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Review Article

EVOLUTION OF BREEDING RESEARCH IN BASMATI RICE (ORYZA SATIVA L.) IN PUNJAB, PAKISTAN

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Abstract: *Breeding research for Basmati rice commenced in 1926 when Rice Farm was established at Kala Shah Kaku in Punjab. 1933 Basmati-370, Mushkan-7, and Mushkan-41 were developed and released for commercial cultivation by the farming community. Despite the high aroma in grains, the Mushkan varieties faced challenges due to low yield potential and other quality issues, making them unsustainable for growers. Hybridization efforts began in 1933, resulting in the first cross of Basmati-370 with Palman-46, aimed at achieving high yield, earliness, and improved grain quality coupled with resistance to stem borers and rice blast. Basmati cultivation is predominant in the Kalar tract of Punjab. Two fine-grain varieties, C-622 and Basmati Pak, were introduced in 1960 through hybridization, with Basmati-Pak gaining popularity as Kernel Basmati. Ongoing research efforts focused on developing high-yielding varieties with enhanced quality. The approval of Basmat-385 in 1985, characterized by long grains measuring 6.6 mm in length and 1.6 mm in breadth, revolutionized Basmati rice production in Punjab. The globally renowned Super-Basmati variety received approval in 1996, featuring extra-long grains measuring 7.5 mm in length and 7.7 mm in breadth. After Super-Basmati, other prominent varieties like Basmati 2000, Basmati 515, PS-2, Kisan-Basmati, Punjab-Basmati, Chenab-Basmati, and Super Kainat-2000 were developed and periodically released for the farming community.*

Keywords: Basmati, Aromatic, Mushkan, Kernel, Hybridization, Super Basmati, Hybrid

Introduction

About half of the population globally consumes rice (*Oryza sativa* L.) as an essential food source. It is grown across Asia, Japan, and Pakistan, accounting for 90 percent of worldwide production and consumption. During 2020, its global production was 505 million tonnes (FAO, 2021). The major rice production countries are China, India, Pakistan, Bangladesh, Philippines, Thailand, Indonesia, Burma, Japan, and Vietnam (USDA, 2021).

Globally, it is the world's second most vital staple food crop, after wheat. Rice is the main food and an economic crop in Pakistan, grown on vast acreage. It had a 3.5 percent share in value-added agriculture and 0.7 percent of the country's GDP, respectively. Pakistan is the 10th largest producer of rice in the world and the fourth-largest exporter (FAO, 2021). According to the USDA, Rice was planted on 3.3 million hectares of land in 2020-21. This year, rice output hit an all-time high of 8.4 million tonnes, a record for the country (GoP, 2021). An FAO ranked Pakistan among the world's top 10 rice-producing countries. Because rice is not a primary food for our people, there is a surplus of rice accessible for export. Over 60% of the rice is produced in excess and ready for sale. Pakistan exported 3.64 million tons of rice worth 2.04 billion US dollars during the fiscal year 2020-21 (REAP, 2021).

Because rice is such a popular crop, it is grown in all its provinces. Punjab and Sindh, on the other hand, are two of Pakistan's largest rice-growing regions. At altitudes ranging from 24 degrees north to 36 degrees north, the country's rice-growing regions range from sea level in southern Sindh to 2500 meters above sea level in the country's northern mountain valleys and terraces. Pakistan has a wide variety of agroecological zones to grow different types of rice. For example, the northeastern districts of Punjab in Pakistan are the motherland of premium quality fine-grained Basmati. Medium long-grain rice is grown in the hot, arid plains of Sindh. Tolerant, grained, sticky, and glutinous rice varieties are popular in the northern mountain valleys (Swat, Dir, and Chitral). The common factor in all these regions is that paddy is raised as a Kharif crop (summer) under a controlled canal irrigation water supply.

