

Development of an Aromatic High Yielding Basmati Rice Variety Having Extra Long Grains and Short Duration

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Abstract

High-yielding rice varieties having shorter growth duration, outstanding physico-chemical traits including better cooking, aroma, extra-long grain, have now become foremost objective of rice breeding research because of increasing demands of quality rice world-wide. Trait pyramiding of these highly valuable traits without compromising yield and quality at the same time is a difficult task using conventional breeding approaches. Excellent grain quality, fertilizer-responsiveness, high yielding varieties can rise income of poor farmers of developing countries as well in the face of considerable rise in world population and trends of international markets. A new improved high yielding, extra-long grain variety also having traits of early maturity, short stature and excellent cooking with aroma was developed at Rice Research Institute, Kala Shah Kaku (RRI KSK) using conventional breeding approaches. The variety approved as "*Punjab Basmati*" with pedigree name i.e. PK8685-5-1-1-1-1 was tested in different varietal yield trials and regional adaptability yield trials in 2009 to 2014. On the average basis, it gave 15% and 7% higher paddy yield than local existing Basmati varieties i.e. *Super Basmati* and *Basmati 515*, respectively as checks. In physico-chemical tests conducted at RRI KSK head rice recovery (58%) and rice kernel length (7.76 mm) were found better than both check varieties. It is two weeks earlier than both check varieties. Being short stature and stiff stem, it is resistant to lodging.

Keywords: Rice; *Oryza sativa*; Basmati variety; Trait pyramiding; High yielding; Early maturity; Extra-long grain

Introduction

Rice (*Oryza sativa* L.) is critical for human nourishment because it serves as basic food for more than two billion people i.e. nearly 60% of the world population according to reports of United States Department of Agriculture [1]. It provides more calories than any other food crop [2]. Rice is playing a vibrant role in Pakistan's economy as it is the second staple food after wheat and largest foreign exchange earning agricultural commodity. It accounts for 3% in value added in agriculture and 0.6% of gross domestic product [3]. In Asia, 90% of the world rice is produced and consumed. International rice export is dominated by a few countries such as India, Thailand, Vietnam and Pakistan, as they contribute around 60-70% in total world export [4]. Pakistan holds 5th position among top ten rice exporting countries. Out of 6.850 million metric tons produced during 2016-2017 (P), 4.20 million metric tons were exported earning valuable foreign exchange of US\$ 1.860 billion [3].

Continuous progress in rice breeding and production, technology has helped Pakistan to fulfill the rising local and international demands. However, the country is experiencing large annual variation in rice production because of water scarcity, slow research progress and non-availability of new or quality seed. During 2017, around 14% decline in rice export was observed compared to previous year due to high input costs, low production and high local consumption [5,6]. Therefore, replacement of low-yielding rice genotypes with promising input efficient and higher yielding basmati cultivars can be a viable option to fetch premium benefits.

Basmati is the most sought-after special type of rice grown in Pakistan and India that is internationally eminent due to its cooking quality parameters. Considering its uniqueness, goodwill among growers and consumers, and changing dietary needs, the demand of such rice type is increasing worldwide [7]. Punjab province is the major producer of basmati rice due to its soil and agro-climatic conditions sharing 70% in total production. The main basmati production areas include Gujranwala, Hafizabad, Nankana Sab, Narowal, Sheikhupura and Sialkot districts. In recent years, hybrid rice cultivars had greatly influenced the basmati production because of their short maturity duration and better yields, that's why basmati production is showing decreasing trend in recent years [8]. Moreover, rice growers and traders has different interests as farmers want early maturing and higher yielding cultivars which provide them maximum profit and enough time for sowing of next crops, whereas traders prefer better grains in terms of aroma, color, shape, size and texture [9].

The traditional basmati cultivars are susceptible to lodging, diseases, photoperiod, and temperature and are lower yielding when compared to non-basmati cultivars [10]. During 1920's, the basmati rice improvement programme was initiated at Rice Research Institute Kala Shah Kaku (RRI KSK), Pakistan [11]. New basmati cultivars possessing higher genetic yield potential, better grain quality parameters, resistance to lodging and different diseases were long awaited. The earlier attempts had limited success due to lack of infrastructure for grain quality evaluation and well defined selection criteria. The varieties developed through pure line selections were good for cooking quality traits but were susceptible to lodging, diseases, and insects and had lower yielding potential [12,13]. The main hurdle in Basmati improvement programme lies in pooling of aroma and grain quality

