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Development Strategies of a New Long Grain, Early Maturing And High Yielding Rice Variety Suitable for Flood-Prone Areas

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ABSTRACT

High-yielding and quality grain rice varieties with submergence tolerance has now become foremost objective of rice breeding research world-wide after loss of thousands of acres due to frequent floods for last five years. New flood tolerant, fertilizer-responsive, high yielding varieties can rise income of poor farmers in the face of considerable rise in floods and world population. To cope with this situation, a new improved high yielding, extra-long grain variety also suitable for flood-prone areas of Pakistan was developed. The variety named as Chenab Basmati was bred by hybridizing line 98PP4 with line 4439 during 1998-99. The pedigree method of selection continued up to seventh filial generation at Rice Research Institute Kala Shah Kaku, Pakistan. The selection was accompanied with marker assisted selection in MAS lab; whereas phenotypic field screening in submergence tank constructed at RRI KSK. It was tested in fine grain yield trials and regional adaptability trials to compare this improved candidate variety with Super Basmati and Basmati 515 as checks. The overall average yield of Chenab Basmati in all the in-station and out-station yield trials was 4.52 t/ha in comparison with 3.65 t/ha of Super Basmati and 3.90 t/ha of Basmati 515. It was observed that the advanced line showed a yield advantage of 24% and 16% over check varieties i.e., Super Basmati and Basmati 515, respectively. Among grain quality attributes, its head rice recovery (58%) and grain length (7.61mm) were found better than checks. Chenab Basmati showed tolerance index of more than 0.9 during both the years indicating its potential to be used as flood tolerant variety.

Keywords: Oryza sativa; rice variety; high yielding, flood tolerant, early maturing, extra-long grain

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INTRODUCTION

Rice (*Oryza sativa* L.) is critical for human nourishment because it serves as basic food for more than two billion people (~ 60% of the world population). It provides more calories than any other food crop (Khush, 2005). 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 (Economic survey of Pakistan, 2016-17). 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 (Memon, 2013). Pakistan holds 5th position among top ten rice exporting countries. Out of 6.850 million metric tons produced during 2016-17 (P), 4.20 million metric tons were exported earning valuable foreign exchange of US\$ 1.860 billion (Rice exports by countries by Daniel Workman, April 13, 2017).

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. 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 (Ghasa *et al.*,

2015). 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, Sheikhpura 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 (Abedullah *et al.*, 2007). 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, colour, shape, size and texture (Khan and Khan, 2010).

The traditional basmati cultivars are susceptible to lodging, diseases, photoperiod, temperature and are lower yielding when compared to non-basmati cultivars (Verma *et al.*, 2017). During 1920's, the basmati rice improvement programme was initiated at Rice Research Institute Kala Shah Kaku (RRI KSK), Pakistan (Ahmad *et al.*, 2005). 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, insects and had lower yielding potential (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 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 "Chenab Basmati".

MATERIAL AND METHODS:

Chenab Basmati has been evolved by crossing line 98PP4 with line 4439 as a donor of trait for submergence tolerance during the year 1998. Line 98PP4 is a high yielding with long grain and good quality characters, whereas line 4439 is also high yielding, early and short stature and possessed the character of submergence tolerance under flooded condition. The pedigree method of selection continued up to F₇ generation with the pedigree No. PK8431-1-2-1-2-4. It was tested in observational plot during 2010, fine grain yield trials and regional adaptability trials at various locations of Punjab, Pakistan from 2011 to 2015. This new candidate variety Chenab Basmati along with Super Basmati and Basmati 515 was tested in 13 trials under two national uniform rice yield trials during 2013 and 2014. During two years, 2014 and 2015, the line was also tested in artificial submergence tank constructed at research area of RRI KSK for submergence stress of about 14 days following protocol developed by International Rice Research Institute, Philippines.

To ascertain the best transplanting date, the variety was passed through transplanting date trials for two consecutive years from 2014-2015. Likewise, to find the best ratio of N-P-K application, a trial was conducted during 2013. To measure the susceptibility and resistance of the variety against diseases (bakanae/ foot rot, bacterial leafblight, 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 recovery %, 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.