The fragrant, long-grained rice known as basmati has been cultivated in the Himalayan foothills of the Indian subcontinent for generations. BAS means fragrant or aromatic, and MATI means QUEEN; hence, the Hindi term "Queen of Fragrance" is translated as "Basmati." As its name suggests, aromatic and fragrant rice is what it is

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(Ashfaq et al., 2015). When cooked, basmati rice exhibits the slightest breadth-wise swelling of any rice variety (Singh *et al*., 2000a).

1. Botanical Classification of Rice

Asian rice (*Oryza sativa* L.) is an actual grass member of the Poaceae family. Rice is the only cereal with a fully sequenced genome with 430 million base pairs, making it the most complex (Ashfaq *et al.*, 2015). The modern-day cultivated genus Oryza, to which rice belongs, has twenty-one wild and two cultivated species designated indica and japonica (Khush, 2000). Nine wild species are tetraploid, while others are diploid. The following three major groupings of Oryza species, according to Morishima and Oka (1960), can be distinguished based on a disparity analysis of 16 species that was founded on 42 morphological features proposed:

1. *Oryza sativa* and its relatives
2. *Oryza officials* and its relatives

Other more distantly related species.

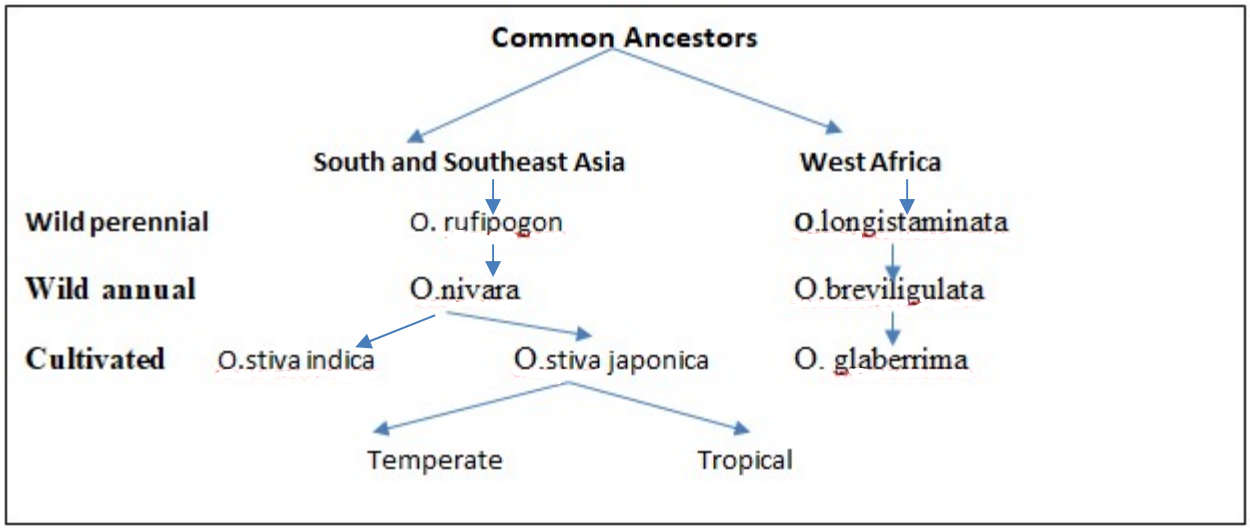

Figure 1: Ancestors of Rice *(Reproduced from G.S.Khussh, 2000)*

2. History of Basmati Rice

The oldest archaeological evidence of rice was discovered during excavations in Harappa (a city in the District of Sahiwal, Punjab) and Mohenjo-Daro (a city in the District of Larkana, Sindh), along with remnants of a cotton culture that date back to the 3rd millennium BC in the region (Oka, 1988). According to the available data, archaeological evidence reveals that Harappa began as an agricultural town along the Ravi River circa 3300 BC. Singh *et al*. (2000b) examined that from an extrapolated archaeological and historical assessment, Basmati rice evolved through natural and human selection over a long period (8000 years) in Northern India. The earliest record of aromatic rice is found about 400 BC when Susruta, an Indian pioneer of medicine and surgery, maintained several scented rice cultivars (Kumar, 1988; Krishnamurthy, 1991). Ain-e-Akbari (written by Abdul Fazal Allami in 1590 AD) contained information on aromatic kinds of rice in India (Akram,2009).

