Paper 22

[Accueil] [Remonter] [Intro 1] [Paper 2] [Paper 3] [Paper 4] [Paper 5] [Paper 6] [Paper 7]
[Paper 8] [Paper 9] [Paper 10] [Paper 11] [Paper 12] [Paper 13] [Paper 14] [Paper 15] [Paper 16]
[Paper 17] [Paper 18] [Paper 19] [Paper 20] [Paper 21] [Paper 22] [Paper 23] [Paper 24]
[Paper 25] [Paper 26] [Paper 27] [Paper 28] [Paper 29] [Paper 30] [Paper 31] [Paper 32]
[Paper 33] [Paper 34] [Paper 35] [Paper 36] [Paper 37] [Paper 38] [Paper 39] [Paper 40]
[Paper 41] [Paper 42]

Developing Basmati Rices with high yield potential

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Abstract

Basmati rice is grown in India, Pakistan and Nepal. Varieties with similar cooking characteristics are also grown in Afghanistan and Iran. Basmati rice is prized in the domestic markets of India and Pakistan as well as in the international markets. It sells at a premium price, usually 2-3 times that of ordinary rice in the domestic as well as international markets. Basmati rice are highly aromatic. Grains elongate lengthwise upon cooking. Cooked rice is soft with sweet taste and remains soft upon cooling. Several Basmati varieties are grown in India, Pakistan and Nepal but they are all tall and low yielding. Efforts have been underway to develop Basmati rices with high yield potential. Progress has been very slow. Crosses of Basmati with high yielding dwarf varieties show considerable sterility and do not yield a full spectrum of recombinants in the segregating generations. Cultivated rice Oryza sativa is divided into 6 groups upon the basis of genetic affinity. Basmati rices belong to group V. On the other hand, high yielding modern indica rices belong to group I and japonica rices belong to group VI. Intergroup crosses in rice show variable levels of sterility and yield poor recombinants in crosses. Thus, genetic differentiation of Basmati rices from indica and japonica rices is the main reason for slow progress in developing Basmati rice with short stature. However, through persistent efforts progenies with short stature and grain characteristics similar to those of Basmati have been developed. These progenies are being evaluated and when released for on-farm production should lead to doubling of Basmati yields.

Keywords

- Isozyme classification, aroma, grain elongation, amylose content, gelatinization temperature

- Asia

Introduction

Basmati rices are well known all over the world for their superior grain quality. They sell at a premium price, usually 2-3 times the price of ordinary rice in the domestic as well as international markets. However, the production of Basmati rices is quite limited and only about 0.8 million tons are traded internationally. Basmati rices are grown primarily in India, Pakistan and Nepal and are exported to countries of Middle East, Europe and North America. Most of the Basmati varieties are tall, lodging susceptible and low yielding. Breeding efforts to develop high yielding Basmati varieties have been underway for the last 30 years, but the progress has been slow.

Taxonomic Status

Till recently rice varieties were divided into three groups, namely indicas, japonicas and javanicas. Basmati rices were classified as indicas. However, genetic analysis of 1688 varieties from different countries of Asia based on allelic association at 15 isozyme loci, Glaszmann (1987) divided the rice varieties into six groups. He confirmed the earlier contention of Oka (1958) and Jacquot and Arnaud (1979) that japonicas and javanicas are closely related and belong to the same group. He placed both of them into group VI. Indicas with global distribution were placed in group I. Early maturing and drought tolerant rices of India and Bangladesh were placed in group II. Small groups of deepwater rices from Bangladesh comprised groups III and IV. Basmati rices were placed in group V. This group also included aromatic rices grown in Afghanistan such as Barah and Lawangin and Sadri rices of Iran. Many aromatic rices grown in India, Bangladesh, Nepal and Myanmar belong to this group (Glaszmann 1987).

Distribution of Basmati Rices

The center of diversity of aromatic rices of group V are the foothills of Himalayas, in the Indian states of Uttar Pradesh (U.P.) and Bihar and Terai region of Nepal. From here these rices spread Northwestward to Punjabs of India and Pakistan, Afghanistan, Iran and Iraq, North Eastward to Bangladesh and Myanmar and Indian states of Bengal, Assam and Manipur. The westward distribution occurred to other states of India such as Rajasthan, Madhya Pradesh, Maharastra, Gujrat, Orissa, etc. Numerous aromatic varieties belonging to group V are now grown under different names such as Kataribhog Badshahbhog, Prasadbhog, Mohanbhog, Tulsimajri, Pankhari, Kamod, Ambemohar, Kalanamak, Hansraj, Tilak Chandan, Bindli, Tulsimajri and Hansraj. However, typical Basmati rices are grown in U.P., Rajasthan, Haryana, Punjab and Jammu region of Jammu and Kashmir and Punjab province of Pakistan.

