the temperature at which the starch in rice begins the process of cooking. At this point the starch granules absorb water and lose their crystalline nature, a change that is irreversible. Rice starch usually gelatinises between 65°C and 85°C. Rice with a gelatinisation temperature at the lower end of the range often cooks to a softer texture and retrogrades less than rice with a gelatinisation temperature at the upper end of the range. Gelatinisation is often measured by the alkali spreading method
Opportunities for improving the nutritional value of rice grains have become increasingly evident. Hidden hunger (micronutrient deficiency) has been recognized in developing countries where rice is the staple, and technology to address particular deficiencies has emerged. Rice is generally consumed as a polished grain. Nutritional components such as minerals and vitamins are either absent, or present at low levels in polished grains. In recent years, transgenic techniques have been successful in (i) elevating the Fe content of rice endosperm by introducing ferritin genes into rice, and (ii) introducing nutritionally valuable amounts of b-carotene into rice endosperm (Golden Rice 2) by introducing the carotene desaturase gene from Erwiniauredovara and the phytoene synthase gene from maize (Zea mays). Although neither of the enhanced rices have left the laboratory yet, both iron and vitamin A deficiency are known to have a major impact on human health in developing countries. Biofortification of staple foods is one part of a long-term strategy for addressing these problems. The main component of rice grains is starch. Digestion of the starch provides the energy to sustain activity. Studies in other cereals show that starch is digested at different rates (glycaemic index [GI]). Low GI starch provides energy for prolonged periods, with benefits of more stable blood sugar levels resulting in sustained concentration and activity. Furthermore, manipulating the rate at which starch is digested could become a tool for managing diseases that are dependent on blood sugar levels, such as Type II diabetes, which is prevalent in the developed world and a growing pandemic in developing countries. Another fraction of the starch, resistant starch (RS), escapes digestion in the small intestine, fermenting in the large bowel. RS leads to an increase in absorption of minerals and other nutrients, resulting in more rapid recovery from conditions like diarrhoea, and a decrease in mortality and negative health impact.

Basmati rice
Not all aromatic types are recognized as Basmati. Typically, rices endowed with unique quality features – pleasant aroma, long slender grains with delicate curvature, remarkable linear elongation which is more than double its original length combined with excellent flaky soft texture on cooking were the ones which were categorized as Basmati. Lengthwise expansion without increase in girth is considered a highly desirable trait in some high quality rices such as Basmati rices of India and Pakistan, Bahra of Afghanistan, Domsiah of Iran, Bashful of Bangladesh and D 25-4 from Myanmar elongate 100% upon cooking. This characteristic which is unique for basmati types is being incorporated into improved germplasm through conventional methods which resulted in the development of several high yielding basmati varieties

Aroma and flavor in rice
Basmati and jasmine are classes of fragrant style rice. Fragrant rice contains particular compounds that give the rice flavour. Otherwise, slightly perceptible changes in flavour of all rice classes can be caused by aging, storage, the depth of milling (ie the amount of polishing), the local environment and probably a number of other things.
Flavour in fragrant rice is produced by volatile compounds, many of which are volatilised during cooking to produce an aroma. The aroma of cooking rice may be described as hay-like/musty, popcorn, corn, alfalfa-grassy-green bean, dairy, sweet aromatic (fairy floss, caramel), grassy, vanilla, sewer, animal, metallic and floral. Environmental conditions can cause a lot of the variation seen in aroma. Aroma is measured by simply sniffing the rice. Otherwise the peaks can be quantified by Gas Chromatography.
The aroma of rice plays a role in its consumer acceptability and it draws a premium price in certain specialty markets. The popcorn-like smell of aromatic rice stemming primarily from its 2-acetyl-1-pyrroline (2-AP) which is the flavour principle detected in cooked aromatic rice. The scent of aromatic rice is a highly heritable trait and reportedly is under the control of one to four genes, depending on the population studied and the empirical methods used to assess rice aroma and examples of these methods include biting kernels, smelling vegetative tissue after warming or soaking in KOH and eating cooked rice. Sensory fatigue is likely a source of error for such methods. The earlier studies were mainly focused on 2-AP in rice. But some other compounds also associated with specific aspect of rice fragrance are benzyl alcohol (BA), a food flavoring agent; 4-vinyl-2-methoxy phenol, an apple flavour and vanillin, a taste enhancer contribute towards consumers acceptance. Most molecular mapping reports advocate for monogenic recessive nature of the gene present on Chromosome 8. Recently, it has been also reported that the deletion in the BAD2 gene is not universal for all fragrant rices (Kuo *et al*., 2005). Tarunbhog (0.064 ppm) and Ganjeikalli (0.012 ppm) have very less 2-AP compound and hence some other compounds may be contributing for fragrance development. As many compounds are responsible

