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Basmati – Rice a Class Apart (A review)

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Abstract

Basmati rice has a unique position in the rice world due to its price, fragrance, aroma, grain morphology, quality and other desirable traits. Various basmati rice varieties have quantitative, distinct features, better plant type and superior characteristics with good growth habit in comparison with other varieties. On the other hand, different rice diseases badly affect its yield and production. To increase its yield potential, growing area and using advanced breeding techniques are the need of the hour. This review is equally beneficial both for the farmers and scientific community for exploring its yield potential by the utilizing various modern techniques and other marker assisted selection for the development of new rice varieties with great genetic potential against biotic and abiotic stress.

Keywords: Basmati; Breeding. *Oryza sativa* L; Traits; Yield; Genetic potential

Introduction

Rice feeds half the people on the planet earth. Its importance can be envisaged by the fact that year 2004 was declared as International year for rice by the United Nations. This reputation has not been conferred to any other cereal crop. Apart from being a staple food, its production and post-production operations are source of employment for millions of people around the world. Majority of these employees are poor farmers of third world countries who produce four fifth of the total rice produced globally. Asian rice or *Oryza sativa* L. is a true grass belonging to family Poaceae. It is the only cereal with completely sequenced genome consisting of 430 mega base pairs [1-4].

Scientific Classification of Rice

- Kingdom: Plantae
- Division: Magnoliophyta
- Class: Liliopsida
- Order: Poales
- Family: Poaceae
- Genus: *Oryza*

The genus *Oryza* to which present day cultivated rice belongs, has twenty-one wild and two cultivated species named *indica* and *japonica* [5].

Taxonomic status of basmati rice

Glazmann assessed 1688 rice cultivars collected from different countries for allelic variations at 15 isozyme loci. He divided these cultivars in different groups. Aromatic cultivars belong to Groups I, V and VI which contain 10, 27 and 7 cultivars respectively.

Basmati–The Queen of Fragrance

Basmati is combination of two Hindi words: BAS meaning fragrant or scented and MATI meaning QUEEN so, together meaning "QUEEN OF FRAGRANCE". As depicted by name it is the worlds' most aromatic and fragrant rice having no parallel in terms of its characteristic fragrance attributed by a chemical compound named 2-acetyl-1-pyrroline. This compound is more concentrated in basmati than any other variety approximately 90 parts per billion. This gives nut-like or popcorn like flavor to rice. Combined with fragrance it has a long, slender, narrow width grain. One such varietal group comprising of aromatic pulao/biryani rice of Indian sub-continent known as 'Basmati' is the highly priced rice in the domestic as well as international markets. Originated in the foothills of the Himalayas, Basmati rice is characterized by extra-long slender grain which gets double in length after cooking but its width remains the same.

History of basmati rice cultivation

Rice cultivation dates back thousands of years. It described to be, first cultivated in china in 7000 B.C.E. It was only found and known in Asia for many years. Later, travelers and tourists introduced it to the rest of the world. Alexander the great brought it to India. From here it moved to Spain by Muslim conquerors in the 700s. Evidences suggest that it has been cultivated from 1500-1000 BC in India subcontinents. Some sources also indicate that it was cultivated 8 thousand years ago in this region. The oldest grain samples found at Mohanjodaro in Pakistan date back to about 2500 B.C. speaking more strictly about Basmati rice it's been grown in Pakistan, India and Bangladesh for centuries. In antique existing written expression it is mentioned in HEER RANJHA an epic Punjabi poem written by Waris shah in the 18th century [6-9].

Nutritional status of basmati rice

Every single grain of Basmati rice is a complete package of balanced nutrients. Rice is mainly a high energy caloric food. About 72-75% of the total rice grain is composed of carbohydrate which is present in the form of starch. Rice protein is called aryznine or glutelin which constitute about 7% of the grain. Biological value of rice protein is 80 which are higher than other cereal crop protein such as maize 50 and wheat 60. It also contains certain minerals e.g. phosphorus and

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enzymes (Figure 1). It also contains gamma-oryzanol, a compound having cholesterol lowering effect [9-11] (Figure 1).

Glycemic Index

The glycemic index is a number related with food that points out the food's effect on a person's blood sugar. It normally ranges between 50 and 100. Basmati rice has a "medium" glycemic index between 56 & 69 therefore making it more appropriate for diabetics [12].