Old Punjabi folk songs mention Basmati's softness and sweet fragrance. The renowned Punjabi poet Syed Waris Shah made an initial reference to basmati rice in his idyllic poem Heer and eleven other rice varieties grown in Punjab of those days. He also mentioned Basmati as one of the rice dishes that was especially served along with other dishes to the barat (wedding party) of Heer that came from Rangpur Khahrey. Syed Waris Shah was born in 1735 in the village Jundiala Sher Khan, District Sheikhupura, and he wrote Heer in 1766. Old Basmati dishes, namely, *Dal Chawal, Khichri, Kheer, Firni,* etc, are still popular in Punjab, and now several Mughal rice preparations, such as *Biryain, Plau* and *Zardah* and some international dishes are also made with raw or parboiled basmati rice.

In assembling rice varieties in India, Basmati has been designated as a variety of rice cultivated in the Punjab (Kalar tract), said to be the "best" for delicacy. Kalar tract comprising Sheikhupura, Gujranwala, and Sialkot districts in the Punjab has a special place in the Basmati's evolutionary history. From time immemorial, Basmati has been cultivated and cherished by farmers of Kalar Tract in Pakistan. It was the priced rice being grown for quality food for the well-to-do. The quality consciousness that has for centuries encouraged the Punjab farmers to select and cultivate the best quality rice, notwithstanding its tallness and susceptibility to lodging and poor yield. Punjab produces 92% of Basmati rice in the country. During 2020-21, Basmati rice in Punjab was planted over 1871 thousand hectares, and its production was estimated at 4041.2 thousand tons with an average of 2145 kg/hectare (CRS, 2021).

3. HISTORY OF BASMATI RICE BREEDING RESEARCH IN PUNJAB

Changing or enhancing agricultural plant genetics in connection to their economic utility is the science and art of plant breeding. The idea of Genetics from improving plants may be applied to improve crops. Plant breeding may be achieved in numerous ways, from simple selection for the propagation of plants with particular features to more complicated molecular approaches. Selection, the first plant breeding technique, was used when humans figured out how to pick the best plants. Hybridization was

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introduced to his repertoire of breeding methods with the discovery of sex in plants in the late 1800s. Individuals, including gardeners, farmers, and plant breeders hired by government agencies, universities, crop-specific industry groups, and research centers, have been engaged in plant breeding for thousands of years, dating back to the dawn of human civilization. Animals and plants can be bred to improve their usefulness to humans by changing their traits and structure (Duvick 1986). There must be an improvement in the quality of new plants created by hybridization, breeding, or other ways of reproduction, such as increased yield potential, more nutritional value, reduced environmental pollution, and fiber properties (such as strength). In Punjab, breeding research in Basmati rice was underway in 1926 with the formation of a Rice Farm at Kala Shah Kaku in the eminent rice bowl named "Kalar Tract." Mr Sardar Khan was a pioneer breeder appointed in 1926. He collected more than five hundred pure lines/accessions of rice from different rice growing areas and divided them into sixteen groups.

Table 1. District-wise Area, Production and Yield of Basmati Rice in Punjab (2020-21)

