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Estimation of genetic variation and traits contributing to grain yield in advance lines of rice (*Oryza sativa* L.) using agro-morphological characters

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Abstract

Genetic diversity is fundamentally essential in plant breeding and its assessment in the available genetic stock provides valued information about its possible utilization in rice breeding program for improvement of yield and quality. The present study was carried out with the objectives to assess the genetic variation in 56 rice advance lines and six control varieties i.e.JP-5, Basmati-385, IR-24, Fakhr–e-Malakand, IRBB-59 and Swat-1 on the basis of 18 economically important quantitative and qualitative agro-morphological traits. The experiment was conducted under the climatic conditions of Mansehra, Pakistan using a randomized complete block design with three replications. ANOVA estimated a considerable amount of variation (CV %) ranging from 0.64 for days to maturity to 19.07 for dry weight of top three leaves, whereas significant differences ($p< 0.05$) were recorded for 15 evaluated quantitative traits. Cluster analysis separated the genotypes into six distinct groups at Euclidean distance of 7. The principal component analysis explained 82.206% cumulative variability in quantitative traits with the formation of five independent components. Among the loadings of patterns of PCA number of tillers revealed highest contribution to grain yield per plant. The analysis estimated high genetic variations for the evaluated traits in the advance lines of rice and could serve in future as potential donor parents in breeding for rice improvement.

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Introduction

Rice (*Oryza sativa* L.) is a staple food for more than half of the global population (Chakravarthi and Naravaneni, 2006). The diversity in rice crop varieties is essential for increasing food production, poverty alleviation and promoting economic growth. Studies of genetic divergence among the plant materials facilitate rice breeders to efficiently select diverse parents for objective use in breeding program (Kwon *et al.* 2002). The diverse nature of *Oryza sativa* is distinguished by its adaptation to different agro climatic conditions, growth habit, height, shapes, size, color of the culms, leaf, panicle and grain characters (Takahashi, 1984). Use of agro-morphological traits is the most common approach utilized to estimate relationships between genotypes (Bajracharya *et al.* 2006). This characterization was employed to assess diversity in rice populations (Ilhamuddin *et al.*1988, Caldo *et al* 1996, Ashfaq *et al.* 2012).

The grain yield is a complex trait and quantitative in nature being influenced by various factors. Selection for yield *per se* may not be much satisfying unless other yield component traits are taken into consideration (Satheesh and Saravanan, 2012). Estimation of variation in morphological traits play important role in the production of promising cultivars for increased rice production (Yang *et al.*, 2007; Yang and Hwa, 2008).

The phonological properties of rice are associated with the yield potential of rice varieties. The cultivars those start flowering earlier score higher filled grain percentages exhibiting higher sink efficiency than the panicles start flowering late in the season, there by reduces dry matter accumulation in grains (Mohapatra *et al.,* 1993).

Similarly, the plant leaves being the organ of photosynthesis are considered to be the important determinant and characterized for higher photosynthetic capacities (Asana, 1968). Grain filling is sustained by photosynthesis of the upper parts of the plant (Tambussi *et al.,* 2007). The top th4ree leaves play important roles in biomass production and grain yield of rice (*Oryza sativa* L.) crop since the three leaves not only assimilate majority of carbon for grain filling during ripening phase, but also provide large proportion of remobilized-nitrogen for grain development (Zhang, 2003). The top three leaves contribute most to grain yield (Yoshida, 1981). The top three leaves of rice plants contribute most to grain yield because the top three leaves (a) have the largest leaf area; (b) have the longest life span; and (c) their functional period coincides with panicle development and grain filling (Ray *et al.,* 1983). Li *et al.,* (1998) reported that at least 50% of photosynthetic products for grain are provided by flag leaf, the most important organ for photosynthesis.

The Plant height is another main determining factor of plant architecture which directly affects the final grain yield. Hitaka (1969) reported that plant height, a major factor in lodging resistance in rice. Lodging is one of the major factors limiting the yield potential of rice cultivars. Many studies have shown that the culm characteristics contributing to lodging resistance include basal internode length and thickness, plant height, culm wall thickness, and leaf sheath wrapping and thickness (Matsuda *et al.,* 1983). Lodging resistance is positively correlated with the culm diameter and wall thickness of the basal internodes (Li *et al.,* 2000). Wu *et al.,* (2011) have shown that large culm rice varieties have a higher number of grains per panicle and a longer spike length. Other than the plant height number of tillers per plant, number of grains per panicle and grain weight has direct influence on grain yield per plant of rice (Selvaraj *et al.,* 2011; Babu *et al.,* 2012).

Understanding correlation between yield and yield components are basic and fore most effort to find out strategies for plant selection (Hasan *et al.*, 2013). Habib *et al.*, (2005) reported that extent and significance of association of yield with yield components should be considered, while determining the selection criteria of germplasm on the basis of available genetic variations. Bagheri *et al.* (2011) reported that there was significant linear relationship between yield and panicle length and the number of panicle per plan and the number of filled grain per panicle in rice (*Oryza sativa* L.) genotypes. Positive phenotypic and genotypic correlation coefficient between grain yield and number of filled grains per panicle, panicle length and number of grains per panicle was recorded in rice (Hairmansis *et al.*, 2010, Idris, 2012:). Azarpour (2013) reported that grain yield in rice had significant and positive correlation with panicle weight and biological yield. Moosavi *et al.,* (2015) reported the highest correlation between grain yield per plant and number of panicles. The study of path analysis for yield related traits revealed that number of productive tillers per plant, number of spikelets per panicle, number of grains per panicle and days to maturity had positive direct effect on grain yield per plant (Imad *et al.,* 2014).

The genetic variations and agronomic characters are useful in breeding of rice. The aim of the present study was to estimate the genetic variation and traits that contribute to grain yield in advance line of rice based on qualitative and quantitative agro-morphological characters.

Materials and methods

Plant material

This study was conducted at National Tea and High Value Crops Research Institute (NTHRI) Shinkiari, Mansehra-Pakistan (latitude 34°20' & 34° 30' N and longitude 73° 05' & 73° 20)' at an altitude of 1000 m from sea level) during 2011. Fifty six rice advance lines (Line-3, Line-4, Line-11, Line-12, Line-15, Line-16, Line-19, Line-20, Line-21, Line-22, Line-25, Line-28, Line-29, Line-31, Line-37, Line-46,, Line-48, Line-49, Line-50,, Line-53, Line-55, Line-57, Line-60, Line-64, Line-73, Line-74, Line-78, Line-80, Line-95, Line-99, Line-106, Line-128, Line-129, Line-130, Line-134, Line-140, Line-146, Line-151, Line-152, Line-168, Line-180, Line-181, Line-182, Line-404, , NPT-1, NPT-22, NPT-54, NPT-86, NPT-146, NPT-156, NPT-160, NPT-174, LB-2, LB-3, LB-4, M-2) developed by Department of Genetics, Hazara University, Mansehra-Pakistan having different crossing backgrounders along with six control cultivars (JP-5, Basmati-385, IR-24, Fakhr-e-Malakand, IRBB-59, Swat-1) were evaluated to estimate the genetic variation and yield contributing traits.

Raising nurseries

Before sowing, seeds of all the rice genotypes were treated with fungicide (2 g Benlate/kg). Nursery beds were thoroughly prepared and seeds of each genotype were sown separately in different blocks. Recommended rice nursery management practices were carried out till transplantation of genotypes in the field.

Soil analysis

Soil was analyzed at Soil & Environmental. Science Department, Agricultural University Peshawar-Pakistan and Physico-chemical characteristics of the soil are reported in Table 1.

Meteorological data

The mean minimum and maximum temperature during the experiment period (April-October) was 15.31°C and 31.00 °C respectively while the average relative humidity was 62.42% and 787.00 mm rainfall was received during the crop period (NTHRI, 2011).

