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Morphological evaluation of green super rice for yield and yield-related traits under agro ecological conditions of Pakistan

Imdad Ullah Zaid[1], Muhammad Kashif Naeem[1], Nageen Zahra[1], Syed Adeel Zafar[1], Shahzad Amir Naveed[1], Ghulam Muhammad Ali[1] and Muhammad Ramzan Khan[1, *]

[1]National Institute for Genomics and Advanced Biotechnology (NIGAB), National Agricultural Research Centre, Islamabad 45500, Pakistan
*Corresponding author's email: mrkhan@parc.gov.pk

Introduction of Green Super Rice (GSR) in Pakistan aims to develop high-yielding, quality and climate-resilient rice cultivars. In this regard, the morphological evaluation of 552 GSR lines for yield and related traits were studied using Alpha Lattice (LS) design with three replications. The phenotypic variability of GSR lines revealed significant mean sum of squares (p<0.01) for all the studied traits. On average, GSR lines showed maximum trait performances for days to flowering, days to ripening, days to maturity, tillers per plant, total biomass, straw yield per plant, grain yield per plant, and harvest index compared with the basmati and non-basmati rice. Relatively high heritability was estimated for days to flowering (97.8%), days to ripening (89%), days to maturity (98.5%), plant height (76.7%), and panicle length (78.8%), whereas, moderate heritability coupled with genetic advance was recorded for tillers per plant (41%), grain yield per plant (43%) and harvest index (53%). Correlation analysis revealed that grain yield per plant had strong and positive correlation with other yield-related traits; tillers per plant (r=0.51**), total biomass (r=0.48**), harvest index (r=0.32**) and straw yield per plant (r=0.28**). Moreover, principal components analysis (PCA) suggested that grain yield per plant, straw yield per plant and total biomass are critical traits that contributed significantly to the total variation in the GSR population. In conclusion, the GSR traits with superior heritability and yield performances are potentially valuable resources for developing high and stable rice cultivars in Pakistan.
Keywords: Phenotypic variability, yield and yield-related traits, phenotypic correlation, genetic parameters, principal components analysis.

INTRODUCTION

Rice is an important food commodity as well as cash crop of Pakistan. After wheat, rice is the second main staple food crop and is second major exportable. Pakistan produced 8.42 million metric tonnes of rice in 2020/2021, ranking ninth among the largest rice producing countries adding 3.0% in value added to agriculture sector and 0.6% to GDP (https://www.statista.com). Pakistan's shares more than 8% of world's total rice trade dominating the Asian rice market after Thailand, Vietnam and India. Sindh and Punjab are the largest (90% of the total rice) rice producing provinces of Pakistan where millions of farmers cultivate rice. In Pakistan Basmati rice is a special type of rice with long or extra-long grains, longer grain elongation after cooking with specific aroma (Akhter and Haider, 2020). Moreover, it is famous in the country due to its excellent cooking quality and good marketing value at national and international levels Basmati rice is considered as Pakistan trademark and at national level it occupied over 40% of rice cultivated area (Shazadi *et al*., 2018). In Pakistan, at present the rice production statistics in largely depends on climatic changes. Lack of elite and stable rice cultivars, severe damages from diseases and insect pests, uneven distribution of water resources, fertilizers management, post-harvest losses and conventional cultivation methods are major limiting factors of rice production. The extreme weather conditions and lack of water storages facilities affecting the rice production causing different glitches including drought stress. Moreover, occurrences of floods, rise in temperatures, droughts, and unusual rain subsequently increases the skirmishes in-between rice production and environmental resources. With these consequences, the present challenge is to develop rice cultivars that are characterized with green traits. The green traits include tolerance of multiple abiotic and biotic stresses, high nutrients-yield potential and fertilizer-water-use

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efficiency (Yu *et al.*, 2020). Hence, to increase the productivity of rice cultivars the cultivation and breeding of enhanced green trait varieties are fundamental goal for increase rice grain yield in Pakistan.