District	Area (000 Hec)	Production (000 Tons)	Yield (Kgs/Hec)	District	Area (000 Hec)	Production (000 Tons)	Yield (Kgs/Hec)
Jehlum	1	1.0	2397	Nankana Sahib	223	214.9	2381
Sargodha	105	80.6	1896	Lahore	51	38.4	1862
Khushab	63	49.8	1953	Kasur	56	41.0	1809
Mianwali	13	13.7	2601	Okara	229	217.9	2351
Bhakkar	4	3.4	2106	Sahiwal	106	102.7	2393
Faisalabad	94	79.2	2083	Pakpattan	182	159.6	2168
T.T. Singh	118	116.5	2439	Multan	61	47.3	1915
Jhang	382	366.6	2371	Lodhran	54	36.7	1679
Chiniot	72	70.6	2425	Khanewal	165	135.0	2021
Gujrat	82	57.5	1732	Vehari	99	85.3	2128
M.B.Din	172	140.3	2015	Muzufargarh	66	49.5	1853
Sialkot	395	249.4	1560	Layyah	14	12.6	2228
Narowal	176	109.2	1533	D.G. Khan	3	2.6	2167
Gujranwala	172	120.7	1734	Bahawalpur	47	39.7	2090
Hafizabad	298	247.7	2277	R.Y. Khan	108	88.8	2031
Sheikhupura	483	379.3	1940	Bahawalnagar	281	260.4	2290

*T.T.Singh: Toba Tek Singh, M.B.Din: Mandi Bahauddin, (**Source: CRS, 2021**)*

Table 2: Agriculture-cum-Commercial Rice Groups

Group	Number of Accessions	Group	Number of Accessions
Jhona	96	Ratria	22
Kangra Valley	90	Red Rice	21
Jhona Kasarwala	54	Jhoni	17
Mushkan	50	Khrsu	13
Sone	42	Santhi	13
Dhan	27	Begonia	9
Sathra	24	Bara or Hansaj	9

(Source: Majid, 1979)

The Basmati group, comprising 51 distinct pure lines, exhibited discernible differences, each possessing unique characteristics suited to specific soil, water, and climatic conditions. Notably, three fine-grain varieties—Basmati-370, Mushkan-7, and Mushkan-41—emerged from comprehensive mass and pure line selections within this group, leading to their introduction for widespread cultivation in 1933. The release of Basmati-370 marked a significant milestone, instigating an economic revolution in the rice-growing region of Punjab (Maan, 1987). Renowned for its premium quality, Basmati-370 featured elongated grains and a silky texture upon cooking. While Mushkan varieties boasted a strong aromatic profile, their limited yield potential, and suboptimal grain quality posed challenges for sustained adoption among growers (Akram, 2009).

The issue of low yield posed a pervasive challenge in rice cultivars, and addressing this concern through pure line selection proved to be a time-consuming process. Recognizing the efficacy of hybridization to enhance yield and agronomic traits in rice crops through heterosis, efforts were directed toward this method. The limited genetic diversity within Basmati germplasm presented a hurdle, resulting in unmet expectations for Basmati varieties. The

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recessive nature of Basmati genetics necessitated both parental lines to have Basmati ancestry for the trait to manifest. Unfortunately, several highly valued Basmati cultivars and promising lines exhibited poor combining abilities, rendering inter-specific hybridization unsuccessful.

Explorations into hybridization commenced as early as 1933, gaining substantial traction more recently, specifically focusing on crafting high-yielding Basmati varieties adaptable to diverse environmental conditions. The pioneering crossbreeding endeavor 1933 involved Basmati-370 and Palman-46, aiming to confer early maturation, heightened yield, improved grain quality, and resistance to blast and stem borers in Basmati rice. This process involved a comprehensive assessment and juxtaposition of materials sourced from various provinces within Indo-Pak. Pursuing elevated yields through the refinement of agronomic traits marked the initial strides in developing high-yielding rice varieties. The distinct seasonal dynamics at the Rice Farm, characterized by prolonged daylight hours and temperature extremities, posed challenges for imported varieties, particularly those responsive to photoperiodism.

Rice varieties sourced from Russia, Australia, Japan, Egypt, Italy, and Spain were classified within the Japonica group, while those originating from other countries were categorized as Indica group members. Japonica rice exhibited a dwarf phenotype, attaining only 2.5 feet. The stems, although slender, were rigid, and the leaves were narrow and diminutive. Additionally, the plant demonstrated prolific and continuous tillering, leading to uneven ripening. The small panicles bore a limited number of grains characterized by short, plump, and roundish morphology. Unfortunately, despite these traits, Japonica rice did not yield favorable results at the Rice Farm Kala Shah Kaku.