Field layout

Four weeks old seedlings were transplanted (two plants/hill) in the experimental field according to Randomized Complete Block Design with three replicates. Each replicate consisted of two lines and each line consisted of twenty plants with 15 cm X 20 cm spacing.

Crop management

The recommended agronomical practices and plant protection measures were awarded uniformly to each genotype to obtain normal plants growth.

Recording data

The genotypes were characterized at various growth stages for estimation of diversity according to descriptors established by the International Rice Research Institute (IRRI, 1996). The quantitative descriptors were days to flowering, days to maturity, Plant height, leaf length, leaf width, flag leaf length, flag leaf width, fresh weight of top three leaves, dry weight of top three leaves, culm basal internode diameter, number of productive tillers per plant, panicle length. number of primary branches per panicle, number of secondary branches per panicle, number of grains per panicle spikelet fertility,1000 grains weight and grains yield per plant, While the qualitative descriptors were lodging resistance, panicle shattering and panicle threshability.

Statistical analysis

Data were analyzed by two-way analysis of variance (ANOVA) and was subsequently followed by LSD test using software Statistix 8.1. Custer analysis and principal Component analysis was also performed by using SPSS.V16 to determine genetic variability for agro-morphological traits in rice genotypes

Results and discussion

The recorded and analyzed data for rice genotypes showed considerable variations for various important agro-morphological Characters.

Table 1. Soil analysis of experimental field.

Depth Cm	pH	EC	Textural Class	AB-DTPA extractable (ug/g soil)						Lime (%)	Total Mineral N mg N/g soil	Organic Matter (%)
				P	K	Zn	Cu	Fe	Mn			
0-15	6.70	0.11	Loam	3.67	64	1.21	4.34	10.18	6.86	0.73	61.25	1.69
16-30	6.72	0.09	Loam*	1.50	57	0.96	3.80	8.36	2.98	2.78	40.25	1.10
31-45	7.02	0.10	Loam*	1.62	59	1.17	3.87	7.98	2.76	2.85	12.25	0.97

*Close to Sandy Loam.

Flowering and maturation cycle are the most efficient traits in the characterization and classification of genotypes. Rice advance lines evaluated in the current study showed significant variations ($p > 0.05$) for days to flowering and maturity. Days to flowering ranged from 88.00 (Line-16) to 123 days (JP-5) with grand mean of 104.08 days and 0.79 % coefficient of variation. Crop maturation cycle also showed significant variations among the rice genotypes. JP-5 took maximum days (164.33) to reach grain maturity and was followed by Fakhr-e-Malakand (161.33 days), Line-64 (157.67 days), Line-130 (157.33 days), Swat-1 (156.67 days), Line-48 (154.67 days), IR-24 (154.67 days) and M-2 (153.67 days). Among the early maturing genotypes, Line-49 took minimum days to maturity (125.67) and was followed by Line-134 (126.67 days), Line-29 (130.33 days), Line-16 (130.67 days), Line-20 (131.33 days), Line-28 (133.00 days) and Line-19 (134.67 days) period to reach crop maturity stage (Table 2). Early or late maturing potential is a genetically controlled character influenced by weather conditions. The significant difference in the flowering and grain maturation periods among the different evaluated rice genotypes reflects their genetic diversity. The mean values (Table 3 and 4) show that the early maturing genotypes have high proportion of filled grains than late maturing accessions. The early maturity give rise to enhanced sink efficiency while the late flowering diminishes the accumulation of dry matter content involved in the filling of the grains (Mohapatra *et al.*, 1993). Ashfaq *et al.*, (2012) also reported significant genetic variability among rice genotypes for days to heading and days to maturity.

Significant variations were recorded in culm traits i.e. plant height, number of productive tillers per plant, basal culm diameter and lodging resistance. Plant height ranged from 87.93 cm (IR-24) to 160.77 cm (Line-129). The other tallest advance lines were Line-48 (155.53 cm), Line-130 (146.06 cm), Line-64 (145.53 cm) Line-99 (143.78 cm) and Line-60 (141.51 cm). The dwarf rice genotypes were IR-24, IRBB-59, M-2, NPT-146, Line-34 and Line-16 with production of 87.93, 89.29, 93.07, 95.59, 97.83 and 101.82 cm tall plants respectively (Table 2). Plant height is the main determining factor of plant architecture which directly affects the productivity.

Table 2. Estimates of genetic variation in quantitative agro-morphological traits in rice advance lines.