Field screening for submergence / flood tolerance:

One hundred and fifteen (115) rice genotypes including Chenab Basmati, six (06) local cultivars/ released varieties and three high yielding varieties i.e. Sabitri, IR6 and NSICRC222 being used as potential variety in many countries of Asia, were used as experimental material. All these genotypes were evaluated in a natural water pond that allows maintenance of water depth of 150 cm for a period of 15 days. The experiment was laid out in a triplicated randomized complete block design (RCBD). Seeds were sown on the wet raised beds and 21 days seedlings were transplanted to well puddle soil in the deep pond/ submergence tank at 20cm x 20cm with two seedlings per hill. Plot size was maintained in two rows of 5m² length for each entry. Non-experimental lines of Super Basmati were also planted on each side of the pond to observe the damages due to submergence. Nitrogen fertilizer was applied at 30:30:30kg/ha as basal dose a day before starting transplanting. Gap-filling was also practice as required 7 days after transplanting (DAT) in order to ensure 100% plant establishment. Plants were counted before applying submergence stress. The transplanted seedlings were allowed to establish their roots

for 20 DAT before submergence. The pond was filled with normal canal water up to depth level of 1500 cm so that all the plants of all the entries were completely submerged within a day. The same water depth was maintained for the period of 14 days by adding water regularly. After completing 14 days of complete submergence, the treatment was terminated. The water was drained out of pond to water level of 1-2 cm. After a day, the water was again filled up to a level of 5cm. Second split of nitrogen fertilizer was applied at the rate of 30 kg/ha after 10 days and the third split of 30 kg/ha was applied after 20 days of second split. All the following agronomic and plant protection measures were adopted as normal in order to allow the plant to recover from submergence stress.

Thirty-three (33) trials were conducted to compare new variety, Chenab Basmati with Super Basmati and Basmati 515. The overall average yield of Chenab Basmati was 4.52 t/ha against 3.65 t/ha of Super Basmati and 3.90 t/ha of Basmati 515. Results of fine grain yield trial, adaptability trials and National Uniform Rice Yield trials clearly showed the superior yield performance of Chenab basmati variety over checks i.e. Super Basmati and Basmati-515. Chenab Basmati has a yield advantage of 24% and 16% over standard check varieties i.e., Super Basmati and Basmati 515, respectively (Table 1). Chenab basmati is also moderately resistant to stem rot and paddy blast diseases (Table 2) while Super Basmati and Basmati-385 are highly susceptible to these diseases.

RESULTS AND DISCUSSION:

Table 1: Description of Basmati 515 in comparison with existing commercial variety Super Basmati.

Characters	Name of variety		
	Chenab Basmati	Super Basmati	Basmati 515
Paddy			
Paddy Length (mm)	11.25	10.75	10.78
Paddy Width (mm)	1.82	1.78	1.85
Paddy Thickness (mm)	1.56	1.66	1.72
Rice kernel			
kernel Length (mm)	7.61	7.44	7.56
kernel Width (mm)	1.53	1.62	1.44
kernel Thickness (mm)	1.45	1.51	1.28
Head rice %	58.0	54.0	53.5
Amylose content %	22.2	23.80	23.45
Plant height (cm)	122	125	132
No. of grains per panicle	158	88	131
1000 grain weight (gm)	21.04	20.81	20.13
Maturity days	107	113	114
Paddy yield (t/ha)	4.52	3.39	3.90

Table 2: Comparison of Basmati 515 with existing commercial variety Super Basmati in all trials on average basis

Name of trial	No. of Trials	Paddy Yield (t/ha)			Yield advantage over	
		Chenab Basmati	Super Basmati	Basmati 515	Super Basmati	Basmati 515
Varietal yield trials	3	4.91	-	4.27	-	+14.9%
Micro plot yield trials	9	4.41	-	3.83	-	+15.0%
Regional Adaptability Trials (NURYT)	13	4.53	3.65	3.74	+24.0%	+21.1%
Sowing date trials	8	4.22	-	3.76	-	+12.3%
Total	33	4.52	3.65	3.90	+24%	16%

Note: Sign (-) shows the variety was not used as check for that trial

Chenab Basmati was tested in observational plot during 2010. The table shows that the new candidate variety, Chenab Basmati gave significantly higher paddy yield (6.24 %) 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, Chenab Basmati gave significantly higher paddy yield (14.9 % on the average of 3 years) than Basmati 515 in station yield trials.