The concept of "Green Super Rice (GSR)" was proposed by Chinese scientists in 2005 to develop elite rice cultivars revealing green traits (Li and Ali, 2017; Yu *et al.*, 2020; Zhang, 2007). The GSR breeding involves fast track evaluation and development of rice cultivars incorporating green traits, in such a way that grain quality and yield-related components are not compromised. The development of GSR lines reveal the composite of conventional and modern breeding strategies as integrating diverse germplasm accessions, genomic resources, molecular technologies and breeding tools. GSR cultivars are more efficient in utilizing nutrients and water, and endure varied biotic and abiotic stresses in any environment with producing high yields and maintaining grain quality (Ali *et al.*, 2012; Zaid *et al.*, 2022). The inherit objective of GSR is to provide resistance against abiotic conditions such as drought, flood, low and high temperatures, and salt stresses. GSR cultivars maintained higher grain yield under the drought stress conditions (Ahmad *et al.*, 2022). The GSR advanced lines were introduced at National Institute for Genomics and Advanced Bio-technology (NIGAB) Islamabad Pakistan, with the aim to develop rice cultivars that retain sustainable yield even when grown under unfavorable environmental conditions of Pakistan. The present study was undertaken to evaluate and compare the yield and yield-related traits of GSR lines under agro ecological conditions of Pakistan.

MATERIALS AND METHODS

Plant Material and Nursery Development: A total of 552 GSR advanced lines were evaluated for yield and yield-related traits at National Institute for Genomics and Advanced Biotechnology (NIGAB) National Agriculture Research Council (NARC), Islamabad (33.6 latitude and 73 longitudes), Pakistan. Before experimental trail, the field was properly levelled, and the healthy seeds of all GSR lines were treated with the recommended dose of fungicide (Apron formulations). On 5th June 2020, seeds of GSR lines were sown on seedling beds. For this purpose 10-inch wide seedling beds on sandy clay loam soil were prepared. The seedling beds were tagged properly with GSR number and name. Rice nursery of 25 days old were transplanted to paddy field, manually.

***Transplantation*:** Transplantation of all 552 GSR lines along with Basmati and non-basmati rice were completed on 1st of July (2020) following straight-rows method in three replications. Each plot was maintained with a net size of 2 m × 0.90 m containing five rows with eight seedlings per row. The distance between rows was 20 cm and within rows was 17 cm, giving a total of 40 plants per plot. Three split applications of nitrogenous fertilizers (after 10 days, 35 days, and 60 days of transplantation); along with phosphorus and potash were used to eradicate the risk of depletion of nutrients and fertilizer among the plants. During the rice growth stages, weeds and were removed and collected by hand. In GSR experimental trail, neither herbicides nor insecticides were used in the experimental trials.

***Phenotypic Evaluation and Traits Measurement*:** All the GSR lines along with Basmati (Super Basmati, Kissan Basmati and Basmati 515) and non-basmati (IIRI-6 and IR-9) cultivars were grown for phenotypic evaluation in three replications, using Alpha Lattice design. Some of the morphological traits were measured at the physiological maturity stage by selecting five plants from each plot randomly. Days to flowering (DF), days to ripening (DP) and days to maturity (DM) of each GSR line in a plot was determined by counting the days from transplantation date to days to maturity. Plant height (PH) at plant maturity stage was recorded with the help of meter rod in centimeters (cm). Panicle length (PL) of selected plants were measured in centimeters (cm) by placing the ruler from panicle's neck to its tip. Tillers per plant (TPP) were recorded by counting the total number of productive tillers. Grain yield per plant (GYPP), straw yield per plant (SYPP) and total biomass yield per plant (BYPP) was recorded in grams (g) after harvesting.

***Statistical Analysis*:** The obtained phenotypic data of 552 GSR lines for 10 yield-related traits were subjected to descriptive statistical analysis using SAS software (Release 9.1.3; SAS Institute, Cary, NC) software. Differences among the GSR lines for traits were determined through the analysis of variance (ANOVA) following the statistical model (Singh and Chaudhary, 1977).

The Mean values of genotypes were statistically separated using the least significant difference (LSD) test taking probability level as ($p \leq 0.01$). Following genetic parameters were estimated by using the mean sum of squares of each traits from ANOVA results. (Asante et al., 2019).