parameters with acceptable agronomic features [14]. *Super Basmati* replaced *Basmati 385* and *Basmati 370* due to its higher yield potential and better grain quality but had weak stem stiffness along with higher insect incidence rates [15,16]. *Super Basmati* is still popular among local farmers, however, its demand has been decreasing in International markets as international buyers are now demanding extra-long grain varieties with acceptable cooking qualities [9,17]. Furthermore, the farmers of traditional rice area are demanding an early maturing, high yielding and lodging resistant basmati rice varieties with good grain quality and resistance to different diseases. Under this scenario, scientists at RRI KSK have developed an early maturing, stiff stemmed, higher yielding and extra-long grain rice variety "*Punjab Basmati*".

Material and Methods

Basmati 385 was crossed with line *48479* during the year 1999. The pedigree method of selection continued up to F7 generation. This line was evaluated in observational lines/plots with entry No. *70684*. It was tested in station yield trials (for three year) and regional adaptability trials (micro plot yield trials and National Uniform Yield Trials) from 2009 to 2014. *Basmati 385* is an approved variety and has high yield potential, earliness and good cooking quality whereas line *48479* is an extra-long grain and short statured genotype. The new candidate variety "*Punjab Basmati*" 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. To ascertain the best transplanting date, the variety was passed through transplanting date trials for two consecutive years from 2011-2012. Likewise, to find the best ratio of N-P-K application, trials were conducted during 2012. To

measure the susceptibility and resistance of the variety against diseases (bakanae/foot rot, bacterial leaf blight, blast and stem rot) and insect pests (stem borer and leaf folder), trials were also conducted along with *Super Basmati* and *Basmati 515* checks.

Data of agronomic traits (yield, maturity days, height, tillers, grain shape length, width, thickness of both grain and paddy), cooking quality parameters (boiled kernel length, cooked grain length, elongation ratios), milling (husk %, bran %, total recovery %, head rice recover %, broken %), nutritional parameters (amylose contents, alkali spread value and aroma) were also measured during all the trials to evaluate the consistency and uniformity of these traits in the successive generations. Quality index was calculated to evaluate and compare the ultimate quality of the newly evolved variety with that of the existing varieties of rice as checks.

Results and Discussion

Forty different trials were conducted to compare new variety, *Punjab Basmati* with *Super Basmati* and *Basmati 515* for all the pyramided traits. The overall average yield of *Punjab Basmati* was 4.30 t/ha against 3.75 t/ha of *Super Basmati* and 4.30 t/ha of *Basmati 515* (Table 1a). Milling results, physico-chemical traits and cooking parameters are depicted in Table 1b along with check varieties. Results of fine grain yield trial, adaptability trials and National Uniform Rice Yield trials clearly showed the superior yield performance of *Punjab Basmati* variety over checks i.e. *Super Basmati* and *Basmati-515*. *Punjab Basmati* has a yield advantage of 15% and 7% over standard check varieties i.e., *Super Basmati* and *Basmati 515*, respectively (Table 2).

Characteristics	<i>Punjab Basmati</i>	<i>Super Basmati</i>	<i>Basmati 515</i>
Plant height (cm)	107	121	132
Leaf colour	Green	Green	Green
Leaf angle	Erect	Semi erect	Semi erect
Stem stiffness	Stiff	Weak	Semi stiff
No. of productive tillers	19	20	18
No. of grains per panicle	153	100	134
Panicle length (cm)	32.5	25.4	31
Maturity days	100	112	114
1000 grain weight (g)	21.5	20.3	21.8
Paddy yield (t/ha)	4.3	3.75	4.03

Table 1a: Description of agronomic traits of *Punjab Basmati* in comparison with already existing famous commercial varieties.

Punjab Basmati was tested in observational plot during 2008 (table not included). The results show that the new candidate variety, *Punjab Basmati* gave significantly ($p \leq 0.05$) higher paddy yield (11%) than *Super Basmati* in observational plots (OPs). Varietal trials were conducted at Rice Research Institute, Kala Shah Kaku from 2011 to 2013 to assess the yield performance of new candidate line on station.

The results showed that the new variety, *Punjab Basmati* gave significantly ($p \leq 0.05$) higher paddy yield (10% on the average of 3 years) than *Basmati 515* in station yield trials. The new variety *Punjab Basmati* along with *Basmati 515* was tested in thirteen Micro Plot Yield Trial/Regional Adaptability Yield trials (Figure 1). The maximum yield was obtained at Gujranwala.