Genotypes	DF	DM	PH	LL	LW	FLL	FLW	FWTTL	DWTTL
Line-3	97.33 X	144.33 RST	111.20 T-W	34.45 S-W	1.45 LMN	32.76 F-P	1.81 L-Q	2.69 J-S	0.82 H-S
Line-4	102.67 PQR	145.00 QRS	104.78 a-d	34.84 S-W	1.63 D-I	32.11 G-R	1.93 E-M	3.59 A-H	1.07 A-H
Line-11	95.67 Y	141.33 VW	105.02 Z-d	28.37 XY	1.05 VWX	23.80 WXY	1.23 fg	2.60 L-T	0.91 E-O
Line-12	102.33 QR	137.67 X	109.93 U-X	45.99 DEF	1.52 I-M	33.96 E-N	1.71 P-V	1.81 U-X	0.61 P-W
Line-15	109.33 EF	151.33 FGH	113.45 STU	43.52 F-J	1.25 Q-T	36.11 B-H	1.58 V-Y	3.10 E-N	0.95 B-M
Line-16	88.00 b	130.67 a	101.82 d	35.56 R-V	1.16 R-W	29.23 P-U	1.44 Y-d	1.83 U-X	0.57 S-W
Line-19	98.00 WX	134.67 Y	106.75 X-b	31.65 WX	0.91 X	22.74 XY	1.19 g	2.69 J-S	0.85 H-R
Line-20	95.00 Y	131.33 a	134.86 HI	34.20 S-W	1.59 F-L	26.35 T-X	1.80 M-Q	2.91 H-P	0.85 H-R
Line-21	105.67 JK	147.00 MNO	136.34 GH	52.17 ABC	1.68 C-H	34.10 E-M	2.00 C-H	3.49 A-I	1.15 A-F
Line-22	102.33 QR	145.67 O-R	108.05 W-a	36.94 P-T	1.46 K-N	36.82 B-F	1.86 H-O	3.48 A-I	1.02 B-J
Line-25	104.33 LMN	146.33 N-Q	111.29 T-W	46.03 DEF	1.77 A-D	36.07 B-H	2.13 BC	3.77 A-G	1.07 A-H
Line-28	92.00 Z	133.00 Z	116.90 QRS	49.36 CDE	1.34 N-Q	46.05 A	1.84 J-P	3.23 A-M	0.93 C-O
Line-29	95.33 Y	130.33 b	108.12 W-a	35.30 R-W	1.23 Q-U	29.97 M-T	1.46 X-c	1.65 VWX	0.54 T-W
Line-31	107.00 I	145.33 P-S	108.93 WXY	45.56 F	1.12 T-W	34.70 C-K	1.48 X-c	2.20 P-W	0.72 K-V
Line-37	108.67 FG	152.67 EF	126.22 KL	43.97 F-I	1.91 A	28.03 R-W	2.07 B-E	2.73 I-S	0.81 H-T
Line-46	107.67 GHI	149.00 JKL	124.71 LMN	51.04 BC	1.47 J-N	38.58 BCD	1.77 N-S	3.02 G-N	1.03 A-J
Line-48	117.33 B	154.67 D	155.53 B	55.72 A	1.51 I-M	34.52 C-K	1.73 O-U	3.95 A	1.196 ABC
Line-49	90.00 a	125.67 b	119.22 OPQ	44.71 FGH	1.11 T-W	35.70 B-J	1.41 Z-d	1.89 T-X	0.66 O-W
Line-50	102.67 PQR	140.67 W	138.94 EFG	40.04 J-P	1.11 T-W	28.35 Q-V	1.32 d-g	2.56 M-U	0.88 F-P
Line-53	102.33 QR	133.67 YZ	124.94 KLM	38.77 M-R	1.14 S-W	31.08 K-S	1.35 c-f	2.37 N-V	0.70 L-V
Line-55	99.67 UV	143.00 TU	117.45 PQR	32.33 UVW	1.14 S-W	26.43 T-X	1.38 a-e	1.87 T-X	0.64 P-W
Line-57	101.00 ST	144.33 RST	103.67 bcd	35.91 R-V	1.33 N-Q	28.81 P-V	1.47 X-c	2.22 O-W	0.683 N-V
Line-60	100.33 TU	145.00 QRS	141.51 DE	45.95 DEF	1.15 R-W	38.89 BC	1.52 W-a	2.63 K-T	0.83 H-S
Line-64	110.00 DE	157.67 C	145.53 C	43.46 F-K	1.41 M-P	33.68 E-O	1.60 U-X	3.08 F-N	1.04 A-I
Line-73	105.67 JK	140.67 W	134.934 HI	50.45 BC	1.54 G-M	32.70 F-Q	2.15 AB	3.11 E-N	1.07 A-H
Line-74	101.67 RS	148.33 KLM	109.29 V-Y	32.19 VW	1.41 M-P	31.64 I-R	1.64 R-W	3.33 A-L	1.01 B-J
Line-78	104.00 L-O	147.33 MN	106.62 X-b	35.16 R-W	1.61 E-K	38.52 BCD	1.98 D-I	3.23 A-M	0.98 B-K
Line-80	103.67 M-P	147.33 MN	105.92 Y-c	36.44 P-T	1.67 C-H	37.01 B-F	2.00 C-H	3.95 A	1.19 A-D
Line-95	104.67 KLM	148.33 KLM	103.71 bcd	34.82 S-W	1.61 E-K	36.35 B-G	1.98 D-I	2.79 I-R	0.79 I-U
Line-99	107.67 GHI	142.33 UV	143.78 CD	50.75 BC	1.11 T-W	31.61 I-R	1.78 N-R	2.69 J-S	0.86 G-Q
Line-106	108.33 FGH	150.67 GHI	121.51 MNO	53.17 AB	1.54 G-M	36.87 B-F	1.97 D-J	3.18 C-M	1.02 B-J
Line-128	103.00 OPQ	149.33 IJK	126.88 KL	44.09 F-I	1.33 N-Q	29.27 P-U	1.62 T-W	2.81 I-R	0.92 D-O
Line-129	101.00 ST	150.00 HIJ	160.77 A	50.90 BC	1.34 N-Q	38.74 BCD	1.62 T-W	2.97 H-O	1.04 A-I
Line-130	111.00 D	157.33 C	146.06 C	49.62 BCD	1.45 LMN	44.67 A	1.82 K-P	3.83 A-F	1.30 A
Line-134	90.33 a	126.67 b	97.83 e	32.45 UVW	1.10 UVW	24.70 V-Y	1.26 efg	1.49 WX	0.54 T-W
Line-140	104.67 KLM	151.33 FGH	137.43 FGH	39.69 L-Q	1.34 N-Q	31.77 H-R	1.51 W-b	3.39 A-K	1.08 A-H
Line-146	101.67 RS	145.33 P-S	109.45 V-Y	36.03 Q-U	1.613 E-J	34.36 D-L	1.92 F-M	3.28 A-M	0.93 C-O
Line-151	103.00 OPQ	144.67 RS	108.40 W-a	33.64 T-W	1.63 D-I	33.81 E-N	1.89 G-N	3.93 ABC	1.20 6 AB
Line-152	104.67 KLM	144.67 RS	108.05 W-a	36.61 P-T	1.71 B-F	35.82 B-J	2.04 B-F	3.16 D-M	0.92 D-O
Line-168	103.33 N-Q	147.33 MN	123.40 LMN	46.05 DEF	1.35 N-Q	32.69 F-Q	1.67 Q-V	3.04 G-N	0.97 B-L
Line-180	92.67 Z	131.00 a	118.03 OPQ	26.85 Y	1.28 P-S	20.81 Y	1.52 W-Z	1.39 X	0.40 W
Line-181	99.00 VW	136.33 X	107.39 X-b	37.29 O-T	1.45 LMN	32.03 G-R	1.45 Y-d	2.13 R-X	0.71 K-V
Line-182	108.33 FGH	144.00 ST	136.02 GH	50.05 BC	1.83 AB	26.92 S-X	2.29 A	3.27 A-M	1.05 A-I
Line-404	98.33 WX	140.67 W	102.29 cd	40.72 I-O	1.43 MNO	24.93 U-Y	1.75 N-T	1.52 WX	0.49 VW
NPT-1	111.00 D	153.33 DE	113.85 RST	45.30 FG	1.22 Q-U	38.90 BC	1.58 V-Y	3.74 A-G	1.12 A-G
NPT-22	100.67 STU	145.00 QRS	141.27 DE	37.47 N-S	1.42 M-P	29.37 O-T	1.73 O-U	2.24 O-W	0.77 J-U
NPT-54	105.00 KL	142.33 UV	109.17 V-Y	34.64 S-W	1.60 E-L	35.95 B-I	1.85 I-O	3.43 A-J	0.98 B-K
NPT-86	105.00 KL	144.33 RST	138.21 E-H	42.56 F-L	1.52 I-M	27.05 S-X	1.78 N-R	2.90 H-Q	0.86 G-Q
NPT-146	108.33 FGH	146.33 N-Q	95.59 ef	34.14 S-W	1.30 O-R	28.26 R-V	1.53 W-Z	1.58 WX	0.53 UVW
NPT-156	107.33 HI	147.67 LMN	112.76 TUV	39.78 K-P	1.74 B-E	34.43 D-K	1.94 E-L	3.86 A-E	1.16 A-E
NPT-160	109.00 EF	151.33 FGH	106.69 X-b	35.00 S-W	1.55 G-M	34.60	1.88 G-N	3.89 A-D	1.13 A-G
NPT-174	104.33 LMN	150.67 GHI	108.94 WXY	36.01 Q-U	1.69 B-G	35.79 B-J	2.05 B-F	3.34 A-L	0.95 B-M
LB-2	95.33 Y	137.33 X	121.07 NOP	45.72 EF	1.53 H-M	37.91 B-E	1.85 I-P	2.24 O-W	0.73 K-V
LB-3	104.67 KLM	141.00 VW	135.27 GHI	44.12 F-I	1.60 E-L	29.64 N-T	1.95 E-K	3.37 A-K	1.02 B-J
LB-4	112.33 C	151.33 FGH	131.97 IJ	50.76 BC	1.64 D-I	31.52 J-R	2.01 C-G	3.78 A-G	1.20 ABC
M-2	110.00 DE	153.67 DE	93.07 fg	42.33 F-M	1.80 ABC	32.74 F-P	2.11 BCD	3.49 A-I	1.02 B-J
JP-5	123.00 A	164.33 A	140.17 DEF	50.08 BC	1.11 T-W	39.53 B	1.37 b-e	3.18 B-M	1.04 A-I
Basmati-385	108.67 FG	151.67 FG	136.07 GH	43.68 F-J	1.03 WX	36.21 B-G	1.32 d-g	2.14 Q-X	0.686 M-V
IR-24	116.67 B	154.67 D	87.93 h	41.14 H-N	1.42 M-P	30.00 L-T	1.63 S-W	1.92 T-X	0.60 Q-W
F. Malakand	117.33 B	161.33 B	108.70 W-Z	41.74 G-M	1.23 Q-U	30.33 K-T	1.41 Z-d	2.08 R-X	0.72 K-V
IRBB-59	106.67 IJ	146.67 NOP	89.30 gh	41.20 H-M	1.13 S-W	33.81 E-N	1.42 Z-d	2.00 S-X	0.69 M-V
Swat-1	116.33 B	156.67 C	128.60 JK	44.01 F-I	1.18 R-V	30.61 K-T	1.43 Z-d	1.81 U-X	0.58 R-W
Minimum	88.00	125.67	87.93	26.85	0.91	20.81	1.19	1.39	0.40
Maximum	123.00	164.33	160.77	55.72	1.91	46.05	2.29	3.95	1.30
G. Mean	104.08	145.22	119.06	41.171	1.41	32.756	1.70	2.8237	0.88
CV	0.79	0.64	1.96	5.59	6.43	8.27	5.18	16.75	19.07
LSD (5%)	1.3280	1.4927	3.7782	3.7201	0.1469	4.3777	0.1431	0.7646	0.2732
Croups	28	28	34	25	24	25	33	24	23