1. Genotypic variance

$$V_g = GMS - EMS$$

Here, V_g is genotypic variance, GMS is grand mean square of a genotype, and EMS is error mean square.

2. Phenotypic variance

$$V_p = V_g + V_e$$

Here, V_p is phenotypic variance, V_g is genotypic variance, and V_e is error variance i.e. EMS.

3. Genotypic coefficient of variation

$$GCV = \frac{\sqrt{V_g}}{\overline{X}} \times 100$$

Genotypic coefficient of variation is calculated as suggested by Burton (1952). Here, V_g is the genotypic variance and $\overline{X}$ is the genotype mean.

4. Phenotypic coefficient of variation

$$\mathrm{PCV} = \frac{\sqrt{V_p}}{\overline{X}} \times 100$$

Phenotypic coefficient of variation is calculated as suggested by Burton (1952). Here, V_p is the phenotypic variance and $\overline{X}$ is the genotype mean.

5. Heritability

$$h^2 = \frac{V_g}{V_p} \times 100$$

Broad sense heritability is calculated as suggested by Lush (1940). Hereby, h^2 is the broad sense heritability, V_g is the genotypic variance, and V_p is the phenotypic variance respectively. The heritability estimate was categorized as low (0-30%), medium (30-60%) and high (>60%)

6. Genetic advance

$$\mathrm{GA} = K\frac{V_g}{\sqrt{V_p}}$$

Hereby, GA is genetic advance, K is the standard selection differential, V_g is the genotypic variance, and V_p is the phenotypic variance respectively. Where, K = 2.06 at 5% selection intensity.

Correlation coefficient (*r*) among traits were calculated at phenotypic level to determine the positive and negative relationship among yield and related traits. Principal component analysis (PCA) was also performed to identify the patterns of morphological variations among 552 GSR lines and to categorize significant variables contributing to the phenotype. Those PCs with E igen values larger than one were selected as suggested (Jolliffe, 1972).

RESULTS

***Genetic Variability*:** In our study, highly significant ($p \leq 0.01$) variations revealed continuous and broad differences for all the studied traits, indicating a significant diversity and genetic variations in GSR lines.

In present study, means for days to maturity of GSR lines ranged between 111 days to 139 days. Our study revealed a total of 146 GSR lines as early matured, 399 GSR lines attributed medium maturity and only 8 GSR lines were found late maturated. PL is the most significant trait to directly contribute for GYPP. Here, minimum value (17.9 cm) for panicle length was recorded by GSR-304 while maximum value (33.4 cm) was recorded by GSR-33. Mean values of GSR lines for GYPP ranged from 42.2g to 99.3g. Our study revealed 30 GSR lines with maximum (> 87g) values for GYPP. The data frequency for SYPP and TBPP was ranged 75g to 286g and 142.8g to 379g, respectively. The mean values of 552 GSR lines for harvest index varied between 0.21 and 0.47.

***Mean performance of GSR, Basmati and non-basmati rice*:** Table 2 and Figure 1 summarizes the mean performances of

Table 1. Phenotypic characteristics of 552 GSR lines for 10 yield and yield related traits

Traits	Mean	Min	Max	C.V (%)	F-Value	Std. deviation
Days to flowering	90.5	80.6	109.3	4.4	10.6	4.0
Days to ripening	24.2	16.7	42.7	10.7	12.7	2.6
Days to maturity	114.3	111.0	139.0	3.4	1.9	4.0
Plant height (cm)	108.6	90.5	163.7	6.8	10.3	7.4
Tillers /plants	22.3	12.0	31.0	11.6	13.6	2.6
Panicle length (cm)	22.3	18.0	33.0	7.1	10.1	1.6
Total biomass (g)	236.4	142.8	379.3	13.4	9.2	31.8
Grain yield/plant (g)	73.2	43.2	99.3	11.3	20.0	8.3
Straw yield/plant (g)	162.0	75.1	286.4	16.9	5.1	27.5
Harvest index	0.31	0.22	0.44	4.7	12.2	0.015

Table 2. Mean performance of the 552 GSR lines along with three Basmati type and 2 non-basmati type rice for yield characters in the 2020 season