Agronomy of Basmati Rice Crop

Time of plant

Basmati is a highly photosensitive crop that requires a tropical, warm and soggy climate its transplantation to its maturation. Temperature range is usually 25-30° Celsius and required humidity is 60.This set of environmental conditions is crucial for the production of fine rice varieties. In Pakistan this environmental condition starts prevailing from May to June. The humid atmosphere helps in making the rice grain longer in size, translucent, glossy in texture, aromatic and pleasant in taste [11,12].

Duration of a crop

The maturity time for harvest of paddy after planting is:

- Early varieties need 110-115 days.
- Medium varieties required 12-130 days
- Late varieties of rice required more than 130.

The main season of rice plantation is from May to July and harvesting takes place between October to November [13,14].

Land preparation

Rice is planted only under irrigated condition in Punjab. There are three methods of land preparation. Choice of method is dependent on availability of water, soil features and farm mechanization.

- Complete paddling
- Partial paddling
- Dry land preparation

Rice Varieties Grown in Pakistan

More than 4000 varieties of rice are grown every year worldwide. The famous basmati rice varieties and their characteristics are shown in the (Table 1):

- Basmati-370
- Super Basmati
- Basmati-385
- Basmati-Pak
- Basmati-198
- Basmati-2000
- Shaheen Basmati
- Basmati-515
- Kashmir Basmati

Basmati-370

Basmati-370 is a very famous rice variety all over the world due to its aroma. Almost all the basmati rice varieties have been developed through cross breeding basmati-370 is one of its parents.

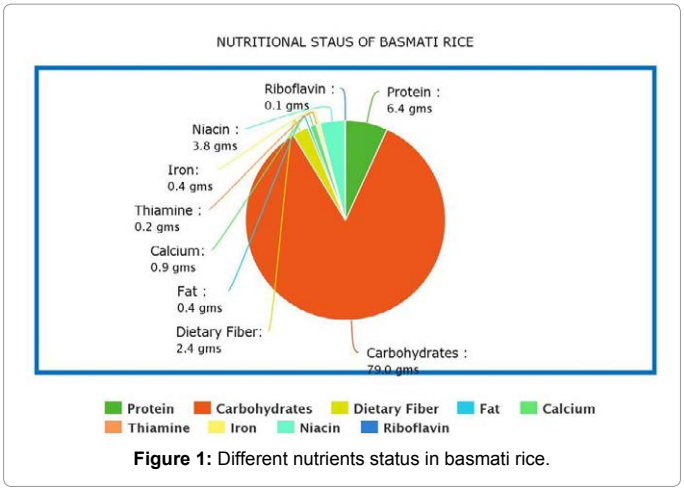


Figure 1: Different nutrients status in basmati rice.

Super basmati/White rice

This basmati rice is grown in the foothills of the Himalaya in Pakistan. Its length is almost four times greater than its width. Its long size pointed edges and exclusive aroma make it king of all basmati varieties.

This has longest average grain length (7.2 mm), width, (1.55 mm to 1.68 mm), L/W ratio 4.50. It has very strong, unique aroma. This variety becomes ripe for harvesting within 115-120 days i.e. November of each year. After receiving paddy of this rice, there is option to make Parboiled/ Sela rice, white rice or brown rice. Scientists at the International Agriculture Research Institute have cross bread super Kernel basmati are developed from it a type of rice, in India known as "PUSA" [7,12,13].

Basmati -385

It is also an expensive rice but competitively lesser than super basmati rice. This variety stands second after super basmati rice in terms of aroma, flavor and taste. Elongation ratio on cooking is about 1.50 can be identified with no thickness in width [7,12].

Basmati-pak

Basmati-Pak was cultivated in 1968 and it is a very prominent rice variety in that era. It is also very famous due to its grain characteristics. It is no longer grown in Pakistan due to plant height, low yielding and late maturity.

Basmati-198

This variety was cultivated in Pakistan in 1980 but after the introduction of basmati 385 this variety was comparatively considered better for sowing. However from the year 2002 this has been cultivated in Sindh with the name of D.98. Some selected lots have aroma and bear characteristic of basmati rice. It is expensive but little bit lesser than basmati 385. It average length is 6.20 to 6.90 mm, width.1.65 mm to 1.80 mm, L/W ratio 4.36, color white Moisture content 0.12% max.