Varieties sourced from Madras, Hyderabad (Deccan), and Indonesia displayed significant height, making them prone to lodging. Strains from Malaya, Thailand, India, Ceylon, and East Pakistan encountered difficulties in flowering, with some failing to initiate flowering altogether. Additionally, the remaining varieties did not match the yield of Jhona-349 and the cooking quality of Basmati-370. Despite these challenges, certain varieties were recognized for their utility in specialized applications:

1. **Raja Sail:**
   Imported from Bengal, Raja Sail proved highly suitable for late planting in low-lying areas with a degree of salt resistance. Notably, it was categorized as a 'season-fixed' variety, consistently ripening in December regardless of the transplanting time.
2. **Honduras:**
   Originating from America, Handuras featured robust, thick stems and were incorporated into hybridization efforts to develop varieties with sturdy stems and elongated grains.
3. **Purple-leaved Varieties:**
   Collected from Central Provinces (now in India), purple-leaved varieties found application in demarcating sub-plots within varietal yield trials.
4. **Japonica Varieties from Japan, Australia, and Egypt:**
   Japonica varieties from these regions possessed advantageous traits such as dwarfism and stiff stems. Specifically, imported varieties like Taichu No. 65 (Japan) and Yabani pearl were identified as suitable candidates for crosses with locally improved varieties. The goal was to produce high-yielding, stiff-stemmed varieties resistant to lodging and responsive to fertilizer applications.

By 1959, the Rice Farm's breeders had cultivated 620 indigenous pure lines, subjecting them to comprehensive test trials. Concurrently, 275 exotic lines underwent evaluation for yield and quality parameters across diverse locations. However, the exotic material exhibited limited adaptability compared to local germplasm, necessitating the integration of local indica-type material in breeding endeavors. Japonica varieties from exotic sources displayed round grains, short stature, stiff stems, low tillering, narrow, erect leaves, a high harvest index (HI), and heightened responsiveness to fertilizers. Notably, these varieties lacked the distinctive Basmati character. Conversely, indica varieties were characterized by tall stature, weak stems, high tillering, and broad, drooping leaves. Despite possessing fine and slender grains, attempts at combining desirable traits through indica x japonica crosses proved futile due to pronounced progeny sterility.

In the realm of cultivated Asian rice, two distinct races were identified: Oryza sativa var. Japonica and Oryza sativa var. Indica. The Japonica rice exhibited characteristics such as a short, stiff straw, a requirement for extended daylight with cooler temperatures, bold grains with a high percentage of rice to paddy, and a pronounced responsiveness to intensive fertilization. Conversely, Indica rice, cultivated in warmer climates, demonstrated vulnerability to heavy fertilization but showcased general resilience to adverse conditions such as drought, floods, diseases, and salinity. Consequently, a project sponsored by the Food and Agriculture Organization (FAO) of the United Nations was launched to develop stiff-stemmed, high-yielding, early-maturing hybrids possessing a robust response to fertilizers for cultivation in the Indica rice zone. Japonica varieties obtained from Japan, initially yielding unsatisfactory results in tropical conditions, were subjected to crossbreeding with Indica varieties contributed by participating nations at the Central Rice Research Institute, Cuttack, India, producing F1 generation seeds. The F2 seeds were subsequently distributed to the respective countries for the selection of desirable plants. Some seeds involving diverse cross combinations between Japonica varieties and those native to East Pakistan were also provided for evaluation at the Rice Farm, Kala Shah Kaku. Unfortunately, due to the non-indigenous nature of the parent plants in the region, no significant outcomes were achieved, with the segregating material predominantly exhibiting delayed maturity and possessing roundish grains. Furthermore, many plants failed to flower under the specific environmental conditions prevailing in Kala Shah Kaku.