Area, Yield and Production of Basmati Rices

Total area planted to Basmati varieties varies from year to year. The best estimates are about 1.0 million ha in India and 0.75 million ha in Pakistan (Table 1). In experimental plots yields of 3-4 tons per ha have been obtained (Angrish 1991). However, yields in farmer's fields average around 2 tons per ha. Thus, total world production of Basmati rices is less than 4 million tons of paddy rice. India and Pakistan, each export about 0.4

million tons of milled rice annually and rest is consumed locally. Major share of exports goes to countries of Middle East (Iran, Saudi Arabia, UAE, Iraq, Oman), Europe (United Kingdom, Russia, Germany, Netherlands) and North America (USA and Canada).

Morphological and grain quality characteristics

All the traditional Basmati varieties are tall (150-160 cm), very weak stemmed and have light green and droopy leaves. They invariably lodge at maturity and are thus difficult to harvest. Because of their weak stems and taller growth habit, they are not responsive to inputs. Thus their yields cannot be increased by fertilizer applications beyond 30-40 kgs per ha. Under higher fertility levels, lodging may occur during grain filling period resulting in poorer yields. Harvest index ranges between 0.25 - 0.30. Panicles of Basmati rices have sparse grains numbering about 80-90 per panicle.

Basmati rices have long slender grains 6.8 - 7.0 mm in length and length width ratio of 3.5 - 3.7. They are slightly twisted towards the tip and thus resemble banana shape. Some Basmati varieties such as Basmati 370 have small white belly.

Basmati varieties have intermediate amylose content (20-22%), intermediate gelatinization temperature, low gel consistency and intense aroma. The most distinguishing characteristics of the cooked rice; are lengthwise elongation and sweet and soft texture. Cooked rice grains remain separate. Cooked rice when cooled retains the grain appearance and soft texture even after several hours.

Inheritance of grain quality characteristics

Amylose content is a monogenic characteristic. Varying levels of amylose content, e.g., 0 (waxy), very low, low, intermediate and high, are controlled by multiple alleles at the waxy locus located on chromosome 6 (Kumar and Khush 1987; 1988). Similarly, gelatinization temperature and gel consistency are also monogenic traits (Tang et al. 1989). Thus, it is not difficult to breed for and fix these traits. However, aroma appears to be a quantitative trait, as segregants with varying levels of aroma are observed in the crosses between aromatic and non-aromatic rices. Monogenic (IARI 1980) or digenic (Geetha 1994) nature of aroma has been reported and a gene for aroma has been tagged with molecular markers (Ahn et al. 1992). Perhaps there is one major gene for aroma and several modifiers or QTL. No information is available on the inheritance of lengthwise elongation of grains. There is a major GxE component in the expression of these traits (Dela Cruz et al. 1989). Best Basmati quality is produced in Northwestern India and Northern Pakistan where rice matures in cool weather of October. Soil types are believed to influence the expression of Basmati quality.

Improvement of Basmati Rices

Basmati rices have been grown in the Indian subcontinent since times immemorial. Many landraces of Basmati were evaluated at Rice Experimental Farm of undivided Punjab located at Kala Shah Kaku now in Pakistan and since renamed as Rice Research Institute. Several pure line selections were made and evaluated in replicated yield trials. A pure line selection was released in 1933 as Basmati 370. this variety has been grown very widely in both India and Pakistan till recently. Another pure line selection was released from Kala Shah Kaku under the name of Pakistan Basmati in 1968 (Shafi and Ahmad 1971). It is still grown to a limited extent in Pakistan as well as Punjab state of India. Several pure line selections of Basmati were released from Rice Research Station Nagina in U.P. such as T3 (Dehradum Basmati) and T9. A pure line selection called Troari Basmati is widely grown in Haryana.

After the introduction of high yielding varieties such as IR8 and TN1 in 1960s, breeding programs were initiated in both India and Pakistan to develop high yielding Basmati varieties by incorporating genes for short stature from IR8 and TN1. Rice Research Institute, Kala Shah Kaku initiated the program in Pakistan in 1968. In India, research was undertaken by several research organizations such as Directorate of Rice Research (DRR) Hyderabad, Indian Agricultural Research Institute (IARI) New Delhi, Punjab Agricultural University, Rice Research Station Kapurthala, Haryana Agricultural University, Rice Research Station Kaul, and G.B. Pant University of Agriculture and Technology, Pantnagar. As shown in Table 3, several short statured Basmati varieties have been released. However, none of the short statured Basmati varieties released in India have found favour with growers and millers because their grain quality does not match that of the traditional Basmati varieties. Thus farmers continue to grow traditional Basmati varieties.