Basmati-2000

Recently grown in Pakistan, it is premium quality rice.it is ready to be harvested in November. It is costly. Average grain length is 8.25 mm and color is white. Parboiled/ Sela rice of such quality is soaked into water for 2 hr before cooking, where as white rice required only 25 minutes for soaking before cooking [7,12].

Variety	Year of release	Variety Status	Tall. (cm)	Maturiy days	Aroma	Grain Length	Paddy yield and potential (Maunds/Acre)
Basmati 370	1933	Cultivated	170	120	++	6.8	30
Super basmati	1996	Cultivated	115	120	+	7.5	72
Basmati 385	1985	Cultivated	133	130	+	6.8	45
Basmati Pak	1968	Cultivated	170	125	+	7.5	30
Basmati 198	1972	Cultivated	135	130	+	7.6	45
Basmati 2000	2001	Cultivated	135	115	+	7.7	72
Shaheen Bas	1996	Cultivated	130	115	+	7.2	40
Basmati-515		Cultivated	125	120	+	7.6	65
Kashmir Bas	1977	Cultivated	115	115	+	6.6	50
Non-basmati rice varieties							
IR6	1971	Cultivated	105	110	-	5.7	100
KS282	1982	Cultivated	115	100	-	7.3	100
KSK 133	2006	Cultivated	115	105	-	7.2	105

Table 1: Characteristics of various prominent basmati rice varieties.

Shaheen basmati

Shaheen basmati was developed by Soil Salinity Research Institute (SSRI) Pindi Bhatian, Pakistan. Long rice grain with awn and cultivated largely in saline area.

Basmati-515

This rice variety was developed in the year 2013 in the Rice Research Institute Kala Shah Kaku, Pakistan with promising characteristics. It is being cultivated in the major rice growing areas of Pakistan with high yield potential.

Kashmir Basmati

Kashmir Basmati is a long slender aromatic rice variety released in the year 1977. Kashmir basmati has very good grain characteristics and other quality traits. It is very famous in India, Pakistan and Azad Jammu and Kashmir.

Basmati Related Characters According to Variety

Rice growing areas of Pakistan

Different rice growing areas of Pakistan are shown in the Figure 2. It is cultivated in all the four provinces of Pakistan. Punjab and Sindh are included high production regions of rice. It is mainly grown in north east regions of Punjab including districts i.e. Gujranwala, Sialkot, Hafizabad, Sheikhupura, Gujrat and Narowal. On the other hand, In Sindh the mainly rice growing areas are Hyderabad, khairpur, Sukkhar, Sanghar, Ghotiki, Nawab Shah and Mir Pur Khas. The province of Baluchistan and Khyber Pukhtoonkhwa also contribute in rice production actively in every year. The main rice growing districts of these provinces are Jafferabad, Nasir abad, Peshwar, Mardan, Swabi and Kohat respectively (Figure 2).

Seed rate and treatment

For one acre of land amount of seed required is 5-8 Kg (approximately).

Seed health testing

Salt treatment is the commonly used procedure to check seed vigor and health. For this purpose 1 Kg of salt is dissolved in 10 L of water, in this solution 8-10 Kg of seeds are dipped. In this way vigorous seed settle down in the container while poor health seeds flow on the surface. Later, flowing seed are discarded and settled seeds are washed with water 3-4 times.

Seed treatment

Treat with very low dose of streptomycin to protect the seeds from any infection.

Nursery preparation

Seeds are grown in nursery for 30-40 days then transplanted into the field.

Transplantation

For transplantation the ideal time of field preparation is mid of July. Plant to plant distance should be 6 inches and row to row distance should be 9 inches. There must be standing water in the field preferably at the height of 4-5 centimeters. This practice will make roots stronger. Weeds appear and removed in august while any disease incidence if occurs should be cured in September.