Traits	GSR lines	Super Basmati	Kissan Basmati	Basmati- 515	IRRI-6	IR-9
Days to flowering	90.5	70.0	69.0	68.0	68.0	63.0
Days to ripening	24.2	51.0	45.0	46.0	28.0	31.0
Days to maturity	114.3	131.0	126.0	121.0	98.0	96.0
Plant height (cm)	108.6	144.0	105.8	174.4	117.0	119.0
Tillers /plants	22.3	17.0	14.6	17.6	25.8	22.2
Panicle length (cm)	22.3	28.6	27.0	27.0	26.3	24.2
Total biomass (g)	236.4	210.0	156.8	152.8	265.0	217.0
Grain yield/plant (g)	73.2	36.0	38.4	22.8	31.2	28.0
Straw yield/plant (g)	162.0	154.0	120.6	130.0	194.0	189.8
Harvest index	0.313	0.172	0.244	0.192	0.117	0.129

Table 3. Genetic parameters of 552 GSR lines for 10 yield and yield-related traits

Traits	Vg	Vp	Ve	PCV	GCV	Heritability (%)	GA
Days to flowering	15.9	16.3	5.9	4.4	4.4	97.8	57.3
Days to ripening	6.2	7.0	2.6	10.9	10.2	88.9	35.8
Days to maturity	15.7	15.9	5.4	3.4	3.4	98.5	56.8
Plant height (cm)	43.1	56.2	26.2	6.9	6.0	76.7	94.2
Tillers /plants	2.8	6.9	4.7	11.7	7.5	41.0	24.1
Panicle length (cm)	2.2	2.8	1.2	7.5	6.6	78.8	21.3
Total biomass (g)	562.0	3150.0	1188.0	23.7	10.0	17.8	339.8
Grain yield/plant (g)	33.2	77.5	49.6	12.0	7.8	43.0	82.8
Straw yield/plant (g)	416.0	1567.0	1269.1	24.4	12.5	26.5	292.4
Harvest index	0.0007	0.0013	0.00	11.4	8.2	53.0	0.37

Vg; Genotypic variance, Vp, Phenotipic variance, Ve; Environment variance , GCV; Genotypic cofficent of variation, PCV; Phenotypic cofficent of variation, GA; Genetic advance

the GSR lines, basmati and non-basmati rice for the traits investigated. In our study, all the GSR lines exhibited better mean performances in all studied traits except of PH and PL. On average, the GSR lines recorded higher performance for DF, DR, DM, TPP, TB, GYPP, SYPP and HI compared with Basmati and non-basmati rice (Table 3).

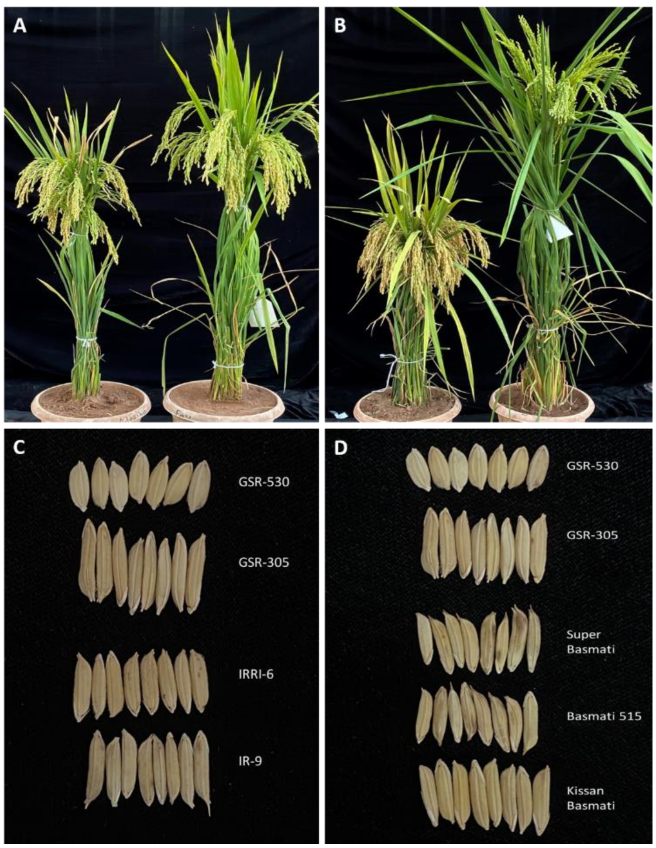

Figure 1. Comparison of GSR lines with Basmati and non-basmati rice for plant height and grain length.