Characters	Varieties		
	<i>Punjab Basmati</i>	<i>Super Basmati</i>	<i>Basmati 515</i>
Paddy (before milling)			
Av. Length (mm)	11.4	10.74	10.75
Av. Width (mm)	1.83	1.86	1.89
Av. Thickness (mm)	1.97	1.68	1.72
Rice kernel (after milling)			
Av. Length (mm)	7.76	7.27	7.56
Av. Width (mm)	1.4	1.59	1.66
Av. Thickness (mm)	1.26	1.46	1.54
Av. Length/Width ratio	5.54	4.57	4.44
Boiled kernel length (mm)	14.2	14.3	14.8
Elongation ratio	1.83	1.94	1.95
Shape	Slender	Slender	Slender
Milling results			
Husk %	19	20	20
Bran %	8	9	7.75
Total recovery %	73	71	72.25
Head rice %	58	54	53.5
Broken %	15	19.5	18.75
Amylose content %	24.8	23.8	23.45
Protein %	8	8.2	8.2
Alkali spreading value	5.5	4.5	4.5
Gel consistency (mm)	62	65	68

Table 1b: Description of milling, quality and physico-chemical traits of *Punjab Basmati* compared with existing famous commercial varieties.

Name of trial	No. of Trials	Paddy Yield (t/ha)			Yield advantage over checks
		<i>Punjab Basmati</i>	<i>Super Basmati</i>	<i>Basmati 515</i>	
Station yield trials	3	4.29 ± 0.34	3.91 ± 0.27	4.34 ± 0.45	+10% (<i>Super Basmati</i>)
Micro plot yield trials	13	4.34 ± 0.27	--	3.61 ± 0.34	+20% (<i>Basmati 515</i>)
National uniform rice yield trials	16	3.95 ± 0.36	3.59 ± 0.28	3.68 ± 0.28	+10% (<i>Super Basmati</i>)
					+7% (<i>Basmati 515</i>)
Transplanting date trials	8	4.61 ± 0.41	--	4.49 ± 0.53	+3% (<i>Basmati 515</i>)
	40	4.30 ± 0.48	3.75 ± 0.21	4.03 ± 0.37	+15% (<i>Super Basmati</i>)
					+7% (<i>Basmati 515</i>)

Table 2: Comparison of *Punjab Basmati* with all existing commercial varieties in all trials on average basis (Mean ± S.E.). Note: Sign (-) shows the variety was not used as check for that trial.

The results indicated that the *Punjab Basmati* gave significantly ($p \leq 0.05$) higher paddy yield (20% on the average of two years) than *Basmati 515* in regional adaptability yield trials (micro plots). The new candidate variety *Punjab Basmati* along with *Super Basmati* and *Basmati 515* was tested in sixteen locations with different agro-climatic conditions under National Uniform Rice Yield Trial (NURYT) trials in

two years (Figure 2). The yield data indicates that the paddy yield advantage of *Punjab Basmati* was 10% and 7% over check varieties *Super Basmati* and *Basmati 515*, respectively (Table 2) in National Uniform Rice Yield Trials (NURYT) conducted during both the years 2013 and 2014.

