Research Article

Genetic variability analysis of wheat (*Triticum aestivum* L.) genotypes for yield and related parameters

Mehnaz Ghaffar^{1*}, Saleem Khan¹ and Waqas Khan²

1. Agricultural Research Station, Baffa, Mansehra, KPK-Pakistan

2. The University of Agriculture, Peshawar KPK-Pakistan

*Corresponding author's email: meena_agri_99@yahoo.com

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Abstract

The present experiment was conducted to find out the genetic variability in 100 different wheat genotypes/germplasms at Agricultural Research Station Baffa, Mansehra, Pakistan. The experiment was laid out in RCBD with three replications. The results of statistical analysis showed significant differences among genotypes for all characters like days to heading, days to maturity, plant height (cm), number of grain/spike, spike length (cm), 1000 grain weight (g), biological yield (tons/ha), grain yield (tons/ha) and harvest index (%). Genetic diversity among genotypes reflect their broad genetic background. The days to heading ranged from 109 to 141 showed by genotypes 3032 and 3008, maturity from 142-184 days by genotypes 3032 and 3023, plant height from 83 to 125 cm by genotypes 3002 and 3077, number of grains/spike from 19 to 75 by genotypes 3173 and 3082, spike length from 8.10 to 12.30 cm by genotypes 3173 and 3082, 1000 grain weight from 21 to 64 gram by genotypes 3148 and 3015, biological yield from 9.30 to 17.50 tons/ha by genotypes 3004 and 3082, grain yield from 1.80 to 5.90 tons/ha by genotypes 3078 and 3082 and harvest index from 14.17 to 44.73 % by genotypes 3144 and 3015. The significant genetic diversity amongst wheat germplasms were recorded in this experiment. Genetic variability analysis revealed that genotypes 3015, 3032 and 3082 were the most promising ones and it is suggested that these lines may be focused and involved in future wheat breeding programme. The use of reported genetic diversity will assist wheat breeders for development of high yielding varieties in future.

Keywords: Genetic analysis; Genetic variability; Wheat diversity; Wheat yield

Introduction

Wheat (*Triticum aestivum* L.) is the major cereal crop which is widely cultivated for food purpose in most area of the world including Pakistan. It is popular for high nutritional value and is used in a variety of products. Wheat is considered a good source of protein, carbohydrate, dietary fiber and

minerals including calcium, iron, magnesium and phosphorous [1]. Wheat is the leading grain crop of the temperate climates and its area and productivity is rapidly increasing throughout the world because of its high adoptability and sustainability under diverse agro ecological zone [2]. Major wheat producing countries

include China, United States of America, India, Pakistan and Russia. Pakistan is amongst the top ten wheat producing countries where more than 70 % of farming community is directly or indirectly involved in cultivating wheat [3]. In Pakistan wheat was grown over an area of 9.1 million hectares which produced 26 million tons [4] while in Khyber Pakhtunkhwa province, the total area under wheat cultivation was 0.72 million hectares [5].

There are various yield limiting factors including biotic and abiotic stresses and responsible for low productivity of wheat. Beside harsh environmental conditions, the use of fertilizers, quality of soil and genetic diversity have also great influence on crop yield [6]. Therefore, to withstand under non-conducive and stressful environmental conditions, a broad genetic diversity is required. Due to modern breeding it has been observed that genetic diversity in wheat has been increasingly narrowed which has directly affected the adoptability and sustainability of wheat under disease and unfavourable conditions. Various strategies are used for assessing genetic variability including morphological analysis in field and molecular analysis using molecular markers such as simple sequence repeats (SSR), restriction fragment length polymorphism (RFLP), random amplified polymorphic DNA (RAPD) and diversity arrays technology (DArT) markers [7]. Due to unavailability of broad genetic diverse varieties, the average yield of Khyber Pakhtunkhwa province (1807 kg/ha) is much lower than the national average yield (2787 kg/ha) [5]. With the increase in population in Pakistan the demands of wheat are continuously increasing. In order to fulfil the demand of population and overcome future food shortage, high yielding and disease resistant varieties of wheat are required. For this purpose wheat varieties with broad genetic background should be developed.