The new variety Chenab Basmati along with Basmati 515 was tested in nine (9) Micro Plot Yield Trial / Regional Adaptability Yield trials (graph 1). The maximum yield was obtained at Kala Shah Kaku. The results indicate that the Chenab Basmati gave significantly higher paddy yield (15 % on the average of two years) than Basmati 515 in micro plot yield trials. The new candidate variety Chenab Basmati along with Super Basmati and Basmati 515 was tested in 13 locations under National Uniform Rice Yield Trial (NURYT) trials in two years (graph 2). The yield data indicates that the paddy yield advantage of Chenab Basmati was 24% and 21% over check varieties Super Basmati and Basmati 515, respectively in National Uniform Rice Yield Trials (NURYT) conducted during both the years.

Yield data of transplanting trials on Chenab Basmati and Super Basmati conducted at Rice Research Institute, Kala Shah Kaku during 2014 & 2015 given in table 3. It is quite clear from the data that on average of two years, yield performance of Chenab Basmati was better for 30th June and 20th July transplanting dates. Therefore, it is obvious that optimum time for transplanting rice nurseries of Chenab Basmati ranges from 1st to 20th July. Fertilizer trial on Chenab 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 above result depicted that fertilizer treatment 133-85-62kg/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 Chenab Basmati was moderately resistant to Stem Borer while moderately susceptible to Leafhopper. Super Basmati and Chenab Basmati were tested during 2011, 2012 and 2013 against paddy blast, bacterial leaf blight and stem rot at Rice Research Institute, Kala Shah Kaku.

Results showed that the new candidate variety Chenab Basmati was moderately susceptible to Bacterial Leaf Blight (BLB), Paddy Blast and

Stem rot whereas Super Basmati was susceptible to all the studied diseases. Chenab Basmati and Super Basmati were tested during 2011 and 2012 against Bacterial Leaf Blight, Paddy Blast and Stem rot by National Agriculture Research Center, Islamabad.

Results showed that the new candidate variety Chenab 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

Table 3: Comparison of Basmati 515 with existing commercial variety Super Basmati in sowing date trials conducted at RRI, KSK during 2006-2009.

Year / Variety	Transplanting dates / paddy yield (t/ha)				Average
	1/6	30/6	20/7	6/8	
2014					
Chenab Basmati	3.26	5.40	5.53	3.26	4.36 A
Basmati 515	2.88	3.21	4.05	3.98	3.53C
<i>LSD_{VAR} (0.05)</i>	0.44				
2015					
Chenab Basmati	3.70	4.44	5.77	3.42	4.33 A
Basmati 515	3.41	4.27	5.50	3.36	4.14 B
<i>LSD_{VAR} (0.05)</i>	0.13				
Average of two years					
Chenab Basmati	3.48	4.92	5.65	3.34	4.34
Basmati 515	3.15	3.74	4.78	3.67	3.83
Yield advantage of Chenab Basmati over Basmati 515					+12

Table 4: Comparing suitable dose of NPK fertilizer for Chenab Basmati

Treatment NPK (kg/ha)	Paddy yield (t/ha)
00-00-00	2.831 c
110-85-62	3.336 b
133-85-62	3.992 a
156-85-62	4.107 a
179-85-62	4.118 a

**Treatments with different letters differ significantly at 0.05 probability*

Paddy Blast and moderately susceptible to stem rot.