In the 1960s, the Rice Research Station in Kala Shah Kaku introduced two fine-grain varieties, C-622 and Basmati Pak, through a dedicated hybridization program. Basmati C 622 received approval in 1964, while Basmati Pak gained official recognition in 1968, earning popularity among farmers as Kernel-Basmati. In 1972, Basmati-198 was sanctioned for cultivation in the Sahiwal area. This variety emerged from a hybridization endeavor involving the crossbreeding of Basmati-370 with Taichu Native I,

followed by three rounds of backcrossing with Basmati-370. Characterized by long, slender, scented, and sword-shaped kernels, Basmati-198 exhibited cooking qualities akin to Basmati-370 while boasting higher yield potential, featuring an average kernel length of 7.6 mm. The dedicated research endeavors in developing high-yielding, high-quality rice varieties culminated in the elevation of the Rice Farm to the status of Rice Research Station Kala Shah Kaku in 1965, subsequently achieving the distinction of a Rice Research Institute in 1970.

The Basmati rice landscape saw significant developments with the approval of Basmati 385 in 1985 for widespread cultivation in Punjab. Characterized as an aromatic rice variety falling within the long-grain category, it possesses dimensions of 6.6 mm in length and 1.6 mm in breadth. In 1996, the globally renowned Supper-Basmati variety gained approval for general cultivation in Punjab, distinguishing itself as an extra-long grain variety with a kernel length of 7.5 mm and a breadth of 1.7 mm. The exceptional quality of its extra-long grains positioned Supper-Basmati as a premier choice in the international market, capturing the attention of global buyers. The year 2000 witnessed the approval of two Basmati varieties, Basmati-2000 and Basmati-Shaheen, featuring extra-long grain qualities. Notably, Basmati-Shaheen emerged as a salt-resistant and early-maturing variety developed by scientists at the Soil Salinity Research Institute, Pindi Bhattian. In 2011, Basmati-515 was released for general cultivation in Punjab, exhibiting characteristics of extra-long grains, a stiff stem, and resistance to foot rot and blast diseases. The subsequent release in 2013 of PS-2, an extra-long grain variety suitable for parboiled and steamed rice, further diversified the Basmati landscape. Three aromatic extra-long grain varieties, Chenab Basmati, Punjab-Basmati, and Kisan-Basmati, were introduced 2016 for general cultivation across Punjab. In 2021, two extra-long grain varieties, Supper Kainat-2020, suitable for both parboiled and white rice, gained approval. Notably, the innovative KSK-111 H, the first Basmati Hybrid developed by scientists at the Rice Research Institute Kala Shah Kaku, secured approval in 2020, presenting a potential paradigm shift in Basmati rice production. Additionally, the introduction of Al-Khalid Basmati in 2021, developed by scientists at the Soil Salinity Research Institute, Pindi Bhattian, was approved for cultivation across Punjab. This particular variety exhibits suitability for parboiled and steamed rice cultivation, offering resilience in saline-sodic soil due to its salt tolerance potential.

5. Characteristics of Basmati Rice Varieties

Basmati-370:

Released by Sardar Khan at the Cereal Section, Lyallpur, before partition in 1933. This variety has a yield potential of 30 munds/acre, with long grain, aromatic, and excellent cooking quality. The average plant height is 170 cm, and the grain length is 6.8 mm. It matures in 120 days after transplantation.

Pak-Basmati:

Developed through the hybridization of CM7-6 with Basmati-370, yielding 30 maunds/acre with extra-long grain, aromatic quality, and excellent cooking characteristics. Tolerant to poor soil conditions, it outperformed Basmati-370 across various agro-climatic zones in Punjab. Approved as "Pak Basmati" in 1968, later gaining popularity as "Kernel Basmati." The average grain length is 7.5 mm, plant height is 170 cm, and maturity occurs in 125 days**.**

Basmati-198:

Developed through hybridization attempts involving Basmati 370 and Taichu Native I, resulting in a medium-height variety (125 cm) with a stiff stem, requiring 130 days to mature. Exhibits long, slender, scented, sword-shaped kernels with cooking quality similar to Basmati 370 and higher yield potential. Approved as "Basmati-198" in 1972 for the Sahiwal area, with an average kernel length of 7.6 mm.

