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Pyramid Breeding Strategy for Integration of Multiple Traits for High Yield, Earliness, Short Stature and extra-Long Grain to Evolve a New Variety

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ABSTRACT

Multiple trait integration (MTI)is a multi-step process involving introgression of genes for some value-added traits (e.g. yield, earliness, shirt stature, cooking quality traits and resistance to insect pests and diseases)into one line throughtrait pyramiding. From a breeding standpoint, MTI involves parallelmultiple crosses, genes introgression, trait pyramiding, fixation, and testing. Along with high yield and excellent cooking, traits such as early maturing for timely harvesting for wheat sowing and short stature to reduce losses due to lodging are also very important in case of rice. Therefore, a variety "Kissan Basmati" was developed at Rice Research Institute, Kala Shah Kaku in Punjab-Pakistan by pyramiding these traits for successful implementation of MIT and integration of useful morphological and physiological characters into same line. It was evolved by hybridizing PS-2 having traits for high yield and excellent cooking quality with another uniform line 99417 (PK9505) having pyramided stable genes for earliness, short stature and extra-long grain length. The resultant F1 was backcrossed with recurrent parent 99417 (PK9505) to make BC1F1. Afterwards pedigree method of selection was continued upto BC1F4 generation from 2007 to 2010 until reached genetic stability. It is high yielding, stiff stemmed, short stature and extra-long grain rice variety which is suitable for parboiled and steam rice. Kissan Basmati is two weeks earlier than other cultivated varieties, hence requires less water due to the shorter life cycle. The new variety, Kissan Basmati gave 9.3%, 15% and 3.8% higher paddy yield than commercial variety Super Basmati, Basmati 515 and PS-2, respectively on the basis of its yield performance in observational plot, station yield trials, regional adaptability yield trials and national uniform rice yield trials (NURYT). The quality characteristics like grain length, head rice recovery and cooked grain length of Kissan Basmati are also better than Super Basmati, Basmati 515 and PS 2.

Keywords: *Rice, trait pyramiding, extra-long rice varieties, parboiled and steam rice, early maturing, water use efficiency*

INTRODUCTION

Farmers in Pakistan need high yielding and extra-long grain Basmati rice variety having excellent grain shape traits and cooking quality good enough to fetch reasonable price in international market. Along with high yield and excellent cooking, traits such as early maturing for timely harvesting for wheat sowing and short stature to reduce losses due to lodging are also very important. The United Nations General Assembly (UNGA) declared the year 2004 as International Year of Rice (IYR) with the slogan 'Rice is life', highlighting the prime importance of rice in human dietary needs. Rice holds top position in daily dietary intakes. It accounts for 715 kilo calories per capita per day, involving 27%, 20% and 3% of the energy, protein and fat supply respectively in developing countries (FAO, 2004). For more than 10,000 years, rice (also known as paddy) has been gathered, cultivated and consumed worldwide (Kenmore, 2003), serving as staple food grain crop for more than half of the world's population (Khush et al., 2004).In Pakistan, rice is the second most consumed grain crop after wheat and largest foreign exchange earning agricultural commodity. Incessant progress in rice breeding has facilitated Pakistan to fulfill the increasing local and international supply demands.

Rice is grown in all provinces of Pakistan, but only Punjab province is famous for top quality Basmati rice production. Rice growers generally follow Rice – Wheat cropping system in this area (Hussain et al., 2012). The popular Basmati

rice varieties among rice growers are Super Basmati and Basmati 515. These Basmati varieties are late maturing and affect the sowing date of wheat crop (Akhtar et al., 2014). Now the farmers of traditional rice area are demanding an early maturing, stiff stemmed and high yielding Basmati rice variety having good grain quality, moderately resistant to different diseases and to avoid monoculture. Furthermore, most of the paddy produced in southern Punjab (comprising Okara, Kasur, Bahwalnagar, Pakpattan and Sahiwal districts) is processed for makingparboiled and steam rice. Parboiling of paddy results in higher milling recovery, translucent kernels, greater nutritional status, easy hulling, and resistance to insect attack during storage, higher bran oil with stability and easy digestibility with higher protein efficiency ratio (Roseline et al., 2010; Ayamdoo et al., 2013). For these reasons, the demand for parboiled rice is also increasing in local as well as international markets.