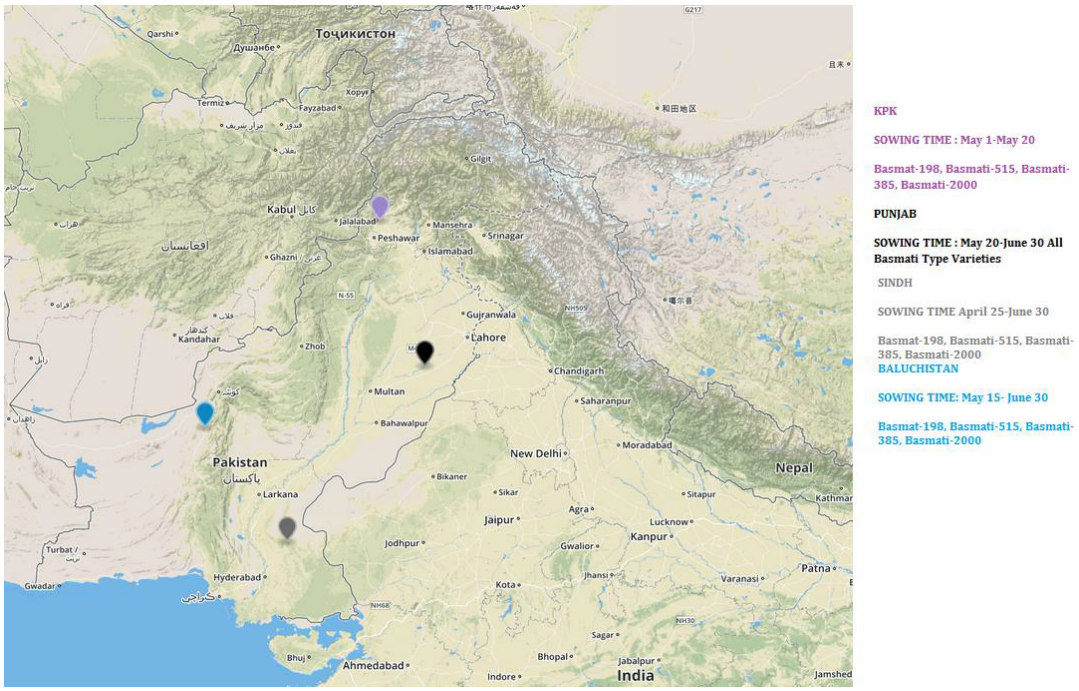
Fertilizers

Basmati rice does not require bulks of fertilizers. It can do well on low to adequately medium dose of fertilizer. Excessive nitrogen can lead towards accelerated vegetative growth. Also its excessive quantity badly affects cooking quality and taste. Soils low in nitrogen mostly produces higher quality aromatic rice grain. Application of nitrogen fertilizer at the time of flowering may enhance milling and nutritional quality of basmati rice. Split method of fertilization is suitable. Removal of water from the field 15 days before harvesting is compulsory to get higher yield.

Harvest

Harvest the crop when it turns golden and moisture content is 20%. Every step is carefully undertaken to produce the finest and highest quality basmati rice.

Pre and post-harvest loses: Post-harvest losses can be prevented by following strict sanitary practices. Grain moisture content should be 12% for long time storage 12% period. Use fumigation before storage. Use the latest methods for grading, packaging, storage and transportation to reduce the losses at farm and market level. Rice is stored in raw form having excessive moisture 16% for brown rice and over 14% for white rice. The stored rice quality improves with the passage of time. The proper ageing means the grain should lose the extra moisture and come to normal moisture content 10-12%, This is the moisture content at which the grains has the ability to sustain its form and germinate if sown. Some rice grains keep on losing moisture



Map is generated by using online GIS features at www.mapbox.com

Figure 2: Basmati rice growing area of Pakistan.

and improve cooking quality from 1-2 years and after 3 years should start losing their cooking quality. So rice shelf life is 3 years. On the other hand, main losses occur due to the incidence of rice diseases caused by different pathogens (Table 2).