Genetic diversity plays an important role in crop improvement. Diversity helps in adaptation to the non favourable environmental conditions such as drought, salinity, temperature stresses and various disease conditions [8]. Plant breeding experiments largely rely on the diversity present in breeding materials. Breeder use the genetic variability for better selection during varietal development. For this purpose, plant breeders can follow the conventional methods of selection such as introduction and selection of superior and promising genotypes from national and international germplasms collection sources [9] or they can get help from the use of molecular markers for selection of quantitative trait loci (QTLs) [10]. To improve genetic diversity of local germplasm, it is important to know the extent of already existing genetic variability in the material. Genetic variability, which is a heritable difference among cultivars, is required in an appreciable level within a population to facilitate and sustain an effective long term plant breeding programme. Introduction of diverse germplasm into the current wheat genetic base may increase genetic variability and lead to greater gains from selection [11]. Therefore, it is necessary to investigate the genetic diversity in wheat germplasm in order to broaden the genetic variation in future wheat breeding.

The genetic potential and variability was assessed in winter wheat and high significant diversity was reported for yield and related parameters [12]. Similarly, genetic variability and broad sense heritability was monitored in sixty wheat germplasms [13]. Wheat landraces and primitive genotypes was considered an important source of genetic variation [14]. Another wheat diversity study reported considerable genotypic variation in Jordanian wheat genotypes [15]. Similarly,

the phenotypic diversity of 298 bread wheat landraces and significant variation was detected for quantitative characters studied [16]. The genetic diversity in spring wheat was studied and considerable variation was found in breeding materials [17]. The similar nature of genetic diversity and variability was reported in soybean [18] and maize [19]. Like wise, highly genotypic variation was detected in wheat genotypes through the study of correlation and association of genetic diversity [20, 21]. Genetic diversity, heritability and interrelationships of agronomic traits was reported in land races of wheat in Iran [22] and Ethiopia [23].

The present study was conducted to find out the genetic variability among the different wheat genotypes, evaluate their performance and determine the plant type for future wheat breeding programme. The outcome of this investigation would help wheat breeders for further improvement and development of wheat varieties.

Materials and methods

The experiment was performed at Agricultural Research Station, Baffa Mansehra. The experimental materials were consisted of 100 different wheat genotypes obtained from CIMMYT (The International Maize and Wheat Improvement Center), Mexico. The pedigree of genotypes/lines are given in (Table 1). Two varieties PS. 2015

and NARC-2011 were also included as a checks in the experiment. The genotypes were planted in a well maintained soil condition. The experiment was designed under RCBD (Randomized complete block design) model with three replications. Each plot were consisted of five rows each of 5 m in length with a row to row distance of 30 cm. The crop was grown under normal experimental conditions. The basal dose of fertilizer of 120 Kg N, 60 Kg P₂O₅ and 40 Kg K₂O was applied at sowing. Irrigation was given when required. Normal cultural practices were followed through out the experiment. Data from six randomly selected plants from each replication was recorded. Data was taken on days to heading, days to maturity, plant height (cm), number of grains / spike, spike length (cm), 1000 grain weight (g), biological yield (tons/ha), grain yield (tons/ha) and harvest index (%). The final yield was calculated as mature seed harvested. Grain weight was recorded as weight of 1000 randomly selected seeds taken from each plot. The data was analysed for analysis of variance through M-Stat-C [24] statistical software. Mean comparisons among genotypes were done by further analysis of the significant data through Least Significant Difference (LSD) test at 5% probability level.