A: GSR-305 with IIRI-6, B: GSR-48 with Kissan Basmati, C: GSR-530 and GSR-305 with IIRI-6 and IR-9, D: GSR-530 and GSR-305 with Super Basmati, Basmati 515 and Kissan Basmati

More specifically, GSR lines displayed 12 days earliest maturity than the Basmati rice, but they recorded 17 days late maturity than the non-basmati rice. In the plant height situation, Basmati rice was found 17cm taller than the GSR lines, while GSR and non-basmati rice revealed similar height. GSR lines recorded 6 more productive tillers on average compared to Basmati rice, but the non-basmati rice had similar counts for tiller per plant. In our study, Basmati and non-basmati rice recorded significantly maximum panicle length than the GSR lines. Basmati and non-basmati rice recorded 4.8cm and 2.7cm longer panicle length than the GSR lines, respectively. The total biomass of GSR lines was 63g greater than Basmati rice, while total biomass of GSR lines and non-basmati rice was similar. GSR lines produced significantly higher grain yield and harvest index than the Basmati and non-basmati rice. In our study, GSR lines had recorded 27g higher straw yield per plant than the Basmati rice, while 29.5g lower than the non-basmati rice.

Heritability Estimates**:** Total phenotypic variance for yield and yield-related traits of 552 GSR lines were divided into heritable (genotypic variance) and non-heritable (environmental variance) components (Table 3). In our study, the results revealed that estimates of genotypic variance was less than their corresponding environmental variance for the traits studied. The genotypic variance ranged from 0.00067 (harvest index) to 562 (BYPP), whereas environmental variance ranged from 0.0013 (HI) to 3150 (SYPP). The GCV value provides a range of genetic variability that exists in different yield-related traits. In our study, GCV value ranged from 3.4–12.5%. Low GCV value was observed for all traits, having value >10% apart from for DP (10.2%), TBPP (10.02%) and SYPP (12.5%). As for PCV, SYPP and TBPP recorded a high percentage (>20%). However, moderate value was recorded for DP (10.9%), TPP (11.7%), and GYPP (12%).

The heritability (H^2) estimates varied from 17.8% to 98%. High magnitude of heritability was recorded for DF, DP, DM, PH and PL, revealing that these traits were influenced by genetic factors and not severely influenced by genotype ×

environment interaction. The heritability estimate for TPP, BYPP, GYPP and SYPP was found low that depicts high influence of environmental factors for trait expressions.

Correlation among yield-related Traits**:** yield and yield-related traits of GSR lines expressed positive and negative trends of relationship among themselves (Figure 2). The results revealed that DF correlated positively with DM (*r*=0.76**), PH (*r*=0.38**) and PL (*r*=0.35**) and negatively with DP (*r*=-0.36**). The TPP showed positive correlation with GYPP (*r*=0.51**), BYPP (0.23**) and HI (*r*=0.27**). GYPP had a significant positive correlation with TPP (*r*=0.51**), BYPP (*r*=0.48**) and HI (*r*=0.32**). SYPP exhibited negative association with HI (*r*=-0.48**), but had a strong positive and significant with BYPP (*r*=0.87**) and GYPP (*r*=0.28**). PL correlated positively with DF (*r*=0.35**), DM and PH (*r*=0.43**). HI also exbihited positive correlation with GYPP (*r*=0.32**).