DF= Days to Flowering, DM= Days to Maturity, PH= Plant Height (cm), LL= Leaf length (cm), LW = Leaf width (cm),, FLL=Flag leaf length (cm), FLW= Flag leaf width (cm), FWTTL= Fresh weight of top three leaves (g), DWTTL= Dry weight of top three leaves (g).

Tillers production capability of a genotype is one of the high yielding attribute in rice. Maximum count for productive tillers per plant was given by NPT-146 (25.13), Line-53 (23.20), Line-28 (23.13), Line-134 (19.53), Line-404 (19.43), Line-31 (19.10) and NPT-22 (18.66), while Line-20, NPT-1, Line-78 and Line-48 produced the least number of productive tillers per plant in the order of 8.23, 9.10, 9.30 and 9.76 respectively. Selvaraj *et al.,* (2011) and Babu *et al.,* (2012) attributed the final yield in rice largely to the number of tillers per plant. Imad *et al.*, (2014) also reported that that number of productive tillers per plant had a positive direct effect on grain yield per plant.

Table 3. Estimates of genetic variation in quantitative agro-morphological traits in rice advance lines.

Genotypes	CBID	NPT	PL	PBP	SBP	NGP	SF	TGW	GYP
Line-3	6.24J-Q	14.10 J-N	27.83 N-U	13.70 K-N	46.63 I-O	238.10 O-W	85.79 F-K	26.72 F-O	74.16 F-K
Line-4	6.10 K-R	9.90 YZa	30.76 D-H	15.10 G-K	59.70 B-G	359.13 B-F	68.58 ST	29.90 B-G	69.73 H-N
Line-11	5.79 O-U	13.10 L-R	26.36 T-Z	8.20 Za	21.43 Za	137.23 efg	80.44 L-O	26.55 G-O	36.07 X
Line-12	5.20 V-a	14.90 HIJ	24.60 b-f	10.13 T-X	33.33 Q-V	186.67 W-e	83.48 I-L	21.83 S-V	48.23 W
Line-15	6.35 G-O	12.90 K-R	27.76 O-U	12.43 N-Q	47.20 H-N	254.43 M-S	85.37 F-L	27.01 E-N	70.82 H-M
Line-16	4.96 YZa	17.70 D-G	24.90 Z-f	8.56 YZa	20.56 Za	129.77 fg	91.89 A-E	28.53 D-L	55.97 R-W
Line-19	6.41 G-N	11.43 Q-Y	27.66 P-V	12.66 NOP	52.46 E-J	314.77 C-L	88.11 B-J	20.89 UV	62.69 M-T
Line-20	7.11 B-F	8.23 a	28.30 M-S	14.76 I-L	50.90 F-L	294.30 H-N	81.02 K-O	33.91 A	63.33 L-S
Line-21	7.29 A-D	14.33 IJK	31.36 DE	16.56 DEF	51.43 E-K	308.77 F-L	84.98 G-L	25.22 K-S	90.89 B
Line-22	5.90 N-T	13.23 J-P	29.16 I-P	15.33 F-J	55.10 D-I	304.33 G-M	60.57 UV	26.71 F-O	60.08 N-T
Line-25	5.94 M-T	13.00 K-R	29.30 H-N	16.23 D-H	60.66 B-E	367.67 ABC	68.12 ST	26.85 E-N	81.70 B-G
Line-28	5.75 Q-W	23.13 B	27.86 N-T	9.86 T-Y	38.43 M-T	226.33 Q-X	90.43 A-H	22.51 Q-V	102.18 A
Line-29	5.50 S-Y	14.10 J-N	24.76 a-f	9.43 V-a	33.20 Q-W	187.57 W-e	85.89 E-L	25.59 I-Q	53.57 T-W
Line-31	5.60 R-X	19.10 CDE	28.33 L-S	10.80 S-V	32.76 Q-X	204.80 S-a	90.44 A-H	22.92 P-V	77.18 D-H
Line-37	6.71 D-J	12.86 K-S	25.10 Y-f	13.56 L-O	42.23 K-Q	250.13 N-U	80.66 L-O	34.03 A	86.14 BCD
Line-46	6.90 C-G	10.20 XYZ	36.43 A	17.23 CD	68.76 AB	393.77 AB	82.51 J-N	28.67 D-K	91.16 B
Line-48	7.85 A	9.76 YZa	31.50 DE	20.10 A	63.23 BCD	364.57 A-E	84.72 G-L	29.23 C-H	83.84 B-E
Line-49	5.80 O-U	13.33 J-P	25.23 Y-f	10.90 R-U	33.90 P-V	193.90 V-d	88.59 B-I	28.98 D-I	62.54 M-T
Line-50	7.55 AB	16.10 GHI	25.86 X-d	15.23 F-J	56.53 C-H	311.23 E-L	88.63 B-I	20.64 UV	86.34 BCD
Line-53	5.75 Q-W	23.20 B	25.50 Y-e	9.10 Y-a	18.43 a	114.57 g	93.67 AB	30.03 B-F	77.02 D-H
Line-55	5.94 M-T	16.10 GHI	25.20 Y-f	10.46 S-X	34.46 P-U	209.33 R-a	88.26 B-J	27.77 D-M	76.45 E-H
Line-57	5.96 M-T	12.76 K-S	23.73 f	14.80 I-L	38.43 M-T	223.87 R-Y	56.02 V	25.14 L-S	36.41 X
Line-60	5.47 T-Y	12.23 O-V	29.20 I-O	10.56 S-W	23.56 W-a	160.23 a-g	80.57 L-O	27.21 E-N	35.45 X
Line-64	7.26 BCD	11.10 S-Y	34.40 B	11.76 P-S	48.10 H-M	261.10 L-R	90.41 A-H	33.05 AB	81.87 B-G
Line-73	6.83 D-I	13.13 J-Q	28.86 J-Q	15.33 F-J	56.23 C-I	338.53 C-J	90.71 A-G	21.42 TUV	82.30 B-G
Line-74	6.40 G-N	10.23 XYZ	30.16 E-K	15.13 G-J	58.56 C-G	331.33 C-K	67.90 ST	27.43 D-M	57.14 P-W
Line-78	5.84 N-U	9.30 Za	31.03 DEF	15.86 D-I	60.33 B-G	344.67 B-H	70.83 Q-T	28.81 D-I	59.91 O-U
Line-80	6.16 J-R	12.43 M-T	31.60 DE	16.86 CDE	62.76 BCD	393.67 AB	65.53 TU	26.16 H-P	78.08 D-H
Line-95	5.82 O-U	10.36 W-Z	30.13 E-K	15.90 D-I	60.56 B-F	342.47 B-I	65.51 TU	29.17 C-H	63.21 L-T
Line-99	6.67 E-K	12.13 O-W	29.83 F-L	15.76 E-J	35.10 P-U	214.20 R-Z	91.36 A-F	23.83 N-U	58.55 P-V
Line-106	5.98 M-T	13.46 J-P	29.50 G-M	16.56 DEF	51.43 E-K	311.23 E-L	85.36 F-L	20.81 UV	76.09 E-H
Line-128	6.29 H-Q	10.46 V-Z	28.76 K-R	14.86 H-L	59.76 B-G	324.80 C-K	76.04 O-R	32.48 ABC	77.98 D-H
Line-129	7.25 BCD	12.53 L-T	31.96 CD	12.23 O-R	34.66 P-U	200.43 T-b	86.12 D-L	25.86 H-Q	54.32 R-W
Line-130	7.46 ABC	10.20 XYZ	37.76 A	19.20 AB	76.90 A	416.10 A	77.16 M-P	28.38 D-L	88.90 BC
Line-134	5.41 T-Y	19.53 C	24.86 Z-f	9.90 T-Y	28.86 T-Z	170.57 Y-f	83.64 I-L	22.03 R-V	58.48 P-V
Line-140	6.63 E-L	12.33 N-U	33.26 BC	13.13 M-P	48.10 H-M	277.77 K-Q	83.01 I-M	28.43 D-L	80.87 C-G
Line-146	5.84 N-U	10.13 XYZ	30.56 D-I	15.63 E-J	64.23 BCD	365.10 A-D	75.50 O-R	28.56 D-L	75.53 E-J
Line-151	6.16 J-R	11.33 R-Y	30.16 E-K	15.76 E-J	68.43 AB	364.23 A-E	68.96 ST	27.89 D-M	74.36 E-K
Line-152	6.26 I-Q	12.10 O-W	29.70 F-M	14.56 I-L	56.66 C-H	290.47 I-O	72.16 P-S	27.46 D-M	66.38 I-P
Line-168	6.48 G-M	11.33 R-Y	28.23 M-S	13.56 L-O	43.10 J-P	252.87 M-T	76.67 N-Q	30.49 A-D	63.88 L-R
Line-180	6.11 K-R	12.13 O-W	24.43 c-f	11.10 Q-T	38.20 N-U	228.13 Q-X	87.42 C-J	29.26 C-H	66.15 J-Q
Line-181	5.06 X-a	17.23 FG	26.53 T-Y	9.90 T-Y	32.10 R-Y	190.43 V-e	86.32 C-L	24.82 M-T	65.80 K-Q