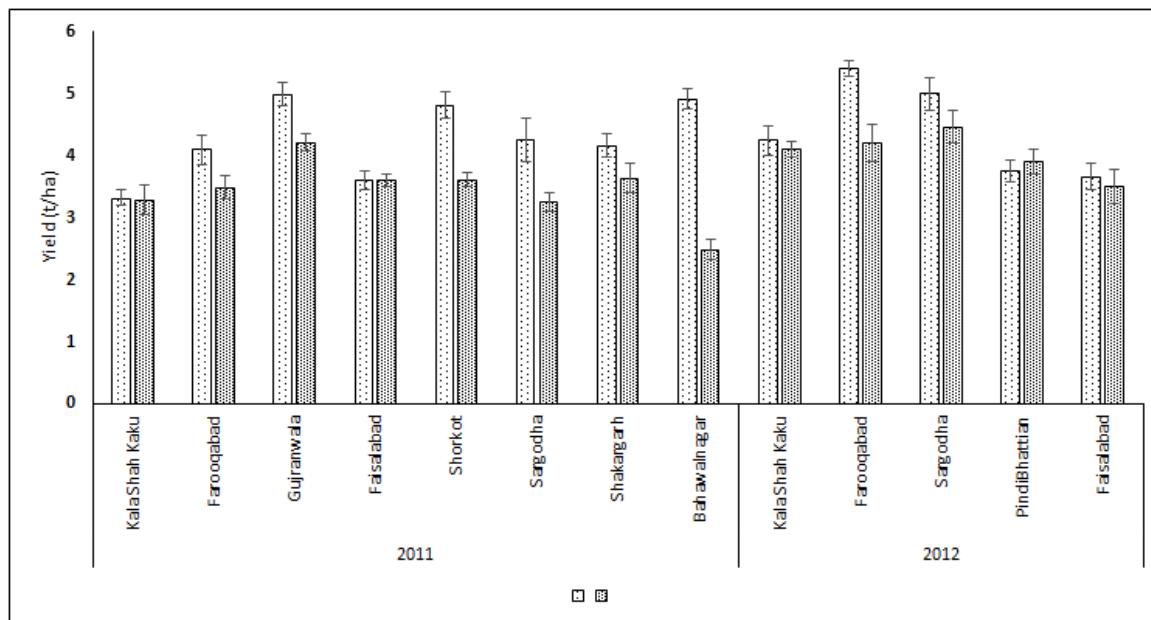


Figure 1: Comparison of Punjab Basmati and Basmati 515 in Adaptability Yield Trials at different locations for two years.

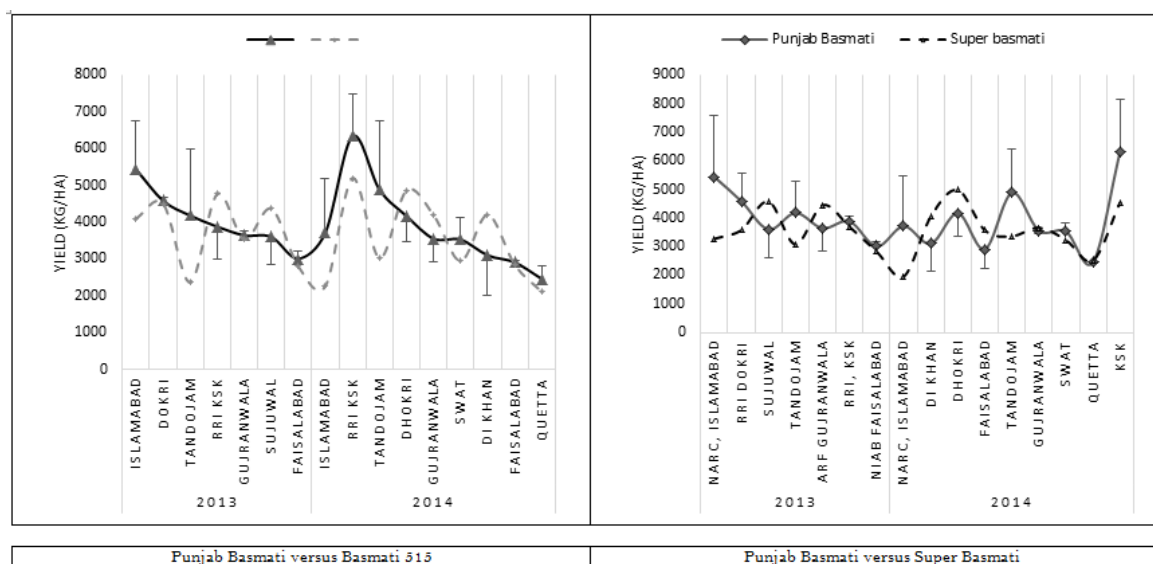


Figure 2: Comparison of performance of Punjab Basmati with local existing check varieties i.e. Super Basmati and Basmati-515 in National adaptability yield trials for two consecutive years 2013 and 2014. Error bars shows the increase or decrease in yield (kg per hectares) as compared with respective checks in each location.

The new variety *Punjab Basmati* along with *Basmati 515* was tested in thirteen Micro Plot Yield Trial/Regional Adaptability Yield trials

(Figure 1). The maximum yield was obtained at Gujranwala. The results indicated that the *Punjab Basmati* gave significantly ($p \leq 0.05$)

higher paddy yield (20% on the average of two years) than *Basmati 515* in regional adaptability yield trials (micro plots).