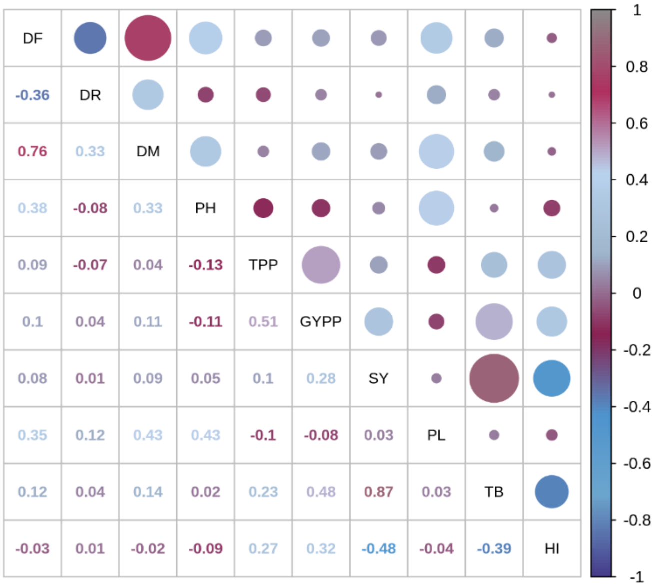

Figure 2. Estimates of correlation coefficients at phenotypic level for 10 yield and yield-related traits of 552 GSR lines

Principle Component Analysis**:** The first four PC's accounted 77.8% of the total variation, where PC1 explained maximum 25.7%; PC2, PC3 and PC4 revealed 21.8%, 17.5% and 12.8% contribution to total variation, respectively (Table 4). In our study, SYPP, BYPP and DF revealed significant contributions to PC1 with BYPP had the highest weightage. In PC2, significant contributions in variation depicted by PL and PH, while in PC3 HI recorded maximum contribution. The PC4 showed positive effects for all traits. It revealed maximum variation for DF and DF. However, the remaining PCs had weak or no discriminatory value. Therefore, the most prominent descriptors were those related with above four PCs.

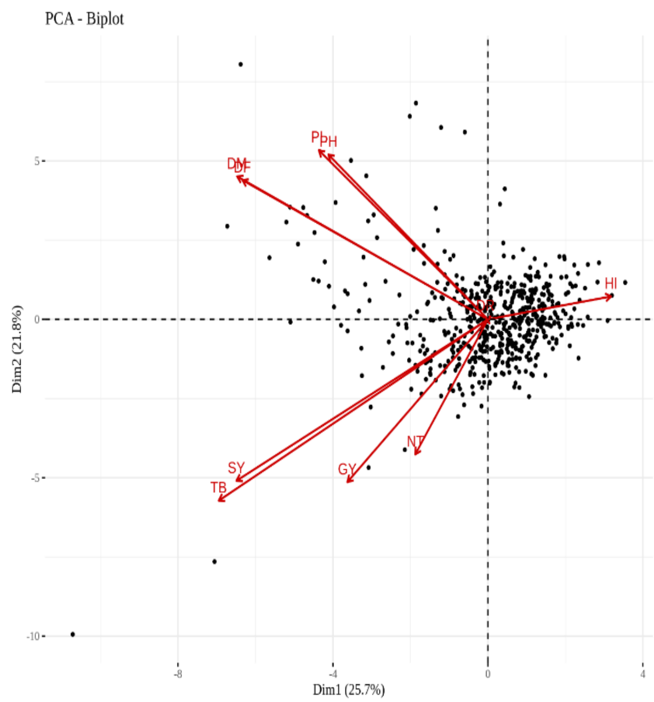

Figure 3. Principal component analysis plot of various yield-related traits.

Table 5. Salient features of 14 elite GSR lines based on field evaluation.