Line-182	7.20 B-E	13.86 J-O	30.33 E-J	16.46 D-G	48.10 H-M	285.67 J-P	87.83 B-J	23.80 N-U	77.31 D-H
Line-404	5.90 N-T	19.43 CD	24.36 def	9.56 U-Z	37.23 O-U	209.10 R-a	88.47 B-J	21.58 TUV	72.75 G-L
NPT-1	6.33 G-P	9.10 Za	27.16 S-X	10.76 S-V	39.76 M-S	233.43 P-X	82.70 I-M	30.73 ABCD	49.30 VW
NPT-22	5.80 O-U	18.66 C-F	26.53 T-Y	8.13 a	31.23 S-Y	170.33 Y-f	95.33 A	26.65 F-O	76.04 E-I
NPT-54	6.06 L-S	13.43 J-P	29.83 F-L	15.10 G-K	55.66 D-I	306.33 F-M	59.88 UV	26.71 F-O	63.12 L-T
NPT-86	7.19 B-E	11.90 P-X	25.93 W-c	14.43 J-M	41.66 L-R	241.90 N-V	88.10 B-J	22.90 P-V	60.01 O-T
NPT-146	4.73 a	25.13 A	26.33 U-Z	9.56 U-Z	29.63 T-Z	170.43 Y-f	90.51 A-H	23.01 P-V	86.20 BCD
NPT-156	6.07 L-S	12.20 O-V	30.83 D-G	16.23 D-H	65.80 BC	357.33 B-G	70.13 RST	28.74 D-J	83.34 B-F
NPT-160	5.61 R-X	10.76 T-Z	27.26 R-X	14.86 H-L	56.67 C-H	312.23 D-L	67.61 ST	26.94 E-N	57.60 P-W
NPT-174	5.76 P-V	10.56 U-Z	29.40 G-M	15.90 D-I	60.80 B-E	330.90 C-K	76.10 O-R	28.01 D-M	70.32 H-M
LB-2	5.91 M-T	16.23 GH	27.40 Q-W	9.80 T-Y	38.10 N-U	218.87 R-Z	91.96 A-D	23.95 N-U	75.51 E-J
LB-3	6.56 F-L	12.33 N-U	30.20 E-K	15.90 D-I	50.80 G-K	306.23 F-M	87.19 C-J	26.00 H-P	83.21 B-F
LB-4	6.86 D-H	13.23 J-P	27.83 N-U	18.10 BC	58.53 C-G	325.23 C-K	90.21 A-H	19.94 V	74.04 F-K
M-2	5.20 V-a	14.23 JKL	24.00 ef	9.10 X-a	24.66 V-a	145.77 c-g	92.30 ABC	30.23 B-E	56.56 Q-W
JP-5	5.32 U-Z	14.30 JKL	24.33 ef	12.66 NOP	34.46 P-U	180.77 W-f	84.63 H-L	27.67 D-M	58.42 P-V
Basmati-385	5.59 R-X	14.13 J-M	29.63 F-M	10.90 R-U	37.13 O-U	197.47 U-c	87.82 B-J	23.34 O-V	53.94 S-W
IR-24	4.74 Za	11.33 R-Y	22.20 g	9.20 W-a	23.33 X-a	132.43 fg	85.10 G-L	27.75 D-M	33.27 X
F. Malakand	5.83 N-U	17.10 FG	25.10 Y-f	10.90 R-U	22.53 Y-a	143.33 d-g	86.72 C-K	28.53 D-L	62.23 M-S
IRBB-59	5.18 W-a	17.43 EFG	25.96 W-b	10.10 T-X	28.56 U-Z	166.77 Z-g	91.88 A-E	26.87 E-N	68.77 H-O
Swat-1	5.16 X-a	16.43 GH	26.16 V-a	10.80 S-V	23.10 X-a	147.57 b-g	84.96 G-L	25.33 J-R	50.28 UVW
Minimum	4.73	8.23	22.20	8.13	18.43	114.57	56.02	19.94	33.27
Maximum	7.85	25.13	37.76	20.10	76.90	416.10	95.33	34.03	102.18
G. Mean	6.11	13.695	28.21	13.18	44.763	257.03	81.919	26.50	68.129
CV	5.84	8.12	3.30	6.72	13.46	12.96	4.54	8.06	8.78
LSD (5%)	0.5772	1.7971	1.5039	1.4313	9..7416	53.854	6.0136	3.4531	9.6649
Groups	27	27	33	27	27	33	22	22	24

CBID= Culm basal internode diameter (mm), NPT= Number of productive tillers per plant, PL= Panicle length (cm), PBP= Number of Primary branches per panicle, SBP= Number of Secondary branches per panicle, NGP= Number of Grains per panicle, SF= Spikelet Fertility (% age), TGW= 1000 grains weight (g), GYP= Grains yield per plant (g).

Variability in the thickness of culm in rice advance lines was recorded with 5.84% CV and basal culm diameter was highest in Line-48 (7.85 mm), followed by Line-50, line-130. Line-21, Line-129, Line-182 and NPT-86 with production of 7.55, 7.46, 7.29 and 7.26, 7.20 and 7.19 mm thick culms respectively. Minimum culm diameter was reported by genotypes NPT-146 (4.73 mm), IR-24 (4.74 mm), Line-16 (4.96 mm), Line-181 (5.06 mm), Swat-1 (5.16 mm), IRBB-59 (5.18 mm) and Line-12 (5.20 mm).. Wu *et al.,* (2011) has found that large culm rice varieties have a higher number of grains per panicle and a longer spike length.