Basmati-385:

Released in 1988, this variety has a yield potential of 60 per acre. It is characterized by high yield, early maturity, long grain, aromatic quality, and good cooking characteristics. The grain length is 6.8 mm, and it requires 130 days to mature after transplantation, with a medium plant length of 133 cm.

Super-Basmati:

Evolved through the hybridization of Basmati-320 and 10486 in 1972, Super-Basmati is medium height (120 cm) with a yield potential of 65 maunds per acre. It features a longer grain length and a higher elongation ratio than Basmati-370 and Basmati-198. Approved for general cultivation in 1996, gaining global recognition for its extra-long grain length.

Basmati-2000:

Released by Rice Research Institute, Kala Shah Kaku, in 2001 with a yield potential of 60 maunds per acre. It is high-yielding, lodging-resistant, extra-long grain, aromatic, and exhibits excellent cooking quality.

Basmati-Shaheen:

Released in 2001 by Scientists of the Soil Salinity Research Institute, Pindi Bhattian. Performs well in salt-affected and normal soils, maturing in 95 days. The kernel length is 7.33 mm, the kernel width is 1.73 mm, and the yield potential is 60 maunds per acre.

Basmati-515:

An extra-long grain variety with a stiff stem, resistant to foot rot and blast diseases. A three-way cross of F1 (Basmati 320 x promising line 10486) with 50021 exhibits a higher yield than Super Basmati. Height is 130 cm, matures in 115 days, with a kernel length of 7.56 mm. Yield potential is 75 maunds/acre.

PS-2:

Tested from 2008 to 2012 at Rice Research Institute, Kala Shah Kaku, with an 8% higher paddy yield than Super Basmati. Suitable for parboiled and steamed rice, exhibiting an elongation ratio of 2.018. Height is 115 cm, maturity occurs in 116 days, and the average kernel length is 8.15 mm. Yield potential is 60 maunds per acre.

Kisan -Basmati

Kisan basmati was tested in varietal yield trials from 2012 to 2015 and was approved in 2016 for the entire rice-growing area of Punjab. It is high yielding, short statues (96cm vs. 114(PS 2), 128 supper Basmati stiff stemmed early maturing (94 vs. 116), and extra-long grain (8.12 mm). Kisan-Basmati is also suitable for parboiled and steamed rice. The quality characteristics of Kisan-Basmati are better than those of Supper Basmati and Basmati 515 and are at par with PS-2. Variety is moderately susceptible to Bacterial Leaf Blight (BLB), moderately resistant to Paddy Blast and Brown Leaf Spot (BLS), and resistant to stem rot. It is

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resistant and moderately resistant to stem borer and leaf folders, respectively. The yield potential of Kisan-Basmati is 65 maunds per acre.

Punjab- Basmati

Punjab Basmati was developed by RRI and KSK and was approved in 2016 for the entire rice-growing area of Punjab. Punjab Basmati with pedigree PK 8685-5-1-1-1-1 has been evolved by hybridizing Basmati 385 with line 48479. It is a high-yielding, stiff stemmed resistant to lodging, short stature, and early maturing with extra-long grain rice variety better than the parental lines. Grain length and head rice recovery of Punjab Basmati is 7.60 mm and 50.80%, respectively. Punjab Basmati variety is resistant to stem borer, moderately resistant to white-backed plant hopper, and moderately susceptible to leaf-roller. The average length of a grain of Punjab Basmati is 7.60mm, the average length-to-width ratio is 5.42, and the elongation ratio is 1.90. The maturity days of this Basmati variety is 100 days, while the average plant height is 107 cm. The variety has a yield potential of 65 maunds per acre.

Chenab -Basmati

Chenab Basmati was approved in 2016 for the entire rice-growing area of the Punjab. Chenab Basmati, with pedigree 8431-1-1-2-1-2-4, has been evolved by hybridizing line 98PP4 by H- 4439. It is an early maturing, higher yielding, stiff stem, lodging resistant with extra-long grain basmati rice variety. The maturity days of this Basmati variety are 107 days, while the average plant height is 122 cm. The quality characteristics, such as grain length and head rice recovery of Chenab Basmati, are better than Basmati 515 and Supper Basmati. This variety is moderately resistant to stem borer and susceptible to leaf folders. The variety has a yield potential of 65 maunds per acre.