Field screening for submergence / flood tolerance:

The obtained results clearly indicated that all the genotypes with submergence tolerant gene (SUB1) showed significantly greater tolerance level as compared to other local cultivars/

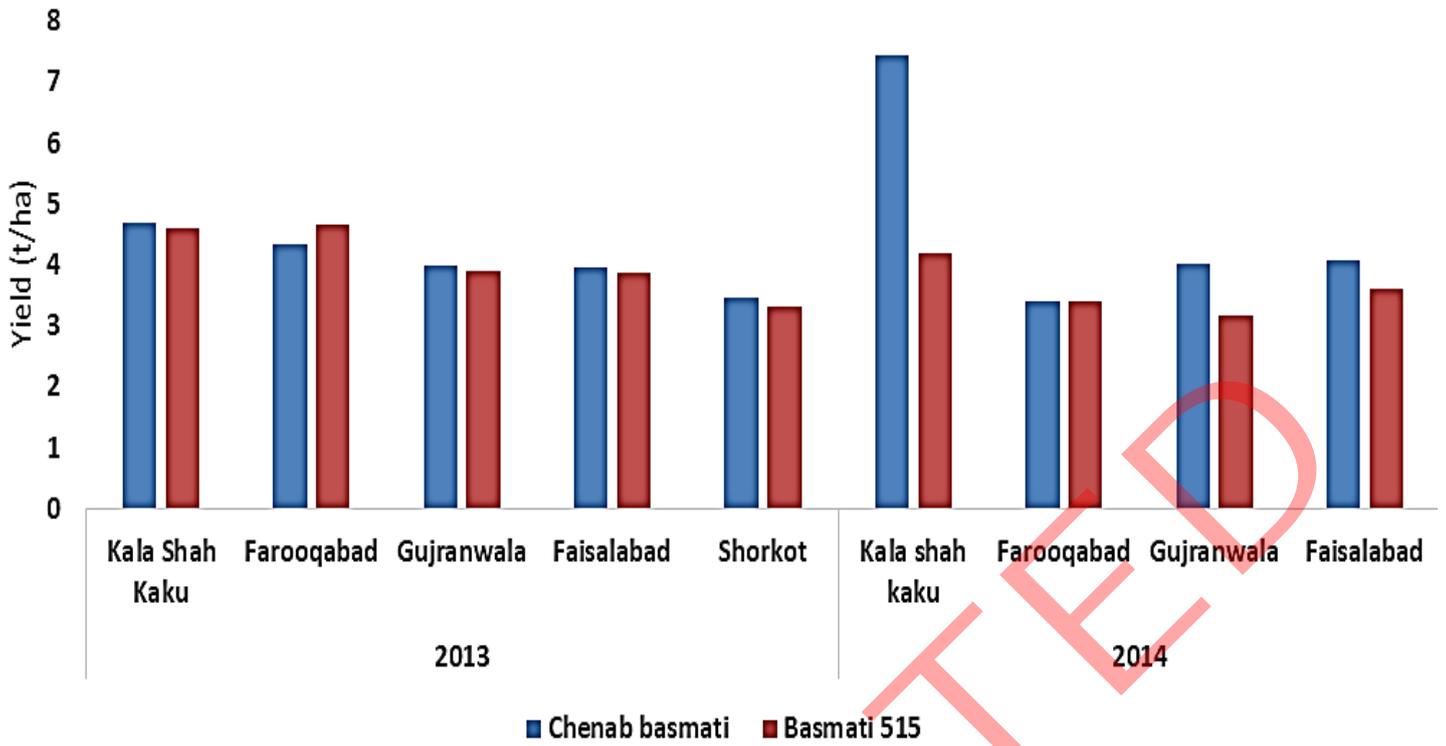


Figure 1: Comparison of Chenab Basmati and Basmati 515 in Adaptability Yield Trials at different locations for two years