Table 1. Pedigree of wheat genotypes/lines obtained from CIMMYT

Genotype	Pedigree	Genotype	Pedigree
3001	PRL/2*PASTOR	3084	BAV92/3/PRL/SARA//TSI/VEE#5/4/WBLL1/5
3002	PBW65/2*PASTOR	3085	AGT YOUNG/5/CROC_1/AE.SUARROSA(205)
3003	QUAIU#1/KINGBIRD#1	3086	BABAX/LR42//BABAX/3/ER2000/4/KA/NAC//TRCH
3004	SUP152/BAJ#1	3088	92.001E7.32.5/SLVS/5/NS-732/HER/3/PRL/SARA
3005	WBLL1/KUKUNA/TACUPETO F2001/3FRANCOLIN#1	3091	CROC_1/AE.SUARROSA(205)//BORL95/3/PRL
3006	WHEAR//2*PRL/2*PASTOR/3/WHEAR/SOKOLL	3092	BAVIS/4/TC870344/GUI//TEMPORALERA M87/AGR
3007	KACHU*2/3/ND643//2*PRL//2*PASTOR	3093	BAVIS/4/SOKOLL/3/PASTOR//HXL7573/2*BAU
3008	KIRITATI/2*WBLL1/KIRITATI/2*TRCH/7/PASTOR	3095	KA/NAC//TRCH/5/W15.92/4/PASTOR//HXL7573
3009	FRET2*2/4/SNI/TRAP#1/3/KAUZ//2/TRAP	3096	NS-732/HER/3/PRL/SARA//TSI/VEE#5/4/FRET2
3010	ND643/2*WBLL1/ND643/2*WAXWING	3097	SOKOLL/3/PASTOR//HXL7573/2*BAU/4/NAVJ07
3012	HUHWAI/KINGBIRD#1	3098	SOKOLL/3/PASTOR//HXL7573/2*BAU
3013	PAURAQ/4/WHEAR/KUKUNA/3/C80.1/3*BATAVIA	3121	KACHU/SAUAL//PRL
3014	NELOKI/KIRITATA/2*TRCH	3128	HUW234+LR34/PRINIA*2//KIRITATI/3/KINGBIRD#1
3015	QUAIU/FRNCLN	3129	YUNMAI 48/4/2*SERI.1B*2/3/KAUZ*2/BOW//KAUZ
3016	KACHU/PRL	3130	FRET2*2/4/SNI/TRAP#1/3/KAUZ*2/TRAP//KAUZ
3017	BAJ#1/DANPHE#1	3131	MELON//FILIN/MELAN/3/FILIN/4/ROLF07/YANAC
3018	BLOUK#1/KINGBIRD#1	3132	NG8201/KAUZ/4/SHA7//PRL/VEE #6/3/FASAN