for fragrance apart from 2-AP, there is a strong possibility of the presence of allelic and gene diversity for these fragrant compounds.

Sensory analysis of aroma and flavor

The aroma of rice is detected when its volatile compounds enter the nasal passage and are perceived by the millions of tiny, hair- like cilia that cover the epithelium located in the roof of the nasal cavity. Generally there is only a 100-fold difference between the threshold (minimum detectable level) and concentration that produces saturation of the receptors. A good perfumer can differentiate 150-200 odorous qualities. Rice aroma is typically described by trained panelists using a lexicon with 10-12 descriptors.

Flavor is the impression perceived through the chemical senses from a product in the mouth Flavor includes aromatics (olfactory perceptions caused by volatile substances released from a product in the mouth through the posterior nares); tastes (gustatory perceptions [salty, sweet, sour, bitter] caused by soluble substances in the mouth); chemical feeling factors that stimulate nerve ends in the soft membranes of the buccal and nasal cavities (astringency, spice heat, cooling, bite, metallic flavor, umami taste). The aroma and flavor of rice can be characterized and analytically measured by panelists trained in descriptive sensory analysis. Descriptive analysis is useful in evaluating sensory changes over time with respect to preharvest and postharvest conditions and shelf life. Combined use of descriptive and preference sensory panels can provide accurate assessment and identify quality characteristics desired by various markets.

Yield, agronomic and grain quality characteristics of export quality traditional basmati varieties

characteristic	Traditional Basmati varieties				
	Taroari Basmati	**Basmati 370**	**Type 3**	**Basmati 386**	**Ranbir Basmati**
Habit (plant Height:cm)	Tall (150cm)	Tall(160 cm)	Tall(140 cm)	Tall(145 cm)	Tall(155 cm)
Response to photoperiod	Sensitive	Sensitive	Sensitive	Sensitive	Insensitive
Days to flowering	120	115	115	105	85
Proneness tolodging	Lodging	Lodging	Lodging	Lodging	Lodging
Tillers/ m^2	331	294	298	300	292
Milled grain characteristics					
Length (mm)	7.15	6.93	6.87	6.81	7.2
Breadth (mm)	1.82	1.86	1.93	1.75	1.8
Length/breadth	3.93	3.73	3.55	3.89	3.9
Colour	White	White	White	White	White,
Milling characteristics					
Hulling (%)	74.9	79.6	80.0	72.0	75.5
Milling (%)	63.0	67.9	75.0	65.0	66.0
Head rice (%)	54.1	46.2	59.0	55.3	52.0
Cooking characteristics					
Alkali value	5.5	4.5	4.5	3.0	5.0
Water uptake (ml)	275	240	230	180	187
VER	4.8	4.0	2.5	4.4	3.9
KLAC	13.7	12.80	12.5	14.1	13.36
ER	1.92	1.85	1.82	2.70	1.86
Amylose (%)	22.35	22.10	23.0	26.2	24.0
Yield (t/ha)	2.5	2.8	2.6	2.9	3.0