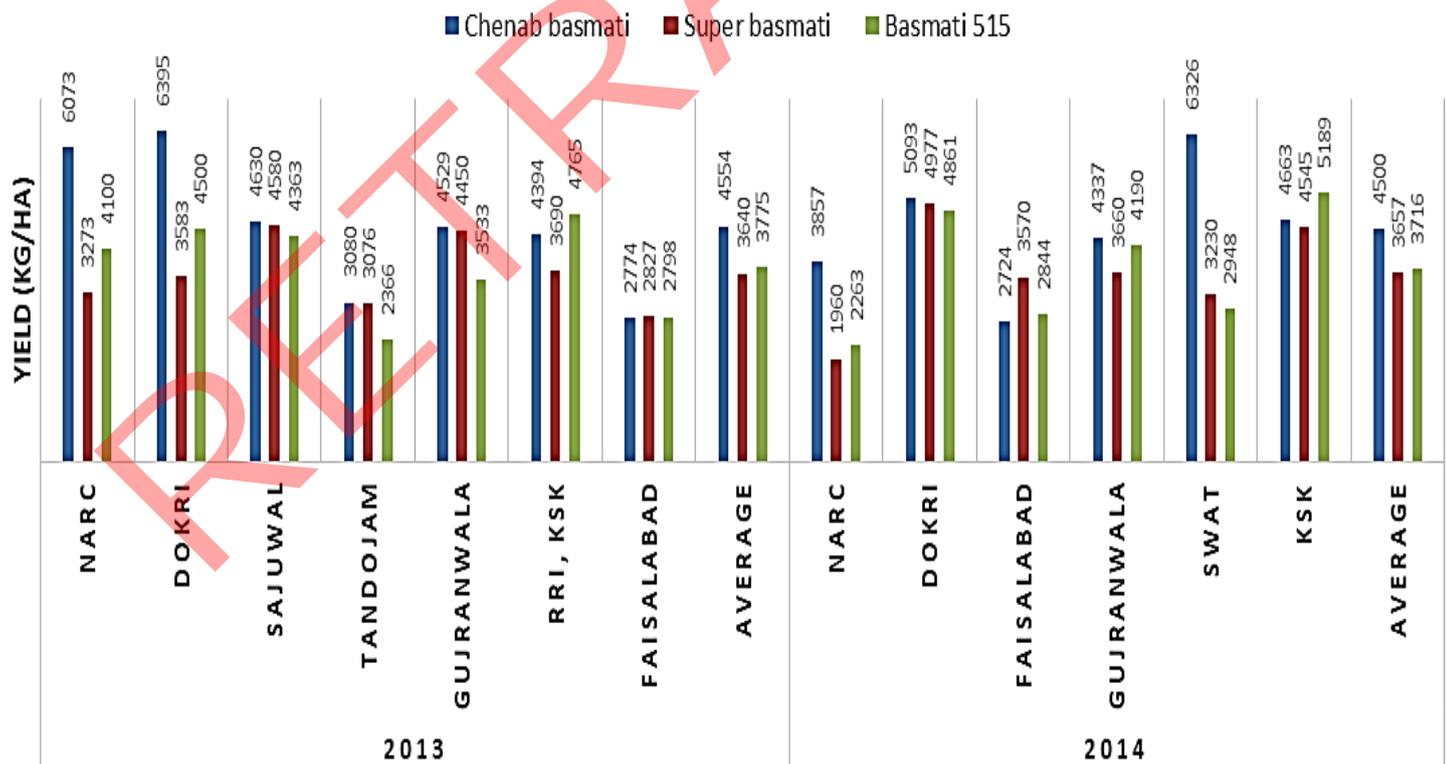


Figure 2: Comparison of Basmati 515 with Chenab Basmati in National adaptability trials in for two years

varieties, authenticating the effectiveness of SUB1 QTL in conferring submergence tolerance. However, a significant variation was observed among the studied cultivars in tolerance for submergence as well as all other traits studied. Chenab Basmati showed tolerance index of more than 0.9 during both the years indicating its potential to be used as flood tolerant variety.

CONCLUSION:

The overall average yield of Chenab Basmati in all the in-station and out-station yield trials was 4.52 t/ha in comparison with 3.65 t/ha of Super Basmati and 3.90 t/ha of Basmati 515. It is very clear that the candidate line has a yield advantage of 24% and 16% over check varieties i.e., Super Basmati and Basmati 515, respectively. This variety was additionally found to be tolerant to submergence stress while moderately susceptible to Bacterial Leaf Blight (BLB), Paddy Blast and Stem rot. Among grain quality attributes, its head rice recovery (58%) and grain length (7.61mm) were found better than checks. The variety exhibited adequate potential to be used as cultivar for yield augmentation and income returns.

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