GSR lines	NIGAB-GSR-305	NIGAB-GSR-176	NIGAB-GSR-48	NIGAB-GSR-252	NIGAB-GSR-210	NIGAB-GSR-158	NIGAB-GSR-366	NIGAB-GSR-75	NIGAB-GSR-40	NIGAB-GSR-82	NIGAB-GSR-12	NIGAB-GSR-112	NIGAB-GSR-277	NIGAB-GSR-357
Grain Length (mm)	8.4	7.5	6.9	6.6	7.8	7.0	6.5	6.7	6.0	6.2	7.3	6.2	8.0	7.4
No. of productive tillers /plant	22.4	19.7	16.6	18.9	16.3	17.5	18.5	17.0	17.3	18.1	20.1	18.3	14.6	20.8
Days to Maturity	94.2	92.5	92.5	93.5	92.5	91.2	97.0	92.2	92.5	90.7	94.7	91.2	100.2	102.5
Grain yield /plant	67.0	68.6	64.4	62.0	53.4	70.1	69.7	68.2	73.6	61.3	71.7	70.8	70.1	72.0
Panicle length (cm)	27.2	24.3	22.9	24.0	23.7	24	23.8	23.7	23.5	22.3	22.8	25.1	26.4	24.5
Grains /panicle	235	270	253	224	201	255	270	321	231	300	236	205	267	253
Bacterial blight	MR	MR	MR	MR	MS	MS	MS	MR	MS	MS	MR	MR	MS	MS
Seed Bursting%	5.0	4.0	4.0	2.0	2.0	6.0	6.0	8.0	4.0	2.0	18.0	10.0	20.0	2.0
Amylose%	25.01	28.25	25.24	20.06	21.27	25.12	27.68	21.62	28.77	25.66	26.67	21.47	27.02	27.22

Table 4. Eigen value, % variance, cumulative eigen values and PCA coordinates of 10 yield and yied-related traits

Variable	PC1	PC2	PC3	PC4
Eigenvalue	2.5	2.2	1.8	1.3
Variation (%)	25.7	21.7	17.5	12.8
Cumulative (%)	25.7	47.5	65.0	77.8
Days to flowering (DF)	-0.663	0.460	-0.294	0.368
Days to ripening (DP)	-0.007	0.002	0.075	-0.985
Days to maturity (DM)	-0.677	0.472	-0.242	-0.316
Plant height (PH, cm)	-0.431	0.544	0.074	0.139
Tillers /plants (TPP)	-0.196	-0.446	-0.628	0.055
Panicle length (PL, cm)	-0.456	0.558	-0.006	-0.196
Total biomass (BYPP, g)	-0.727	-0.598	0.200	-0.022
Grain yield/plant (GYPP, g)	-0.379	-0.537	-0.590	-0.084
Straw yield/plant (SYPP, g)	-0.679	-0.533	0.382	0.020
Harvest index (HI)	0.332	0.076	-0.818	-0.093

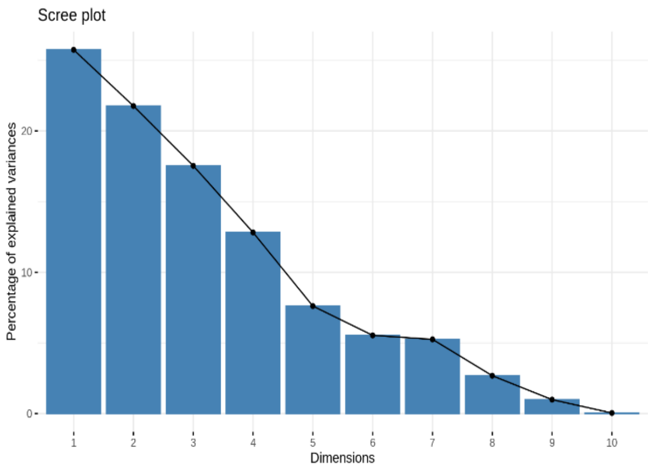

Figure 4. Scree plot of principal component analysis of 552 GSR lines between percentage of explained variances and number of principal components

Scree plot defined the variation percentage in relationship to each PC drawn between principal components and percentage of explained variances (Figure 4). The scree plot in present study revealed 10 principal components with first four Eigen values correspond to the whole percentage of variation in the GSR population. The first four components were declined straight with maximum positive associations while gradual declined with semi curve line was obtained after four components. Graph clearly explained that maximum variations in PC1 and PC2 in comparison to other 10 PCs. So, selection of lines from these PCs will be useful.

DISCUSSION

The primary objective of GSR breeding in Pakistan is to develop quality rice revealing sustainable yield potential. Our study revealed significant differences among the 552 GSR lines for the 10 yield and yield-related traits. The existence of sufficient differences among GSR lines indicated the existence of genetic variations, revealing opportunity to enhance desirable traits and perhaps to be used as superior parental types to for grain yield improvement.