Lodging resistance potential of genotypes was also evaluated and the rice population was categorized according to their lodging resistance potential as very weak (3.22%), weak (11.29%), intermediate (14.51%), moderately strong (24.19%) and strong (46.77%) Table 4. Lodging is one of the major factors causing severe yield loss and poor grain quality because of reduced canopy for photosynthesis and reduced translocation of nutrients and carbon for grain filling (Hitaka, 1969). Strong lodging resistance was found in genotypes with thick basal internodes, while the resistance level was weak with decreased culm diameter. These results agree with the findings of Li *et al.*, (2000) who reported positive correlation of lodging resistance with the culm diameter and wall thickness of the basal internodes. Matsuda *et al.,* (1983) reported that lodging resistance depends on basal internode length and thickness, plant height, culm wall thickness, and leaf sheath wrapping and thickness.

Plant leaves being the active sites for photosynthetic activities are important plant organs and determine the yield capabilities of the cultivars (Asana, 1968).

Table 4. Qualitative analysis of lodging resistance, panicle shattering and panicle threshability in advance lines of rice.

S,No	Genotypes	Lodging resistance	Panicle shattering,	Panicle threshability
1	Line-3	Mod. Strong	Low	M difficult
2	Line-4	Strong	Low	M difficult
3	Line-11	Intermediate	M.High	Loose
4	Line-12	Weak	M. high	Loose
5	Line-15	Strong	V. Low	M difficult
6	Line-16	Weak	Moderate	Loose
7	Line-19	Strong	Low	Intermediate
8	Line-20	Strong	Low	M difficult
9	Line-21	Strong	Low	Intermediate
10	Line-22	Strong	V. Low	M difficult
11	Line-25	Mod. Strong	V. Low	M difficult
12	Line-28	Mod. Strong	M. High	Loose
13	Line-29	Intermediate	Moderate	Intermediate
14	Line-31	Intermediate	Moderate	Loose
15	Line-37	Strong	Low	Intermediate
16	Line-46	Strong	Moderate	Loose
17	Line-48	Strong	Low	Intermediate
18	Line-49	Mod. Strong	V. Low	M difficult
19	Line-50	Strong	Low	Intermediate
20	Line-53	Intermediate	Moderate	Loose
21	Line-55	Weak	Moderate	Intermediate
22	Line-57	Intermediate	Low	Intermediate
23	Line-60	Mod. Strong	Moderate	Loose
24	Line-64	Strong	Moderate	Intermediate
25	Line-73	Strong	Low	Intermediate
26	Line-74	Mod. Strong	V. Low	Intermediate
27	Line-78	Mod. Strong	V. Low	M difficult
28	Line-80	Strong	V. Low	M difficult
29	Line-95	Strong	Low	M difficult
30	Line-99	Strong	Low	Intermediate
31	Line-106	Strong	Low	Intermediate
32	Line-128	Mod. Strong	Low	Intermediate
33	Line-129	Mod. Strong	Moderate	Loose
34	Line-130	Strong	Low	Intermediate
35	Line-134	Weak	M .High	Loose
36	Line-140	Strong	Moderate	Intermediate
37	Line-146	Strong	V. Low	M difficult
38	Line-151	Strong	Low	M difficult
39	Line-152	Strong	Low	M difficult
40	Line-168	Strong	V. Low	M difficult
41	Line-180	Intermediate	Moderate	Intermediate
42	Line-181	Weak	M. high	Easy
43	Line-182	Strong	Low	Intermediate
44	Line-404	Intermediate	M. high	Easy
45	NPT-1	Mod. Strong	V. Low	Difficult
46	NPT-22	Very weak	M high	Easy
47	NPT-54	Strong	V. Low	M difficult
48	NPT-86	Strong	Low	Intermediate
49	NPT-146	Intermediate	Moderate	Easy
50	NPT-156	Strong	V. Low	M diff+icult
51	NPT-160	Strong	V. Low	M difficult
52	NPT-174	Strong	V. Low	M difficult
53	LB-2	Mod. Strong	Moderate	Easy
54	LB-3	Mod. Strong	Low	Intermediate
55	LB-4	Strong	Low	M difficult
56	M-2	Mod. Strong	Low	Intermediate
57	JP-5	V. Weak	Moderate	Intermediate
58	Basmati-385	Weak	M. High	Intermediate
59	IR-24	Mod. Strong	Moderate	Loose
60	F. Malakand	Intermediate	Moderate	Intermediate
61	IRBB-59	Mod. Strong	Moderate	Easy
62	Swat-1	Weak	Moderate	Intermediate

Rice advance lines showed significant variation for different traits of top three leaves (Table 2). Dry weight of top three leaves showed grand mean of 0.88 with 19.07% CV. Maximum production of dry matter in the top three leaves was in the order of Line-130 (1.30 g), Line-151and LB-4 (1.20 g) and Line-48 (1.19 g), while Line-180, Line-404, NPT-146 and Line-29 produced the minimum dry weight of top three leaves i.e. 0.40, 0.49, 0.53 and 0.54 g respectively. Dry weight of top three leaves recorded the highest Coefficient of variation (19.07%) in all the evaluated quantitative characters of rice advance lines (Table 2). Ilhamuddin *et al.,* (1988) also reported a wide range of variation in leaf characteristics of cold tolerant varieties of rice. Mean data on flag leaf length showed that Line-28 recorded the highest flag leaf length (46.05 cm) which produced highest grain yield (102.18 g) per plant. The results are supported by the findings of Li *et al.,* (1998) who reported that at least 50% of photosynthetic products for grain are provided by flag leaf. Tambussi *et al.,* (2007) reported that grain filling is sustained by current photosynthesis of flag leaf. Ray *et al.,* (1983) also revealed the important role of top three leaves in the grain yield due to their largest leaf area, longest life period and coincidence of their functional period with the panicle development and grain filling. In the current study, it was also found that the rice genotypes with larger leaf area of top three leaves generally produced more grain yield per plant (Table 3 and 4).

Table 5. Computed Eigen values of the different principal components with corresponding proportion and cumulative explained variance.

Component	Total	Extraction Sums of Squared Loadings		Total	Rotation Sums of Squared Loadings	
		% of Variance	Cumulative %		% of Variance	Cumulative %
1	7.744	43.024	43.024	5.411	30.061	30.061
2	2.539	14.104	57.128	2.692	14.955	45.016
3	1.977	10.985	68.113	2.439	13.55	58.566
4	1.494	8.297	76.41	2.328	12.934	71.5
5	1.043	5.796	82.206	1.927	10.706	82.206

Panicle and spikelet traits evaluated in the current study included panicle length, number of primary and secondary branches per panicle, number of grains per panicle, spikelet fertility, thousand grains weight, panicle shattering and threshability.

Significant variations were recorded in panicle length of rice genotypes with LSD value of 1.50 for comparison at 5% level of probability. The grand mean panicle length of all the genotypes was 28.21 cm. Lager panicle produced more number of grains with enhanced yield potentials. Line-130, Line-46, Line-64, and Line-140 with higher panicle length of 36.43, 34.40, 33.26 and 31.96 cm respectively gave more yield than genotypes with short panicles i.e. IR-24 (22.20 cm), Line-57 (23.73 cm), M-2 (24.00 cm), JP-5 (24.33 cm) and Line-404 (24.36 cm). Khush and Peng, (1996) proposed the development of new plant types with ideal morphology, large panicles and photosynthetic efficiency.