3019	PFAU/MILAN/5/CHEN/AEGILOPS SQUARROSA	3133	ROLF07/YANAC//TACUPETO F2001/BRAMBLING
3021	PFUNYE #1/KINGBIRD #1	3134	CHWINK/3/ROLF07/YANAC//TACUPETO F2001
3022	ND643/2*WAXWING// PFUNYE # 1	3135	PICAFLO #1/5/FRET2/KUKUNA//FRET2/3/YANAC
3023	KIRITATI/4/2*SERI.1B*2/3/ KAUZ*2/BOW// /KAUZ/5/	3138	PRL/2*PASTOR/6/TRAP #1/BOW/3/VEE/PJN//2*TUI
3024	KIRITATI//2*PRL/2*PASTOR/3/HUHWAI	3139	KACHU/3/PBW343*2/KUKUNA//PBW343*2/KUKUNA
3025	WAXWING/KRONSTAD F2004//PRL	3141	WBLL1*2/BRAMBLING/5/BAV92//IRENA/KAUZ
3026	KINDE/4/ HUW234+LR34/PRINIA/ /PBW343	3142	DANPHE/3/PBW343*2/KUKUNA//PBW343*2/KUKUNA
3027	SHA7/VEE#5/5/VEE#8//JUP/ BJJ/3/ F3.71/TRM	3143	BECARD/6/FRET2*2/4/SNI/TRAP #1/3/KAUZ*2/TRAP
3028	TRCH*2//WHEAR/SOKOLL	3144	NELOKI//WHEAR/KRONSTAD F2004
3029	PRL/2*PASTOR//WAXWING2*/KRONSTAD F2004	3145	ND643/2*WBLL1/3/PBW343*2/KUKUNA//PBW343*2
3030	DANPHE/2*BAJ#1	3146	KACHU/6/YAR/AE.SQUARROSA(783)/4/GOV/AZ
3032	SERI.1B*2/3/KAUZ*2/BOW//KAUZ/4/CIRCUS/5/	3147	KACHU/PAURAQ
3039	ELVIRA/5/CNDO/R143//ENTE/MEXI75/3/AE.SQ	3148	BAJ #1/PAURAQ
3061	FRNCLN*2/BECARD	3149	BAJ #1/8/NG8201/KAUZ/4/SHA7//PRL/VEE #6
3062	WBLL1*2/BRAMBLING//SAAR/2*WAXWING	3150	BAJ #1/6/WBLL1*2/4/YACO/PBW65/3/KAUZ*2/TRAP
3063	CHIBAI//PRLII/CM65531/3/MISR2, EGY*2	3153	PAURAE #1/8/NG8201/KAUZ/4/SHA7//PRL/VEE #6
3064	GRACKLE#1*2/KINGBIRD#1	3154	FRANCOLIN #1/BAJ #1
3065	BECARD/2*FRNCLN	3157	FRANCOLIN #1/ NELOKI
3066	MUNAL#1/5/2*PRL/2*PASTOR/4/CHOIX/STAR/3/	3165	MELON//FILIN/MELAN/3/FILIN/6/YAR
3067	WAXWING*2KRONSTAD F2004*2/4/PRL/2*PASTOR	3173	MUTUS*2/ KIRITATI
3068	PRL/2*PASTOR//SUNSTATE/3/MUNAL#1	3186	SUP152*2/ PFUNYE #1
3069	TILHI/PALMERIN F2004//KBIRD/3/BAJ#1	3194	CHIBIA//PRLII/CM65531/3/KAUZ/BAV92
3070	BERKUT//PBW343*2/TUKURU/3/KINGBIRD#1	3196	NAVJ07/SHORTENED SR26 TRANSLOCATION/3
3073	BECARD/3/BERKUT//PBW343*2/KUKUNA/4/OTUS	3208	ALTIGO/BAVIS//BAVIS #1
3074	SHA7//PRL/VEE#6/3/FASAM/4/HAAS8446/2*FASAN	3218	BAJ #1/3/TRCH/SRTU//KACHU
3075	MELON//FILIN/MILAN/3/FILIN/4/PRINIA/PASTOR	3219	FRANCOLIN #1/8/PBW343*2/KUKUNA/6/PVN
3076	WHEAR/SOKOLL/3/BERKUT//PBW343*2/KUKUNA	3222	CAL/NH//H567.71/3/SERI/4/CAL/NH/H567.71/5
3077	URBINA S2007*2/3/GUAM92/KAUZ/ZHENGYOU6	3226	ATTILA*2/HUITES//FINSI/3/ATTILA*2/PBW65
3078	BJY/COC//PRL/BOW/3/FRTL*2/4/QUAIU#1	3227	ATTILA*2/HUITES//FINSI/3/ATTILA*2/PBW65/4
3079	MILAN/KAUZ//BABAX/3/BAV92*2/4/BERKUT	3229	WAXWING/KIRITATI/6/PVN//CAR422/ANA/5/BOW
3081	DOY1/AE.SQUARROSA(447)/3/KA/NAC//TRCH	3230	BAV92//IRENA/KAUZ/3/HUITES/4/DOLL/5/SERI.18
3082	ZANDER-44/3/ATTILA/BAV92//PASTOR/4/NAVJ07	3233	ROLF07/YANAC//TACUPETO F2001/BRAMBLING
3083	PREMIO/2*BAVIS	3235	FRET2*2/KUKUNA*2/4/BOW/URES//2*WEAVER

Results and discussion

Results indicated that means of wheat genotypes/lines differed significantly for various plant traits studied. The mean data and their comparison are given in the table 2.