Production Statistic

Production statistics world wide and pakistan

According To Food and Agriculture Organization of the United Nations Statistics Division FAOSTAT 2012, Pakistan is the 11th largest producer of rice in the world. Each year it produces an average of 6 million tones and together with the rest of South-Asia, the country is responsible for the supply of 30% of the World paddy rice output Most of these crops are grown in the fertile land of Sindh and Punjab region with millions of farmers relying on rice cultivation as their major source of employment [14-16]. Punjab has 59.46% of total harvest area, Sindh has 32.13%, N.W.F.P has 2.86% and Baluchistan has 5.52% total harvest area. Below is year wise comparison of production in Pakistan Figure 3. It is clear from the above comparison that Punjab is the largest rice producing province representing 91.2% of all basmati crop produced in Pakistan followed by Sindh, KPK and the NWFP. A survey carried out to determine the increase in rice area in the current year showed the following results, there has been an overall of 24% increase in the cultivation area. The major increase of area under rice crop was in the cotton-wheat cropping zone 46.4 per cent. After this comes mixed cropping zone 27.4%. Very small area of 2% increase in the rice-wheat zone. This is mainly because rice was already cultivated in this area and it was only replaced by fodder and vegetable cultivation. The fine varieties, super Basmati was the major variety covering 15 per cent of the area, followed by the Russi and B-2000 varieties (Figure 3).

Exports

Pakistan major basmati rice export markets are: U.A.E, Saudi Arabia, U.K, Yemen, Qatar, Bahrain, Kuwait, Malaysia and USA (16-18). Below is shown in the the year wise export of Pakistan basmati rice (Figure 4).

Molecular breeding approaches to improve basmati

Difficulty in differentiating genuine basmati from other types of rice and significant price difference between them has led to deceitful trader to adulterate basmati rice with cross bread basmati varieties and long-grain non-basmati varieties. In Britain the food Standard Agency found in 2005 that about half of all basmati rice sold was adulterated with other strain of long grain rice, prompting rice importers to sign-up to a code of practice. A PCR based assay similar to DNA finger printing in human allows adulterated and non-basmati rice use “purity certificates” based on DNA tests for their basmati rice consignment [17,18].

Research on Basmati Rice

President of Basmati Grower Association of Pakistan (BGA) says:

“Research is almost non-existent as no new high yield variety has been evolved in the past decade that could replace the super basmati rice introduced in 1996, which is still planted in more than 90% of the basmati growing areas [9].

Plant breeding techniques are used to work on developing new varieties of basmati rice aiming at the following objectives

- Enhance crop quality and yield.
- Increase tolerance against inevitable environmental factors e.g. salinity temperature extremes, floods and droughts.
- Resistance to plant pathogens e.g. viruses, fungi and bacteria.
- Increase tolerance to crop damage by insect and pest.
- Increase tolerance to herbicides.

Diseases	Pathogen	Prevailing stage	Favorable Environment	Losses
Grain Discoloration/kernel spotting	*Burkholderia glumae Pseudomonas Fuscovaginae, Curvularia* spp, *Fusarium* spp, *Sarocladium oryzae*	Panicle emergence stage/ maturity stage	Wet/ Humid	Severe
Bacterial blight	*Xanthomonas oryzae* pv. *Oryzae*	Seedling stage/Early growth stages of crop	Wet/High Humid	Severe
Blast	*Pyricularia grisea*	Early stage/Tillering/Maturity stage	Temperate Humid	Severe
Brown spot	*Cochliobolus miyabeanus*	Near maturity stage	Temperate	Severe
Sheath blight	*Rhizoctonia solani and Th anatephorus cucumeris*	Nursery stage/Seedling stage	High Humidity	Severe
Stem rot	*Magnaporthe salvinii*	Later growth stages of rice	Wet/High Humidity	Moderate
False smut	*Ustilaginoidea virens*	Flowering stage	Temperate Humid	moderate
Sheath rot	*Sarocladium oryzae*	Early panicle emergence stage	Wet /Humid	Moderate
Bacterial panicle blight	*Burkholderia glumae And Burkholderia gladioli*	Later stage/Panicle emergence stage	Temperate/ Humid	Severe
Bakanae	*Gibberella fujikuroi*	Seedling stage	Temperate/ Humid	Severe
Tungro virus	*RTBV/RTSV*	At any stage	Temperate	Moderate
Bacterial leaf streak	*Xanthornonas oryzicola*	Tillering stage	Wet/temperate	Moderate
Black kernel	*Curvularia lunata*	At maturity stage	High humidity	Moderate

Table 2: Impact of diseases on production of basmati rice crop [31-51].