Basmati varieties are lower yielding and susceptible to different biotic and abiotic factors when compared to non-basmati varieties (Verma et al., 2017). During 1920's, the basmati rice improvement programme was initiated at Rice Research Institute Kala Shah Kaku, Pakistan (Ahmad et al., 2005) and new basmati varietiesretaining higher yield potential, betterquality parameters and resistance to different biotic and abiotic factors were long awaited. The earlier efforts had partialaccomplishments due to lack of facilities for grain quality assessment. The varieties developed through selections and breeding were good for quality parameters but were lower yielding and susceptible to diseases, insects and lodging (Inayatullah et al., 1986; Shobha, 2009). The main hurdle in Basmati improvement programme lies in pooling of aroma and grain quality parameters with acceptable agronomic features (Khush and Juliano, 1991). 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 (Akhtar et al., 2014 & 2015). 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 (Khan and Khan, 2010; Jafar et al., 2015). Furthermore, the farmers of traditional rice area are demanding early maturing, high yielding and lodging resistant basmati rice varieties with good grain quality and resistance to different diseases. Keeping this scenario in view, scientists at Rice Research Institute, Kala Shah Kaku put their efforts underway to develop an early maturing, stiff stemmed, extra-long grain and high yielding rice variety 'Kissan Basmati' that is also suitable for parboiled and steam rice.

Material And Methods

The new basmati variety"Kissan Basmati" was evolved at Rice Research Institute, Kala Shah Kaku in Punjab-Pakistan by pyramiding some useful traits including high yield, earliness, short stature, extra-long grain, resistance towards harmful insect pests and disease along with successful integration of useful morphological and physiological characters into a same line. It was evolved by hybridizing PS-2 having traits for high yield and excellent cooking quality with another uniform line 99417 (PK9505) having pyramided stable genes for earliness, short stature and extra-long grain length. The resultant F1 was backcrossed with recurrent parent 99417 (PK9505) to make BC1F1. Afterwards pedigree method of selection was continued upto BC1F4 generation from 2007 to 2010 until reached genetic stability. The newly developed line was tested in observational plots in 2011 along with two commercial check varieties Super Basmati and PS 2. Kissan Basmati was also evaluated in fine grain yield trials and regional adaptability trials from 2012 to 2015.

To ascertain the best transplanting date, the variety waspassed through transplanting date trials for two consecutive years from 2014-2015. Likewise, to find the best ratio of N-P-K application, a trialswere conducted during 2012-13. To measure the susceptibility andresistance of the variety against diseases (bacterial leafblight, paddy blast, brown leaf spot and stem rot) and insect pests (stem borer and leaf folder) trialswere also conducted along with super basmati and PS 2checks.

Data of agronomic traits (yield, maturity days, height, tillers, grain shapelength, 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 %), nutritionalparameters (amylose contents, alkali spread value and aroma) were alsomeasured during all the trials to evaluate the consistency and uniformity ofthese traits in the

successive generations. Quality index was calculated toevaluate and compare the ultimate quality of the newly evolved variety withthat of the existing varieties of rice as checks.

Results And Discussion

Characteristic Features

Kissan Basmati is a semi dwarf aromatic rice variety which attainsan average plant height of 98 cm. It has fully green erect leaves and stiff stem. It is sensitive to photoperiod and matures in about 94 days after seeding. On an average, it bears 16 productive tillers per plant, 105 grains per panicle, 1000

grain weight of 26.8 g and paddy yield of 4.01 t/ha. The salient morphological characteristics of Kissan Basmati in comparison with Super Basmati and PS 2 are listed in Table 1.