Up-till now, several studies have been conducted to reveal phenotypic variations among rice genotypes for yield and yield-related traits. Asante *et al.*, (2019) evaluated 100 rice genotypes to study the presence of variability. Similar studies of significant genetic variability among rice genotypes were also reported (Anyaoha *et al.*, 2018; Gyawali *et al.*, 2018). In present study, coefficient of variation (CV %) was ranged from 4.4% (DF) to 16.9% (SYPP). CV was found low for most of the traits except for BYPP (13.4%), TPP (11.6%), GYPP (11.3%) and SYPP (16.9%). Similar CV value of 4.4%, 3.4%, 6.8 % and 7.1% for DF, DM, PH, and PL was also reported in rice (Sabri *et al.*, 2020).

In this study, to select elite GSR lines for further multiplication trails at different agro ecological conditions of Pakistan. We considered DM, TPP, PL, and GYPP as an important quantitative parameters to determine high yielding GSR lines. In rice breeding, early maturity is one of the most prominent character that is significantly exploited to deal with various biotic and abiotic stresses. The early mature genotypes as to late ones easily escaped from drought and heat stress by early completing their life cycle (Laghari *et al.*, 2012). The findings indicated that GSR lines with early maturity along with maximum number of productive tillers, long and dense panicles and grain yield contribute to final yield. Based on above trait performances, 14 elite GSR lines of early maturity and high grain yield were selected (Table 5).

Presence of genetic variability in any crop population for trait is a primary requirement of selection and planning for plant breeding strategies. Genetic variability is the coefficient of variation that divided the total variation into GCV, PCV and environmental variations. In our GSR population, the estimates of genotypic and phenotypic coefficient measured the extent of genetic and phenotypic variability for the studied traits. The estimates of heritable and non-heritable components for yield and yield-related traits are prerequisite for indication of variability. In current study, genetic variability analysis pointed out that the estimates of PCV was slightly higher than their corresponding GCV for DF, DP, DM, PH and PL. The magnitude of variation between PCV and GCV indicates the environmental effects that influence the traits expression. Slight differences reveal less environmental effects, whereas large differences indicate maximum genetic influence in the expression of the given traits under study (Bhadru *et al.*, 2012; Tiwari *et al.*, 2019). Higher PCV value was also noticed in a related study (Adjah *et al.*, 2020) revealing that the degree of differences in the PVC and GCV value is strongly influenced by environmental effects. Furthermore, it is recommended that selection of GSR lines with moderate to high GCV values will reveal productive results in rice breeding. Our results illustrated low differences among the PCV and GCV values for various studied traits. Previous findings confirm our present results of low differences for DF, DM, PH and GYPP (Islam *et al.*, 2015). Therefore, selection based on phenotypic performances such as DF, DP, DM, and PH would be an effective source for genetic improvement (Adhikari *et al.*, 2018).

The magnitude of heritability in our study was found varied. High magnitude of heritability together with genetic advance was recorded for DF, DP, DM, PH, and PL. This result is an indication that these traits were strongly influenced by genetics and could be useful for rice selection program. On contrary, moderate heritability together with genetic advance as mean per cent was observed for TPP and GYPP revealing the role additive and non-additive gene actions to influence the traits (Kishore *et al.,* 2015).

Conclusion: In present study, the evaluation of 552 GSR lines for yield and yield related traits identified several elite GSR lines that could be acclimatized well under agro ecological conditions of Pakistan. Consequently, the selected GSR lines will be cornerstone for future rice breeding program in Pakistan. In particular, GSR lines selected in this study are recommended as high-yielding rice genotypes for commercial cultivation in Pakistan.

***Conflict of interest*:** No potential conflict of interests was reported by the authors

***Author's Contribution statements*:** MRK, GMA and IUZ conceptualized the experiment; MKN, SAZ and SAN carried out field trails and collection of data; IUZ, MKN, NZ assembled the results and analysed the data. IUZ wrote the manuscript. MRK did the overall supervision.

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