Significant variations were found in the number of primary and secondary branches per panicle. Line-48, Line-130, LB-4, Line-46 and Line-80 produced the highest number of primary branches per panicle, while it was lowest in NPT-22, Line-11, Line-16 and M-2. Genotypes also recoded significant differences in number of secondary branches per panicle with13.46% CV of and 44.76 grand mean for all the tested genotypes.Line-130 produced the highest (76.90),

Number of grains per panicle is highly correlated with yield (Moosavi *et al.,* (2015), In the present study the rice genotypes showed significant variations (p>

0.05) for this trait with the formation of 33 groups with critical value of 53.85 in which the means were not significantly different from one another. Parikh *et al.*, (2012) also reported a wide range of variability for the morpho-agronomical traits in accessions. Number of grains per panicle ranged from 114.57 (Line-53) to 416.10 (Line-130). It is evident from the table 3 that genotypes producing high number of grains per panicle also recorded high grain yield per plant. Bagheri *et al.,* (2011) also reported a linear positive relationship of yield with number of grains per panicle. Majority of rice advance lines were superior in production of the number of grain than cultivars used as check.

Table 6. Factor loadings (eigenvectors) for the different morphological characters for the principal components retained.

Descriptor	Principal Components				
	PC 1	PC 2	PC 3	PC 4	PC 5
Days to Heading	9.00	86.30	15.70	12.60	-16.60
Days to Maturity	12.80	85.30	9.00	5.30	-27.80
Plant Height (cm)	17.50	25.00	-13.30	85.10	4.00
Leaf Length (cm)	10.60	63.40	7.60	48.50	38.50
Leaf Width (cm)	30.20	11.20	89.80	-5.60	-9.90
Flag Leaf Length (cm)	58.30	56.60	-12.40	-21.20	30.50
Flag Leaf Width (cm)	37.60	16.10	85.40	-2.00	4.60
Fresh Weight of Top Three Leaves (g)	73.40	37.40	38.80	8.90	-10.90
Dry Weight of Top Three Leaves (g)	73.20	42.30	30.90	20.70	-4.40
Culm Basal Internode Diameter (mm)	45.05	-2.70	16.70	80.60	-13.40
Number of Productive Tillers/Plant	-50.50	-10.00	-12.40	-17.80	72.60
Panicle Length (cm)	81.20	16.30	1.90	30.40	1.00
Number of Primary Branches/Panicle	74.80	11.90	38.50	28.90	-18.10
Number of Secondary Branches/Panicle	86.80	-4.40	36.00	12.80	-13.80
Number of Grains/Panicle	86.60	-6.10	37.50	14.80	-12.60
Spikelet Fertility (% age)	-58.60	4.50	-14.60	48.20	48.00
1000 Grains Weight (g)	7.70	11.30	5.00	0.00	-63.20
Grains Yield/Plant (g)	41.60	-7.30	31.60	35.00	55.80

High spikelet fertility is a desired yield enhancing characteristic of commercial rice cultivars. The Genetic of cultivar with environmental conditions and crop management practices play basic role in the grain filling and development. The genotypes evaluated for estimating their agro-morphological diversity recorded significant variations with CV value of 4.54% and 81.91 grand mean. Spikelet fertility ranged from 56.02 (Line-57) to 95.33% (NPT-22). Hairmansis *et al.,* (2010) also recorded diversity in rice cultivars and reported significant association of grain yield with spikelet fertility.

The weight of grain also contribute in the final yield of rice and it was found that 1000-grains weight showed variability among the rice genotypes with the formation of 22 significantly different groups at LSD value of 3.45 (5% level of probability). The weight range of 20-25 g, 26-30 g. and 31-35 g for 1000-grains accommodated 23 35, and 4 genotypes respectively. The grains of Line-37 were found as the heaviest by giving the maximum weight (34.03 g) for 1000 grains while it was lowest (19.94 g) in LB-4.

Grain yield of rice is a complex trait, quantitative in nature and is the expression of combined functions of a number of constituent traits (Satheesh and Saravanan, 2012). LSD all-pair wise comparisons Test with critical value of 9.66 formed twenty four statistically divergent groups of genotypes on the basis of per plant grain yield. The top ten high yielding genotypes wereLine-28 (102.18 g), Line-46 (91.16, g), Line-21 (90.89 g), Line-130 (88.90) , Line-50 (86.34 g), NPT-146 (86.20 g), Line-37 (86.14 g), Line-48 (83.84 g), NPT-156 (83.34 g) and LB-3 (83.21 g).

Out of 56 advance lines evaluated, 31 advance lines produce more grain yield per plant than the check cultivars. Grain yield per plant in the check cultivars was in the order of IRBB-59 (68.77 g), Fakhr-e-Malakand (62.23 g), JP-5 (58.42 g), Basmati-385 (53.94 g), Swat-1 (50.28 g) and IR-24 (33.27 g).

It is evident that the advance lines evaluated in the current study proved high yielder than the locally cultivated varieties i.e.JP-5, Fakhr-e-Malakand, Swat-1 and Basmati-385. Ashrafuzzaman *et al.,* (2009) also found variation in morphological and yield components in different varieties of aromatic rice, while Roel *et al.*, (2014) reported phenotypic diversity in traditional rice varieties in the Philippines by using morphological traits.

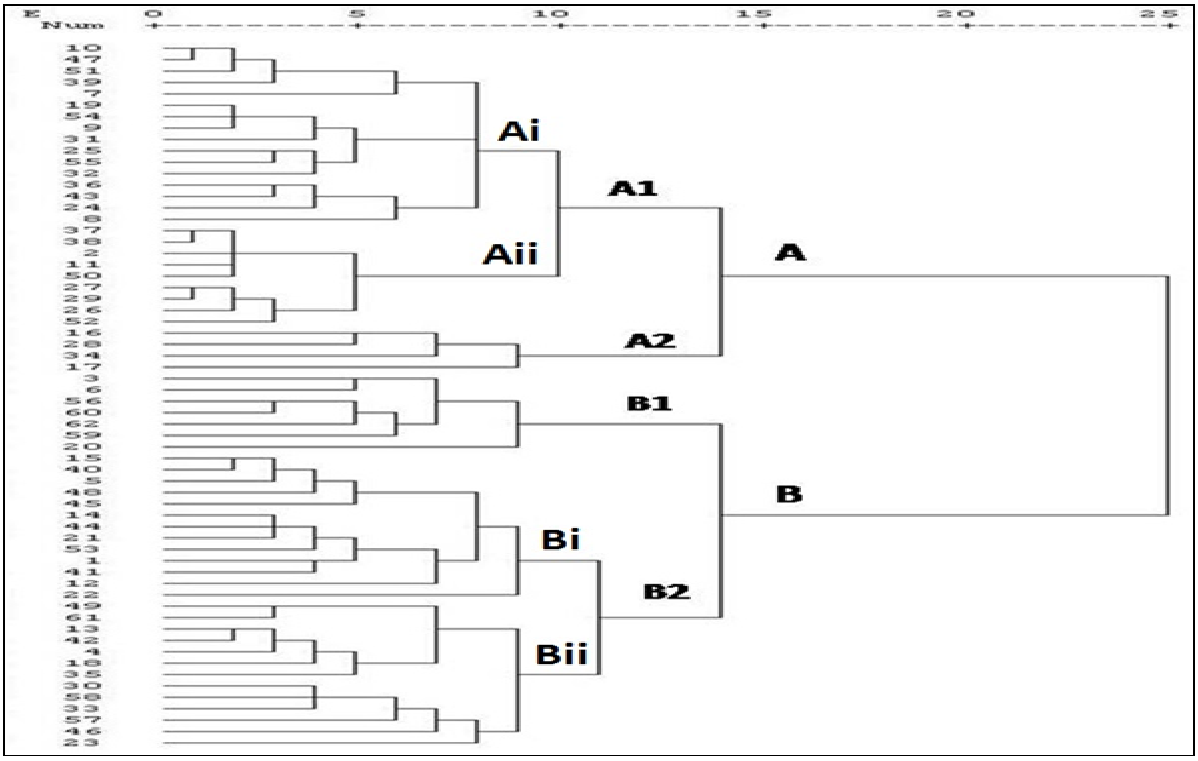

Fig. 1. Cluster tree for rice genotype.