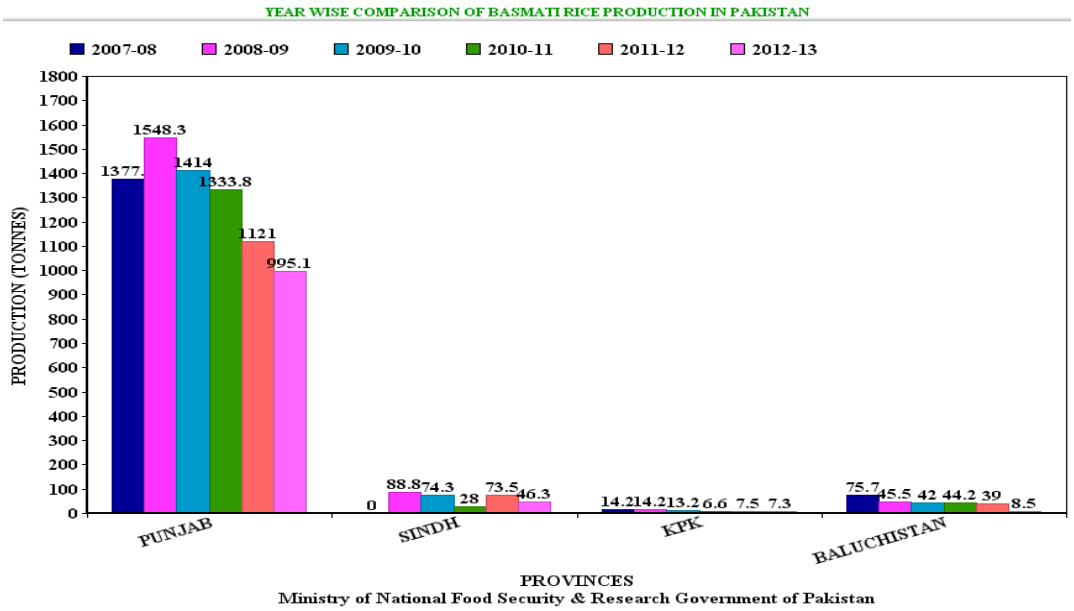


Figure 3: Year wise Production status of basmati rice in the major rice growing areas of Pakistan.

- Waterlogging and drought tolerance.
- Improved germination ability.
- Early maturity
- Better root development
- Flag leaves remain green through the cropping season.

Research is continued to developed rice varieties which are resistant to bacterial blight, sheath blight, stem-rot resistance and rice water weevil tolerance. Long and slender kernels with distinctive aroma are under consideration. Salt and drought tolerant, many of transgenic lines of basmati rice are under evaluation. There is a concern over the basmati trademark as the Geographical Indication not restricted to Indo-Pak, Punjab but includes the Bangladesh, Indonesia, Maya mar, Vietnam, Cambodia and China, these countries have introduced fragrant rice and an not limiting basmati to early geographical locations. The development and deployment of high yielding varieties of good grain quality and introduction of technologies that reduce production cost would have positive effect on sustainable rice production. Now Sindh basmati rice D-98 have aroma, length, taste it is surely basmati but not grown in geographical belt identified by Rice Research Institute. But Pakistan follows a geographical indication law. It is because of this