VER: Volume expansion ratio; KLAC: Kernel after cooking; ER: Elongation Ratio

Testing of breeding materials developed through convergent breeding methodology using diverse gene sources to transfer the array of quality parameters into semi dwarf plant stature, has resulted in the identification of 11 elite cultures for on farm testing. Among this elite collection, IET 14720 (CSR 30) was released as Yamini, the first basmati variety suitable for sodic soils; IET 15391 as Vasumati, a semi dwarf basmati variety with higher yield than Pusa Basmati 1 for traditional basmati growing areas; Pusa Sugandh 2 and Pusa Sugandh 3, semi dwarf high yielding basmati varieties earlier to Pusa Basmati 1; Pusa RH 10, the first fine grained aromatic hybrid of the country coming from the hybrid programme and IET 13549 released as Mugad Sugandha in Karnataka and also as Bhogavati in Maharashtra suitable for parboiling (sela basmati). In 2002 another basmati variety was released in Uttranchal as Pant Sugandhdhan 15 as state release. In the year 2004, Sugandhamati (IET 16775) from IIRR (Formerly DRR) and Pusa Sugandh 5 from IARI, were approved for release for traditional basmati growing areas of Northwestern India by the Central Sub Committee. Mention may be made of Pusa Sugandh 4/Pusa Basmati 1121 (Pusa 1121) (IET 18004) which is unique in having aromatic extra long slender grains with very high elongation on cooking. This variety has replaced Pusa Basmati 1 in many traditional basmati growing areas since 2007 and accrued higher returns to the farmers. Other long slender medium duration aromatic rices released from different states include RajendraSweta (IET 18052) from Bihar, Pant Sugandhdhan 17 (IET 17263) from Uttarakhand and Geetanjali (CRM 2007-1) from Orissa. Improved Pusa Basmati (IET 18990) was developed using molecular marker assisted selection and released in 2007 possessing Xa21 and xa 13 genes providing moderate resistance to bacterial leaf blight without compromising the yield and quality of Pusa Basmati 1. Pusa Basmati 6 (IET 18005) for New Delhi and Malviya Sugandh 105 and Malviya Sugandh 4-3 for the state of Uttar Pradesh has been released in 2008.

Other basmati cultures identified for release by VIC and under processing for notification by CVRC

- IET 22778 (Pusa 1609-09-9-4): IET 22778 is a semi-dwarf basmati culture with a flowering duration of 97 days. It recorded yield superiority over the checks and possesses extra-long slender aromatic grains with elongation on cooking similar to Taroari Basmati. It has moderate resistance to leaf blast and neck blast and identified for the basmati growing areas of Uttar Pradesh,

Uttarakhand, Punjab and Delhi.

- IET 22289 (Pusa 1592-06-5-2): IET 22289 with BB resistance validated is identified for release in Punjab, Haryana, Delhi where PusaSugand 5 (RP) was earlier notified. It has a flowering duration of 97 days and is similar to Pusa Sugandh 5 in its agro-morphological and quality traits.
- IET 21960 (Pusa 1509-03-3-9-5): The committee observed that this entry with 93 days flowering duration is earlier to Pusa Sugandh 5 by 20 days. It has excellent grain quality parameters. Per day productivity of this early culture is similar to check varieties. It has resistance to leaf blast. Based on its earliness and superior Basmati quality traits, IET 21960 is approved for basmati growing areas of Western Uttar Pradesh and Delhi.
- IET 22290 (Pusa 1612-07-6-5): This NIL basmati entry claimed for blast resistance in the background of Pusa Sugandh 5 is approved by the Committee based on its resistant score for 2 consecutive years at Malan (HP). It is suggested for notification in the state where Pusa Sugandh 5 was released earlier. It is a semi-dwarf culture of 96 days flowering duration, extra long slender translucent aromatic grains and elongation on cooking on par with Pusa Sugandh 5.
- IET 20827 (MAUB 171): The culture recorded yield superiority over Pusa Basmati-1. The culture has a flowering duration of 113 days and possesses moderate resistance to brown spot and sheath rot. IET 20827 is therefore identified for the traditional basmati rice growing areas of Western Uttar Pradesh, Haryana and Jammu & Kashmir.
- IET 19492 (MAUB 162): A semi dwarf basmati culture resistant to lodging, with a flowering duration of 116 days showed yield advantage over Taroari Basmati with quality on par with it. This culture is identified for release in Uttar Pradesh and Haryana.
- IET 21665 (RP 3644-1-19-5-5): The basmati variety has extra long slender aromatic grains having good yield advantage in semi dwarf plant stature with superiority over PB 1 and P 1121. With flowering duration of 110 days, desirable basmati quality traits having moderate resistance to leaf blast, neck blast and brown spot is identified for the basmati growing areas of Delhi, Uttarakhand and Uttar Pradesh.