Panicle shattering and threshability are important varietal characteristic in rice. Low panicle shattering is a preferred quality of rice genotype which saves the produce from loses in the field and harvesting operations. Strong wind and hailing inflicts shattering in rice crop and the genotypes with low shattering panicles are damaged minimum. Out of 62 genotypes, 35.48% genotypes recorded low panicle shattering, while the position of remaining genotypes was in the order of moderate (29.03%), very low (22.58%) and moderately high (12.9%) panicle shattering. Panicle threshability is also a trait of consideration in overall acceptability of the rice cultivars. Majority of rice genotypes (40.32%) represented intermediate threshability and was followed by genotypes proportion for this trait as moderately difficult (30.64%), Loose (17.47%), easy (9.67%) and difficult (1.61%). Wellington *et al.,* 2011 reported a high degree of variability among 146 the rice accessions for quantitative and qualitative traits.

Cluster Analysis of Rice Genotypes

The cluster analysis performed for the different quantitative traits of rice formed two main clusters A and B diverged at Euclidean distance of25 which accommodated29 and 33 genotypes respectively. Cluster A and B truncated at Euclidean distance of 14 resulted in the production of four sub-groups A_1, A_2 and B_1, B_2. Clusters A_I and B_2 were further truncated at Euclidean distance 7 and produced four groups denoted by Ai, Aii and Bi, Bii (Fig 1). Thus total six clusters namely Ai, Aii, A_2, B_1, Bi, and Bii grouping 16, 9, 4, 7, 13 and 13 genotypes respectively were formed at Euclidean distance of 7. Each group was assigned with number of genotypes which has less variation to one another and more variation to other groups (Fig 1).

Cluster Ai is the largest group contained 16 genotypes i.e. Line-22, NPT-154, NPT-160, Line-152, Line-19, Line-50, LB-3, Line-21, Line-106, Line-73, LB-4, Line-128, Line-140, Line-182, Line-64 and Line-20. Most of the genotypes of cluster Ai have similarity in traits like leaf width, number of grains per panicle and spikelet fertility. Cluster Aii contained nine genotypes i.e. Line-146, Line-151, Line-4, Line-25, NPT-156, Line-78, Line-95, Line-74, and NPT-174. They show nearly similar results for traits like days to flowering, days to maturity, plant height, leaf width, panicle length and spikelet fertility. Cluster A2 is the smallest cluster and comprises of four genotypes i.e. Line-46, Line-80 and Line-130 and Line-48, which are distinctive from other advance lines due to their high values for diameter of basal internode, fresh and dry weight of top three leaves and number of grains per panicle. Cluster B1 consists of seven genotypes namely Line-11, Line-16, M-2, Fakhr-e-Malakand, Swat-1, IR-24, and Line-53. Members of this cluster were close in the agro-morphological traits like culm diameter, flag leaf length and width, panicle length, number of primary and secondary branches per panicle, number of grains per panicle and 1000-grains weight. Cluster Bi having13 genotypes comprises of Line-37, Line-168, Line-15, NPT-186, NPT-1, Line-31, Line-404, Line-55, LB-2, Line-3, Line-180, Line-28, and Line-57. The members of this cluster were close for leaf length, culm basal internode diameter, number of productive tillers per plant, panicle length and number of grains per panicle characters. Cluster Bii grouped 13 genotypes i.eNPT-146, IRBB-59, Line-29, Line-181, Line-12, Line-49, Line-134, Line-99, Basmati-385, Line-129, JP-5, NPT-22 and Line-60. The genotypes showed less variation in flag leaf width, fresh and dry weigh of top three leaves and spikelet fertility.

Principal Component analysis

The KMO test was conducted which calculated high value of 0.715 and indicated that the data is able to conduct principal component analysis. In the first iteration the scree plot extracted seven components having Eigen value more than one. The 1st components, 2nd component, 3rd component, 4th component and 5th component contributing 43.024%, 14.104%, 10.985%, 8.297% and 5.796% of variance to genetic diversity, respectively. All the five components were accountable for 82.206% cumulative variability in quantitative traits. The extraction was followed by rotated factor pattern for first five retained components which was linearly transformed using Varimax (uncorrelated orthogonal rotation which maximize the explained variance and interpret the dimension of loadings). The rotation altered the extraction that 1stcomponents, 2nd component, 3rd component, 4thcomponent and 5th component contributed 30.061%, 14.955, 13.55%, 12.934% and 10.706% of variability in genotype, respectively (Table 5).

It was found that some general patterns created by principal component analysis. Thirteen traits i.e. leaf width, flag leaf length, flag leaf width, fresh weight of top three leaves, dry weight of top three leaves, culm basal internode diameter, number of productive tillers per plant, panicle length, number of primary branches per panicle, number of secondary branches per panicle, number of grains per panicle, spikelet fertility and grain yield per plant donating 30.2%, 58.3%, 37.6%, 73.4%, 73.2%, 45.5%, -50.5%, 81.2%, 74.8, 86.8%, 86.6%, -58.6%and 41.6% individual variation to the 1st component, respectively (Table 6). The loadings of 1st PC revealed that increase in one loading confer an increase to other loadings while the negative value suggests the adverse effect of number of productive tillers per plant and spikelet fertility on the rest of significant loadings. The 2ndpattern was formed by days to heading (86.3%), days to maturity (85.3%), leaf length (63.4%), flag leaf length (56.6%), fresh weight of top three leaves (37.4%) and dry weight of top three leaves (42.3%). Although, the component showed high genetic variation but do not elevate the grain yield per plant. The third component has eight meaningful loadings; leaf width (89.8%), flag leaf width (85.4%), fresh weight of top three leaves (38.8%), dry weight of top three leaves (30.9%), number of primary branches per panicle (38.5%), number of secondary branches per panicle (36%), number of grains per panicle (37.5%)and grain yield per plant (31.6%). The six loading i.e. plant height (85.1%), leaf length (48.5%), culm basal internode diameter (80.6%), panicle length (30.4%), spikelet fertility (48.2%) and grain yield per plant (35%) lies on the 4th component. Similarly, six meaningful loadings lies on 5th component which comprised of leaf length, flag leaf length, number of productive tillers per plant, spikelet fertility, 1000-grain weight and grain yield per plant with 38.50%, 30.5%,72.6%, 48%, 63.2% and 55.8% loading respectively (Table 6).

The 1st component of PCA analysis contributes 41.6% to grain yield which clearly exhibit that number of grains per panicle is the basic constituent. The numbers of grains per panicle which are indirectly elevated by number of primary and secondary branches per panicle which got a bigger panicle size due to decrease in number of tillers per plant which also give more space to rice stem to achieve large basal internode diameter and high biomass for top three leaves. Ashfaq *et al.,* 2012 also found significant correlation of grain yield per plant with seed per plant, seed weight per plant and panicle length. However, panicle length was correlated with flag leaf area and primary and secondary branches per panicle, while seed per panicle were also significantly associated with flag leaf area and primary and secondary branches per panicle and negative correlation with tillers per plant. Idris (2012) also reported a positive phenotypic and genotypic correlation coefficient between grain yield and panicle length of rice cultivars. The component also revealed grain yield per plant, number of primary and secondary branches per panicle, panicle length, top three leaves fresh and dry weight, flag leaf length and width leaf width, culm basal internode diameter share common genetic architecture while the non-functionality give rice to low tillers number per plant. Moosavi *et al.,* 2015 reported the significant direct correlation of panicle number on grain yield. Similarly, our 5th component also revealed highest elevation of grain yield among the components. The 5th component is based on large proportion by tillers per plant.

Conclusion

Thus, the current study inferred that for increasing rice grain yield it is essential for a genotype to carry high number of tillers per plant, large panicle size and 1000 grain weight. Further, the genetic divergence and identification of desirable traits in advance lines of rice could be utilized for breeding as new rice varieties that may be able to break yield stagnation which rice breeders are currently trying to address.

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