Days to heading

Days to heading ranged from 109 to 141 days. The genotypes 3032 was recorded early as it reached heading stage in 109 days comparably to genotypes 3008 which was found late where heading was completed in 141 days as showed in table 2. Other genotypes like 3092, 3006, 3062 and 3083 were also recorded earlier with 111, 112, 113 and 114 days to heading respectively. On the other hand, line 3023 which took 140 days to heading and five other genotypes like 3005, 3030, 3061, 3075 and 3081 which took 139 days to heading were observed as late. These results are significantly at par with varieties PS. 2015 and NARC-2011 used as checks. The similar results were

found by Ishaq [12] in 20 wheat genotypes where heading ranged from 116 to 133 days. The results are also in line with the finding of Jaradat [15] and Cheema [17].

Days to maturity

Days to maturity is another important parameter which provide information that whether the genotype is early or late mature. In this experiment, wheat lines showed significant variation in terms of days to maturity. The range of days to maturity was recorded from 142 to 184 days. Large variation in genotypes maturity indicate the genetic diversity among the experimental lines. Genotype 3032 took minimum days (142) to maturity while genotype 3023 was found late mature where it took 184 days to full maturity. Other lines such as 3139, 3235, 3092 and 3088 also showed close results of early maturity as these genotypes took 143, 144, 145 and 146 days to maturity respectively. Some late mature lines were 3069 and 3208 which reached to maturity

stage in 180 and 179 days respectively. The above findings are in accordance with the results of Masood [16], Ishaq [12] and Kalimullah [20] where significant variation in maturity were observed in different wheat genotypes.

Plant height (cm)

Plant height in wheat is usually positive correlated with more number of spike and high yield. Genetic analysis study observed significant variation in plant height amongst wheat genotypes in experiment (Table 2). Line 3077 was recorded the tallest as it reached to maximum height (125 cm). On the other hand, line 3002 was found with minimum height (83 cm). Other taller genotypes such as 3067, 3074, 3007 and 3165 were recorded with 122, 119, 118 and 117 cm height respectively. Genotypes 3227 and 3085 were observed as short with only 84 cm and 86 cm height respectively. The genetic variability for plant height in present experiment represented the diversity of genes responsible for plant height in wheat. Earlier report of Jamil [13], Ishaq [12], Masood [16] and Ali [21] also showed significant variation of plant height in various wheat germplasms and landraces.

Number of grains/spike

Grains per spike is considered an important yield related parameter in wheat. Highly significant variation was recorded for number of grains per spike in present experiment. Grains/spike ranged from 19 to 75. Variation in grains/spike was highly effected due to various wheat genotypes and differences in their genetic makeup. The genotype 3082 was recorded with maximum number of grains per spike (75) followed by 3032 and 3005 genotypes which produced 73 and 71 grains per spike respectively. In contrast, some experimental lines such as 3173 (19 grains/spike), 3142 (22 grains/spike) and 3069 (25 grains/spike) possessed minimum grains/spike. Similar results of grains per spike in wheat was

observed in genetic analysis study by Jamil [13] where significant variation in grains/spike was reported in 60 bread wheat genotypes. The finding of Jaradat [9], Cheema [17] and Kalimullah [20] are in great unity with these results.

Spike length (cm)

Spike length in wheat is not always positively correlated with yield. Usually large spikes contain more number of grains but occasionally instead of long spikes, some genotypes possess less number of grains in each spike. The present finding showed significant mean variation for spike length in experimental genotypes. The spike length ranged from 8.10 cm to 12.30 cm. Maximum spike length (12.30 cm) was recorded in genotype 3082 followed by 3153 genotype which produced spikes up to 11.80 cm long. Some genotypes were recorded with very short spikes such as spike length in 3173 and 3022 genotypes were only 8.10 cm and 8.20 cm respectively as shown in table 2. Majority of other lines were recorded with an average spike length from 9 to 10 cm. These results are significantly at par with varieties PS. 2015 and NARC-2011 used as checks. These results showed harmony with the findings of Masood [16], Ali [21] and Belay [23].