Influence of environment on aroma

- 2AP concentration in aromatic rice products of the same cultivar in the same area varies with the conditions of cultivation or soil.
- Late harvest and high temperatures lower the 2AP concentrations.
- Aromatic rice cultivated at a high altitude or later than usual had a stonger aroma than that cultivated at a low altitude or according to the usual schedule (Nakamura, 1998).
- 2AP is formed from proline that is increased at dry conditions
- Khao Dawk Mali 105, the most important aromatic rice cultivar in Thailand has the strongest aroma and the best quality when grown at Tung Kula Rong Hai region, located at a high altitude often suffered from drought. (Yohihashi *et al*., 2002; Yoshihashi, 2002).
- The 2AP concentration in an aged (shelf stored) rice sample was about half that of a fresh rice sample of Thai aromatic rice, KhaoDawk Mali 105 (Laksanalamai and Ilangantileke, 1993)

Aromatic short grain rices

Almost every state of India has its own collection of non-basmati short and medium grain aromatic rices and are tentatively estimated to be grown in about 6 lakhs hectares. Many of these are cultivated in other than designated basmati growing areas of northwest India mainly in Uttar Pradesh, Bihar, Orissa, West Bengal, Assam, Chhattisgarh, Madhya Pradesh, Maharashtra and also in other states. The cultivation of these rices is limited to small areas in specific locations. Farmers still seem to grow these cultivars mainly for personal consumption despite being aware of their poor productivity and limited markets. These are generally consumed locally and are widely used for making kheer (sweet rice) for religious and festive occasions. Often it is very difficult to even retain the produce for seed purpose. Since long time farmers are using their own saved seeds which resulted in seed deterioration. There are scattered conservation efforts and seed production or improvement programmes for these rices. As a result in the last several years many valuable aromatic rice varieties have either disappeared or are in the process of disappearing which requires to be arrested.

Speciality Rices

Speciality rices include Bora, Chakua rices of Assam; Njavara rices of Kerala; black rices of Manipur and Kalanamak rices of Uttar Pradesh. Bora and Chakowa are soft rices of Assam. Bora rice is glutinous having mainly amylopectin and only traces of amylose. The amylose content of bora rice varies from 2-9%. Chakowa (Chakua) referred to as KomalSawl is another class of rice possessing 15-20% amylose and used for instant preparation. Many communities in Assam also prepare high class rice beer out of bora rice. Bora rices are used in the preparation of Pithas (Biscuit like confectioneries), Chira (flaked rice), Hurum (Expanded waxy rice), Chung Choul (Roasted rice inside bamboo internode), Handohguri (Fried rice power). Further it is used as pharmaceutical excipient in formulation of mucoadhesive controlled drug delivery systems. These rices are mainly consumed in the form of plain boiled rice which generally takes around 15-20 minutes in cooking. Due to fast changing life style and increasing the number of working women, the demand of easy to cook and convenience food is increasing day by day.