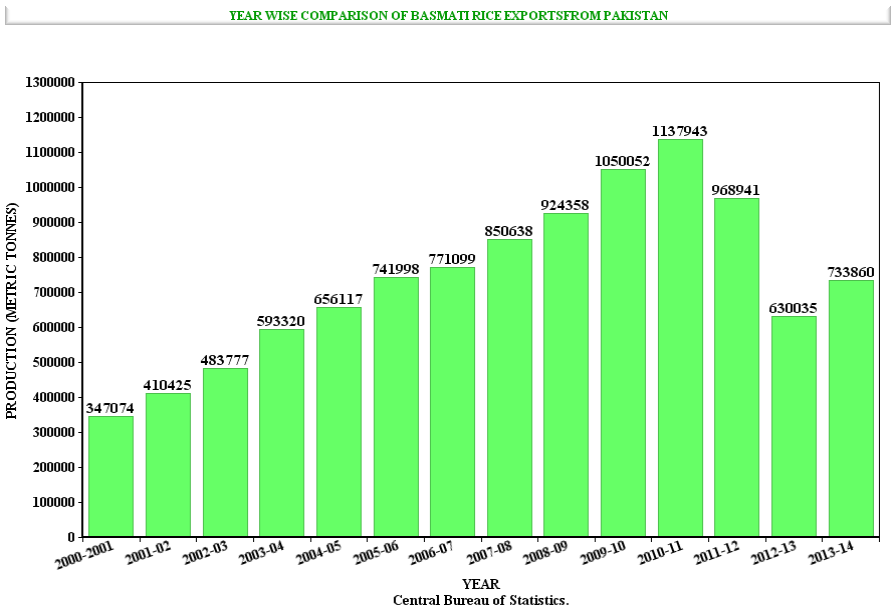


Figure 4: Internationally year wise export status of basmati rice.

deficiency that basmati is awarded a trade mark which is awarded to a distinctive sign, name, symbol or device identifying a product. It is also suggested that basmati rice will be selected on the basis of its aroma, length, width, thickness, L/W ratio and cooking qualities, instead of GI . Both India and Pakistan now agree to jointly seeking registration of geographical indication for basmati. Also Pakistan has asked India to work-out a joint strategy on marketing the premium basmati rice to counter the non-tariff barrier imposed by other countries [13&18-24].

Application of DNA Markers in Basmati Rice

In the evolution of rice and its genetic differentiation into distinct varietal groups, consumer quality preferences have played a significant role besides agro-ecological factors. Since Basmati and non-Basmati rice varieties belong to the same species, *Oryza sativa*, the variability of genome regions used for DNA-barcoding is not sufficient to differentiate varieties. Basmati differs from non-aromatic rice by a specific mutation, a deletion in the gene coding for the enzyme betaine aldehyde dehydrogenase, BAD, which theoretically causes the typical aroma. But the same deletion also occurs in other fragrant rice varieties from the Indian subcontinent and Southeast Asia, which are not classified as Basmati. Keeping the foregoing in view studies were undertaken with the following objectives:

a) Genetic analysis of traditional and evolved Basmati and non-Basmati rice varieties.

b) Detection and quantification of adulteration in Basmati rice.

Genetic analysis of traditional and evolved basmati and non-basmati rice varieties

Conventional methods of identification i.e., based on morphology and chemical features are not precise and accurate enough to make a distinction between basmati and non-basmati varieties, although these are most commonly used. But molecular techniques are more reliable method of identification. They cannot only differentiate among but also within the cultivars. One such technique is marker assisted selection.

Marker assisted selection: DNA markers are most commonly used markers. The screening is not based on trait but marker associated with it. Some of the molecular markers are RAPD, RLFP, SNPS and SSR. DNA Fingerprinting based on microsatellite is also used as a reliable identity test. From these mentioned markers SSR are most effective. They can detect high degree of polymorphism. Also, they do not require high quality DNA to run on. DNA of medium to low quality/quantity is sufficient. ISSR markers along with SSRs are used to detect genetic relationships of basmati and non-basmati varieties.

Detection and quantification of adulteration of basmati rice

Basmati rice, in addition to the desired quality traits, holds many unwanted traits that include

- Tall Stature
- Low Yield
- Photosensitivity

Cross breeding technique/mutation breeding: Since 1970s efforts have been made to develop high yielding basmati through conventional cross breeding methods but these evolved basmati varieties could not match the standards of traditional basmati. Many basmati rice varieties have been evolved through mutation and other modern breeding techniques. Traditionally employed morphological and biochemical assays for detecting adulteration in Basmati rice have not been found to be discriminative enough warranting more precise high-throughput techniques [17,18&22-31].

Capillary electrophoresis [CE]: A capillary electrophoresis [CE] based microsatellite DNA profiling method eases quick and accurate detection and quantification of the adulteration in Basmati rice [8].

Primers to detection of adulteration: Following microsatellites are used to detect adulteration RM1, RM55, RM44, RM348, RM241, RM202, RM72 and RM171.

Conclusion

It was concluded from all above discussion rice is a very important cereal

food crop and mutation breeding play a significant role in developing rice varieties. Mutation breeding plays an important role in improving aroma and quality of the parents in rice crop. It is also important in improving yield of rice, because through mutation breeding rice varieties can be developed which are resistant against biotic and abiotic stresses. On the other hand, it is equally beneficial both for scientific and farmers community for the screening and development of high yielding basmati rice varieties.

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