Table1. *Salient characteristics of Kissan Basmati in comparison with commercial checks*

Characteristics	Kissan Basmati	Super Basmati	PS 2
Plant height (cm)	98	128	114
Leaf colour	Green	Green	Green
Leaf angle	Erect	Semi erect	Semi erect
Stem stiffness	Stiff	Weak	Stiff
No. of productive tillers	16	20	15
No. of grains per panicle	105	84	73
Panicle length (cm)	28	25.4	28.2
Maturity days	94	116	116
1000 grain weight (g)	26.8	20.8	28.5
Paddy yield (t/ha)	4.01	3.47	3.95

Yield Performance

Kissan Basmati has been tested in 31 research and adaptability trials across various locations of the Punjab and shown an eminent gain in genetic yield over standard check varieties. Based on average performance, Kissan Basmati gave paddy yield of 4.01 t/ha and it out yielded the Super Basmati (3.47 t/ha) by 9.3%, PS 2 (3.95 t/ha) by 6% and Basmati 515 (4.00 t/ha) by 15%. Summary of these trials is given in Table 2. The new variety was also tested in national uniform rice yield trails (NURYT) for two consecutive years, it gave paddy yield of 3792 Kg/ha and out yielded the Basmati 515 (3185 Kg/ha) by 15%, PS 2 (3577 Kg/ha) by 6% and Super Basmati (3773 Kg/ha) by 1%. Results of individual trials are shown in table 3-5.

Table2. *Summary of yield performance in different trials as compared with checks*

Name of trial	No. of Trials	Paddy Yield (t/ha)				Percent increase over check varieties
		Kissan Basmati	Super Basmati	PS 2	Basmati 515	
Observational Plots	1	3.95	3.52	3.84	-	+12% (Super Basmati) +3% (PS 2)
Station yield trials	3	3.82	3.39	-	-	+13% (Super Basmati)
Micro plot yield trials	12	3.56	3.21	-	-	+11% (Super Basmati)
National uniform yield trials	13	3.79	3.77	3.57	3.19	+1% (Super Basmati) +6% (PS 2) +19% (Basmati 515)
Sowing date trials	2	4.91	-	4.43	4.80	+2% (PS 2) +11% (Basmati 515)
Average	**31**	**4.01**	**3.47**	**3.95**	**4.00**	**+9.6% (Super Basmati) +3.66% (PS 2) +15% (Basmati 515)**

Table 3.*Results of 12 regional adaptability yield trials conducted at various locations across Punjab during 2014 and 2015.*

Year	Location	Varieties / Paddy yield (t/ha)	
		Kissan Basmati	Super Basmati
2014	Kala Shah Kaku	+3.14 a	2.80 bc
	Farooqabad	-3.49 ab	3.55 a

	Gujranwala	+3.11 ab	2.99 c
	Faisalabad	+3.20 ab	3.16 ab
	Sargodha	+3.22 a	3.15 a
	Shakargarh	+3.45 a	3.28 bc
	Bahawalnagar	+2.98 bc	2.72 d
	Average	+3.23 a	2.70 c
2015	Kala Shah Kaku	+3.75 ab	3.54 bc
	Farooqabad	-4.27 bc	4.53 ab
	Sargodha	+4.26 a	4.23 a
	Pindi Bhattian	+4.05 a	3.61 cd
	Faisalabad	+3.12 b	2.71 d
	Average	+3.89 a	3.72 c
Average of two years		+3.56	3.21
% increase over Super Basmati		+11%	-

different letters are shows significantly different values at 5% probability level ($p \leq 0.05$)

Table4. *Results of 13 national uniform rice yield trials conducted across various locations of Punjab during 2014 and 2015.*

Year	**Location**	**Varieties / Paddy yield (Kg/ha)**			
		Kissan Basmati	**Super Basmati**	**Basmati 515**	**PS 2**
2014	Kala Shah Kaku	-3662 e	4545	5189	-
	Swat	+6174 b	3230	2948	-
	Faisalabad	+3096 c	3570	2844	-
	Islamabad	+2763 bcde	3167	2263	-
	Gujranwala	+3663 de	3660	4190	-
	Tandojam	+3703 cd	3363	-	-
	Dokri	+5556 a	4877	4861	-
	Average	**+4088**	**3773**	**3185**	-
2015	Thatta	+4281	-	-	3652
	Swat	+1428			668
	Faisalabad	-4310			5328
	Tandojam	-3327			4553
	Quetta	+3900	-	-	3810
	RRI, KSK	+3735	-	-	3456
	Average	**-3496**			**3577**
Two years average		**+3792**	**3773**	**3185**	**3577**
%increase over checks		+1% (Super Basmati), +19% (Basmati 515) +6% (PS 2)			

different letters are shows significantly different values at 5% probability level ($p \leq 0.05$)