Super- Kainat 2020

Supper Kainat 2020 was developed by RRI KSK and released in 2020 for the entire rice-growing area of Punjab. Supper Kainat 2020, with pedigree PK10683-12-1, evolved by hybridization line PK1044 (a fine grain line carrying Basmati 370 genome shared as a female parent) with PK1121 aromatic. Its head rice recovery is 43%, and cooked grain length is 14.7%. The variety is 132 cm tall and matures in 103 days, two weeks earlier than PK1121 aromatic. It is suitable for both parboiled and white rice. Its yield potential is 71 maunds per acre.

KSK- 111 H

KSK 111 H is a high-yielding, early maturing, long grain fine aromatic hybrid. The hybrid was developed by scientists from RRI and KSK and was approved in 2020. It has good cooking quality, a mild aroma, and a good market price. Its maturity days are 105 days. It is tolerant to salinity up to 5 EC. Its kernel length is 6.87 mm, while the cooked grain length is 13 mm. Its plant height is 120 cm, and head rice recovery is 58%. The hybrid is approved for the entire rice-growing area of Punjab. Its yield potential is 92 maunds per acre.

Al-Khalid Basmati

Al-Khalid Basmati was developed by the Institute of Soil Sanity Pindi Bhattian and was released in 2021 for the entire rice-growing area of Punjab. The stiff stem of the variety makes it suitable for lodging resistance and mechanical harvesting. Its head rice recovery is 27.5%. Its average grain length is 10.01 mm, while the cooked grain length is 19.05 mm. Al-Khalid Basmati is suitable for both parboiled and steamed rice. Its plant height is 138 cm, and it matures in 116 days. It is suitable for saline-sodic soil due to salt tolerance potential. Its yield potential is 73 maunds per acre.

Table 4: Characteristics of Basmati Rice Varieties Released by Ayub Agricultural Research Institute, Faisalabad.

s	Variety	Year of Release	Plant Height (cm)	Maturity Days	Paddy Yield Potential (Maunds/acre)
1.	Basmati- 370	1933	170	125	s
2	Mushkan -7	1933	175	110	32
3.	Mushkan- 41	1933	146	115	32
4.	Basmati -C622	1964	165	110	35
5.	Basmati- Pak	1968	170	125	30
6.	Basmati -198	1972	135	130	45
7.	Basmati -385	1985	130	105	65
8.	Super- Basmati	1996	120	115	72
9.	Basmati- 2000	2000	135	115	72
10.	Shaheen- Basmati	2000	130	115	60
11.	Basmati -515	2011	120	115	75
12.	PS-2	2013	115	116	60
13	Kisan- Basmati	2016	98	94	75
14	Punjab- Basmati	2016	107	100	75
15	Chenab- Basmati	2016	122	107	75
16	Super -Kainat 2000	2020	132	103	71
17	KSK-111H	2020	120	105	92
18	Al-Khalid- Basmati	2021	138	116	73

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Conclusion

Rice Research Institute, Kala Shaw Kaku, was established in the east-central region of Punjab by keeping in view the presence of the Kallar Tract comprising Sheikhupura, Gujranwala, Hafizabad, Mandi Bahauddin, Sialkot districts. The soil of Kallar Tract has excellent quality micronutrients, especially zinc and boron. Along with other rice varieties, Basmati-515, Kisan Basmati, Punjab-Basmati, Chenab-Basmati, KSK-111H, and Alkhalid Basmati are considered to be the mega varieties in Pakistan, producing more than 75 monds/acre.

Declarations

Data Availability statement
All data generated or analyzed during the study are included in the manuscript.
Ethics approval and consent to participate
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The authors declared the absence of a conflict of interest.

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