The new candidate variety *Punjab Basmati* along with *Super Basmati* and *Basmati 515* was tested in sixteen locations with different agro-climatic conditions under National Uniform Rice Yield Trial (NURYT) trials in two years (Figure 2). The yield data indicates that the paddy yield advantage of *Punjab Basmati* was 10% and 7% over check varieties *Super Basmati* and *Basmati 515*, respectively (Table 2) in National Uniform Rice Yield Trials (NURYT) conducted during both the years 2013 and 2014.

Yield data of transplanting trials on *Punjab Basmati* and *Super Basmati* conducted at Rice Research Institute, Kala Shah Kaku during 2012 and 2013 given in Table 3. It is quite clear from the data that on average of two years, yield performance of *Punjab Basmati* was better for 30th June and 20th July transplanting dates. Therefore, it is obvious

that optimum time for transplanting rice nurseries of *Punjab Basmati* ranges from 1st to 20th July. However, *Punjab Basmati* also gave better yield when translated late. Fertilizer trial on *Punjab Basmati* was conducted at Rice Research Institute, Kala Shah Kaku during 2013. The average paddy yield with different doses of fertilizer is given in Table 4.

The results given in Table 4, depicted that fertilizer treatment 133-85-62 kg/ha is economical. Pest population was recorded at Rice Research Institute, Kala Shah Kaku under non-sprayed conditions for three years i.e., 2011, 2012 and 2013. Pest population data recorded showed that *Punjab Basmati* was moderately resistant to Stem Borer while moderately susceptible to Leaf folder. *Super Basmati* and *Punjab Basmati* were tested during 2011, 2012 and 2013 against paddy blast, bacterial leaf blight and stem rot at Rice Research Institute, Kala Shah Kaku.

Year/Variety	Transplanting dates/Paddy yield (t/ha)				
	1st June	30th June	20th July	5th August	Average
2011					
<i>Punjab Basmati</i>	3.23	3.74	4.53	3.65	3.79
<i>Basmati 515</i>	3.11	3.52	4.21	3.26	3.53
LSD value for varieties comparisons (p ≤ 0.05) = 0.18					
2012					
<i>Punjab Basmati</i>	3.26	3.86	4.69	3.76	3.89
<i>Basmati 515</i>	3.27	3.73	4.77	3.54	3.83
LSD value for varieties comparisons (p ≤ 0.05) = 0.14					
Average of 2 years					
<i>Punjab Basmati</i>	3.25	3.8	4.61	3.71	3.84
<i>Basmati 515</i>	3.19	3.63	4.49	3.4	3.68

Table 3: Comparison of Punjab Basmati with existing commercial variety Basmati 515 in sowing date trials conducted at RRI.

Treatment NPK (kg/ha)	Paddy yield (t/ha)
00-00-00	2.82 c
110-85-62	3.76 b
133-85-62	4.51 a
156-85-62	4.67 a
179-85-62	4.71 a

Table 4: Comparing suitable dose of NPK fertilizer for Punjab Basmati. *Treatments with different letters differ significantly at 0.05 probability (p≤0.05).

Punjab Basmati along with other commercial varieties such as *Super Basmati* and *Basmati 515* were also tested during 2011 and 2012 against bacterial leaf blight, paddy blast and Stem rot by National Agriculture Research Center, Islamabad. Results obtained in these

trials showed that the new candidate variety *Punjab Basmati* was susceptible to bacterial leaf blight, moderately susceptible to paddy blast and moderately resistant to stem rot whereas *Super Basmati* was susceptible to bacterial leaf blight, highly susceptible to paddy blast and moderately susceptible to stem rot.

Conclusion

The newly evolved basmati/aromatic rice variety, *Punjab Basmati* gave 15% and 7% higher paddy yield in all the in-station and out-station yield trials, on the average basis, than local existing basmati *Super Basmati* and *Basmati 515*, respectively as checks. In physico-chemical tests conducted at RRI KSK head rice recovery and rice kernel length were found better than *Super Basmati*. It is two weeks earlier than both check varieties. Being short stature and stiffed stem, it is resistant to lodging. It is very clear that the candidate line has a yield advantage of 15% and 7% over check varieties i.e., *Super Basmati* and *Basmati 515*, respectively. Among grain quality attributes, its head rice recovery (58%) and grain length (7.76 mm) were found better than

both checks. The variety exhibited adequate potential to be used as cultivar for yield augmentation and income returns.

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