Table5. *Result of transplanting date trials conducted at Rice Research Institute, Kala Shah Kaku during 2014 and 2015.*

Year / Variety	**Transplanting dates / Paddy yield (t/ha)**				
	1/6	**23/6**	**14/7**	**5/8**	**Average**
2014					
Kissan Basmati	3.11d	3.40c	**4.60a**	4.49a	**3.90**
Basmati 515	3.88b	3.21c	**4.05b**	3.98b	**3.78**
LSD $_{var}$ ($p \leq 0.05$)	**0.19**				
2015					
Kissan Basmati	2.98g	3.67f	**5.21ab**	5.06b	**4.23**
PS 2	4.30d	3.93e	**4.80c**	4.71c	**4.44**
Basmati 515	**5.40a**	5.13b	4.10de	4.05e	**4.67**
LSD $_{var}$ ($p \leq 0.05$)	**0.25**				
Average of 2 years					
Kissan Basmati	3.05	3.54	**4.91**	4.78	**4.07**
Basmati 515	4.09	3.57	**4.43**	4.35	**4.11**

PS 2	4.30	3.93	**4.80**	4.71	**4.44**
% increase over Basmati 515					**+10.8**
% increase over PS 2					**+2.3**

Treatment means with different letters are significantly different at 5% probability level ($p \leq 0.05$)

It is quite clear from the data that on average of two years, Kissan Basmati gave highest yield 4.91 t/ha in transplanting date of 14th July whereas the lowest yield (3.05 t/ha) was obtained in transplanting date of 1st June. Therefore, it is obvious that the optimum time for transplanting nurseries of Kissan Basmati ranges from 10th July to 1st August.Fertilizer trial on Kissan Basmati was also conducted at Rice Research Institute, Kala Shah Kaku during 2013 to 2014. The average paddy yield with different doses of fertilizer is given in table 6. The result depicted that fertilizer treatment 156-85-62 kg/ha is economical in case of Kissan Basmati.

Table6. *Result of fertilizer doses trial conducted at Rice Research Institute, Kala Shah Kaku during 2014 and 2015.*

Treatment NPK(kg/ha)	Paddy yield (t/ha)
	2012-13
00-00-00	2.21 c
110-85-62	3.44 b
133-85-62	3.76 b
156-85-62	4.12 a
179-85-62	4.24 a

Treatments with different letters are significantly different at 0.05 probability (LSD=0.34)

Disease and Insect Pest Resistance

During station yield trials conducted at RRI, KSK Kissan Basmati was found moderately resistant to leaffolders, while resistant to stem borers attacks. Whereas, all commercial check varieties tested were moderately resistant to these insect pests (Table 7). Furthermore, the new variety was found moderately resistant against bacterial leaf blight (BLB), paddy blast and brown leaf spot diseases but moderately susceptible against stem rot. Whereas, check varieties were moderately susceptible or susceptible against these diseases. Almost similar results were reported by national agricultural research center (NARC), Islamabad for disease resistance (Table 8).