Njavara rices have esteemed attributes making them suitable to the traditional Ayurvedic Medicinal Systems of Kerala. Grains of this traditional rice strain are used in several Ayurvedic treatments like ‘njavarakizhi’, the acclaimed therapy for neural disorders, and in the preparation of a replenishing health drink ‘marunnukanji’. Njavara based treatments and preparations have attracted people world-over and the Ayurveda tourist resorts (Ayurveda tourism) and hospitals. But so far the active component ingredients/chemicals/bioactive compounds which are characteristic of medicinal rices in general and Njavara in particular have not been isolated and characterized. Rajiv Gandhi Centre for Biotechnology (RGCB) is attempting to characterize the genetic diversity of Njavara rices. CFTRI is analysing nutrient composition of Njavara grains. Kerala Agricultural University is involved in agronomic characterization of Njavara.

The black glutinous aromatic rice of Manipur with good quality and cooking characteristics are in demand in the domestic market. Chakhao Amubi is the the popular balck glutinous rice which is used in the many ceremonies of

Meiteis, the biggest community of Manipur. Systematic efforts to improve this rice has not been done so far.

Many of the indigenous scented rices have been found to possess excellent grain quality traits and could be ideal candidates for gene transfer to the high yielding background. Notable among these are black hulled Kalanamak accessions highly popular in Uttar Pradesh. Few studies were undertaken at GBPUAT, Pantnagar and promising accessions with higher yield as well as tolerance under usar soil were identified. Rice preparations of these speciality rices are very popular in community feasts, festivals and ceremonies. However, the complete knowledge on the nutritional aspects of these varieties is not known particularly the biochemical composition of these grains which render them special. Despite the availability of tremendous rice diversity possessing every type of variation in physicochemical properties, very little has been done to develop value added products at affordable prices suited to the changing needs of Indian rice consumers. Therefore, concerted efforts are needed to identify molecular descriptors giving this group particular research emphasis.

Rice based products

The food processing industry in India ranks fifth in terms of production, consumption, export and expected growth. The industry is worth Rs 350,000 crores including Rs. 9,000 crores worth of value added products. The growth per annum in processed foods would be about 10%, primary processed foods 7%, and value added foods 15%. It is expectd that 200 million people in India will shift to processed and packaged food / rice and there is need for farmers to tranform themselves as into producer cum processor by attending to certain primary and secondary processing value added activities to meet the related challenges ahead. It would provide employment to rural youth overcoming social and economic problems by establishing rural rice processing industries at production catchments. There is a wide scope for product diversification in rice which include easy cooking and instant rices - retort rice, canned rice, alpha rice, frozen rice, easy to cook brown rice, boil-in-bag rice; roasted and puffed rices - rice flakes, puffed rice, shredded rice; convenience foods - canned soups with rice, meat & rice dinner; rice flour based foods - rice noodles, rice bread, rice cakes& crackers; infant foods - first solid food, genmai meal; fermented foods/drinks - rice wines, beer adjunct, parboiled idli, dosai; dry breakfast cereals or expanded (puffed, popped) rice. End users typically require specific characteristics to produce a food product with the desired qualities.

Suggestions for export promotion with improved quality

- Collection and conservation of this native wealth of aromatic rices, premium rices and their documentation.
- Strengthening of collaboration among Scientists of ICAR, SAUs and Extension functionaries; Post Harvest Technologists, cereal chemists, Rice Industry, Ministry of Commerce by conducting regular meetings to sort out all emerging issues concerned with research and trade would go a long way in enhancing export of quality rice from India
- Establishment of most modern laboratories for quantification of aroma compounds and collaborative efforts to continue with Indian Institute of Chemical Technology, Hyderabad on this critically important area of fragrance as a subject of study
- Value addition, preparation of new and novel products should go along with sound marketing strategies for creating vast domestic and export demand for the aromatic short grain produce.
- Rice trade should analyse the needs of the rice importing countries and give information on varietal preference, quality requirements to the researchers at frequent intervals. Feasibility of ensuring the volume of such varieties preferred for export should be looked into to develop competitive edge over other countries.

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