Improved Basmati varieties have almost entirely replaced the traditional Basmati varieties in Pakistan. Basmati 385 and super Basmati are grown in traditional Basmati growing areas of Central Punjab and Basmati 198 is grown in southern districts. These three varieties are non-dwarf and have intermediate height. Basmati 385 occupies the largest area. These varieties have a yield advantage of about 20% over the traditional Basmati varieties (Chaudhry and Rahman 1986). However, their level of aroma does not match that of traditional varieties and they are susceptible to lodging.

Reasons for lack of progress in developing dwarf basmati varieties

Thirty years of breeding efforts at several research institutes have not resulted in high yielding Basmati varieties to-date. Several factors are responsible for this lack of progress. As mentioned earlier, Basmati rices are genetically differentiated from high yielding short statured indica varieties and belong to a distinct group. In rice, intergroup crosses show varying levels of sterility and this trait is passed on to their progenies. Secondly, the crosses between Basmati and short-statured indica varieties do not produce full spectrum of recombinants. For example, in such crosses in contrast to expected 3:1 segregation, short statured recombinants are rarely observed. Perhaps a gamete eliminator located close to the sd-1 locus for short stature is responsible for such distortion. Thirdly, aroma and grain elongation are quantitative traits and difficult to combine all the polygenes for these traits into the same line. Fourthly, satisfactory methods for evaluating the degree of aroma and texture of cooked rice of breeding lines are not available.

Breeding high yielding basmati rices at International Rice Research Institute

Breeding work to develop high yielding Basmati rices was initiated at IRRI in early 1970s. Original crosses were made between Basmati 370 and improved indica lines with intermediate amylose content and intermediate gelatinization temperature. Large segregating populations were grown and a few lines with short stature were selected. These lines had varying levels of sterility and some had poor plant types. From intercrosses of these lines, segregants with less sterility and better plant types were selected. These segregants were evaluated for amylose content, gelatinization temperature, aroma and grain elongation. Intercrosses between selected lines have been made over the years to combine all the quality characteristics. Other Basmati varieties released in India and Pakistan such as Sabarmati, Punjab Basmati 1, Pusa Basmati 1 and Basmati 385 have also been utilized in crosses. Each year 50-100 crosses are made and 4000-5000 breeding lines are grown. All these lines are evaluated for Basmati grain quality characteristics every season. Selection is based on short stature, improved plant type, less sterility, shorter growth duration and various components of grain quality. Lines with poor plant type, sterility, poor grains, lack of aroma and poor grain elongation are discarded each generation. After several cycles of hybridization and recurrent selection, improved plant type line with short stature that match the grain quality characteristics of

Basmati rices have been selected (Table 3). These lines are being evaluated in replicated yield trials at IRRI and in observational nurseries in India and Pakistan. We hope improved Basmati varieties with high yield potential will become available in next 2-3 years.

Table 1. Area planted to Basmati varieties annually.

Country	State	Estimated Area in Million Ha
India	U.P.	0.50
	Haryana	0.25
	Punjab	0.10
	Rajasthan	0.05
	Himachal Pradesh	0.05
	Jammu	0.05
Pakistan	Punjab	0.75

Table 2. Improved Basmati type varieties released in Pakistan and India

Name of Variety	Year of Release	Breeding Organization
Pakistan		
Basmati 198	1978	Rice Research Institute Kala Shah Kaku
Basmati 385	1986	Rice Research Institute Kala Shah Kaku
Super Basmati	1996	Rice Research Institute Kala Shah Kaku
India		
Punjab Basmati 1	1981	Rice Research Station Kapurthala, Punjab
Guarev	1985	Rice Research Station Kaul, Haryana
Sabarmati	1970	IARI, New Delhi
Improved Sabarmati	1971	IARI, New Delhi
Pusa Basmati 1	1995	IARI, New Delhi
Kasturi	1995	DRR, Hyderabad

Table 3. Improved plant type lines with Basmati grain characteristics developed at International Rice Research Institute.

Breeding line	Plant height (cm)	Growth duration (days)	Grain length (mm)	Amylose content (%)	Gelatinization temperature	Aroma	Grain Elongation
IR70416-82-4-3	90	116	7.00	21	I	Strong	1.96
IR70418-78-2-3	92	113	7.22	21	I	Strong	1.88
IR70422-44-3-3	90	115	6.78	18	HI	Strong	2.06
IR70422-95-1-1	93	112	7.26	20	HI	Strong	1.91
IR70422-141-3-3	95	119	8.06	22	I	Moderate	1.91
IR70423-169-2-2	95	116	6.84	21	HI	Strong	2.28
IR70423-170-2-3	93	117	7.14	21	HI	Strong	1.95
IR70446-85-3-2	94	116	6.98	21	HI	Strong	1.97
Basmati 370	161	118	6.98	22	HI	Strong	2.30

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