Table7. *Results of insect pest and disease resistance trails conducted at RRI, KSK.*

Name of insect pest or disease	**Varieties**		
	Kissan Basmati	**Super Basmati**	**PS 2**
Stem borer	R	MR	MR
Leaffolder	MR	MR	MR
2013			
Bacterial leaf blight (BLB)	MR	MS	MS
Paddy Blast	MR	MS	MS
Stem rot	MS	S	MS
Brown Leaf Spot (BLS)	MR	MS	MS
2014			
Bacterial leaf blight (BLB)	MR	MS	MS
Paddy Blast	MR	MS	MS
Stem rot	MS	S	MS
Brown Leaf Spot (BLS)	MR	MS	MS

S = Susceptible, MS = Moderately Susceptible, MR=Moderately Resistant, R=Resistant

Table8.*Results of disease resistance trial conducted at NARC, Islamabad.*

Disease	**Varieties**		
	Kissan Basmati	**Super Basmati**	**PS 2**
Bacterial leaf blight (BLB)	MR	S	MR
Paddy Blast	R	HS	MR
Stem rot	R	MS	R

Brown Leaf Spot (BLS)	R	MS	R

HS = Highly Susceptible, S = Susceptible, MS = Moderately Susceptible,

MR = Moderately Resistant, R = Resistant

Grain Quality Traits

Grain quality characteristics of Kissan Basmati are listed in Table 10. It has 1000 grain weight of 26.8 g as compared to 20.8 g of Super Basmati. It has an average paddy length, width and thickness of 11.20 mm, 1.83 mm and 1.73 mm, respectively, as compared to 10.75 mm, 1.78 mm and 1.66 mm of Super Basmati. It possesses extra-long slender clear translucent grains with average length width ratio of 16.6. On an average, it has good cooking and eating qualities with strong aroma.

Table9. *Grain quality characteristics of Kissan Basmati as compared to checks.*

Characters	Varieties		
	Kissan Basmati	**Super Basmati**	**PS 2**
Paddy			
Av. Length (mm)	11.20	10.75	11.5
Av. Width (mm)	1.83	1.78	1.98
Av. Thickness (mm)	1.73	1.66	1.83
Rice kernel			
Av. Length (mm)	8.10	7.44	8.10
Av. Width (mm)	1.56	1.62	1.63
Av. Thickness (mm)	1.32	1.51	1.45
Av. Length/Width ratio	5.47	4.52	5.22
Boiled kernel length (mm)	16.6	14.6	16.5
Elongation ratio	2.05	1.96	2.04
Shape	Slender	Slender	Slender
Milling results			
Husk %	23	20	22
Bran %	7.0	9.0	8.9
Total recovery %	70.0	71.0	69.4
Head rice %	44.5	54.0	39.5
Broken %	25.5	19.5	29.9
Amylose content %	22.5	23.8	23.0
Alkali spreading value	6.7	4.5	6.8
Gel consistency (mm)	68.0	65.0	68.0
1000 grain weight (gm)	26.8	20.8	28.5

Table10. *Parboiled characteristic of Kissan Basmati in comparison with check PS 2*

Parboiled Rice	Kissan Basmati	PS 2
Rice kernel		
Av. Length (mm)	8.20	8.20
Av. Width (mm)	1.56	1.63
Av. Thickness (mm)	1.31	1.43
Av. Length/Width ratio	5.26	5.03
Boiled kernel length (mm)	17.0	17.12
Elongation ratio	2.07	2.09
Shape	Slender	Slender
Milling results		
Husk %	20.5	20.0
Bran %	10.0	9.8
Total recovery %	69.5	70.2
Head rice %	62.5	62.6
Broken %	7.0	7.6

Conclusion

The results predicted the phenomenon of trait pyramiding using distant parents having multiple traits can be utilized by intercrossing to introgress useful traits into one line. The newly developed variety possessing all traits declares that it is a very useful tool to evolve

new rice varieties having multiple desirable traits. The newly evolved Basmati variety i.e. Kissan Basmati was found high yielding, stiff stemmed, early, short stature and extra-long grain rice variety which was also found suitable for parboiled and steaming. Kissan Basmati was two weeks earlier than other cultivated varieties, hence requires less water due to the shorter life cycle. It gave 9.3%, 15% and 3.8% higher paddy yield than commercial variety Super Basmati, Basmati 515 and PS-2, respectively on the basis of its yield performance in observational plot, station yield trials, regional adaptability yield trials and national uniform rice yield trials (NURYT). The quality characteristics like grain length, head rice recovery and cooked grain length of Kissan Basmati were also found better than Super Basmati, Basmati 515 and PS 2.

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