1000 Grain weight (g)

Grain wheat is an integral yield parameter which vary from genotype to genotype. In the present study 1000 randomly selected grains were used for grain weight. The range for grain weight was recorded from 21 to 64 gram. Genotype 3015 showed maximum weight (64 g) for 1000 seed while minimum grain weight (21 g) was recorded in genotype 3148. Similarly, genotypes 3135 and 3157 were also recorded superior with high grain weight of 61 and 60 g respectively. Masood [16] reported similar results in 298 landraces genotypes. The result of genetic diversity for grain wheat in

Iranian wheat reported by Ehdaie [22] are in accordance with the present results.

Table 2. Mean performances for various plant trait of wheat genotypes

S. No.	Genotype/Lines	Days to heading	Days to maturity	Plant height (cm)	No. of grain / spike	Spike length (cm)	1000 grain weight (g)	Biological Yield (Tons/ha)	Grain Yield (Tons/ha)	Harvest Index (%)
1	3001	136 BCD	160 BCDE	97 FGH	51 BCDE	8.60 DEF	42 DE	11.30 EFG	4.10 DEF	36.28 BC
2	3002	124 BCDE	149 EFG	83 I	59 BCD	9.20 DE	49 CDE	11.60 EFG	4.60 CDE	39.65 ABC
3	3003	130 BCD	158 BCDE	103 DEFG	64 BC	9.60 CDE	38 DEF	10.40 FG	3.70 EFG	35.57 BC
4	3004	128 CDE	152 DEFG	108 CDEF	52 BCDE	9.80 CDE	43 DE	9.30 H	1.90 IJ	20.43 DE
5	3005	139 B	174 AB	114 BCD	71 AB	9.10 DE	48 CDE	10.60 FG	3.10 FGH	29.24 CDE
6	3006	112 DEF	151 DEFG	106 DEFG	32 EFG	8.40 FG	46 CDE	10.50 FG	3.90 EFG	37.14 BC
7	3007	127 BCD	169 ABC	118 ABC	54 BCDE	9.60 CDE	42 DE	10.60 FG	3.60 EFG	33.96 BCD
8	3008	141 A	161 BCDE	105 DEFG	58 BCD	9.10 DE	44 DE	10.40 FG	3.70 EFG	35.57 BC
9	3009	134 BCD	158 BCDE	107 DEFG	51 BCDE	8.90 DEF	49 CDE	11.80 EFG	4.10 DEF	34.74 BCD
10	3010	119 CDE	153 DEFG	93 FGH	68 BC	9.50 CDE	45 CDE	10.40 FG	2.70 GH	25.96 CDE
11	3012	124 BCD	158 BCDE	102 EFG	50 BCDE	9.60 CDE	45 CDE	11.30 EFG	4.60 CDE	40.70 AB
12	3013	130 BC	154 DEFG	87 GH	53 BCDE	8.70 DEF	31 EFG	16.80 BCD	4.90 CDE	29.16 CDE
13	3014	132 BC	153 DEFG	108 CDEF	47 DEF	10.40 CD	48 CDE	9.80 GH	2.00 GHI	20.40 DE
14	3015	135 BC	167 BCD	93 FGH	53 BCDE	10.2 CD	64 A	11.40 EFG	5.10 BCD	44.73 A
15	3016	132 BCD	169 ABC	96 FGH	66 BC	9.40 DE	44 DE	10.80 FG	3.00 FGH	27.77 CDE
16	3017	125 BCDE	173 ABC	117 BCD	38 EF	10.80 BCD	49 CDE	10.70 FG	3.50 EFG	32.71 BCD
17	3018	133 BCD	150 DEFG	94 FGH	52 BCDE	9.10 DE	50 BCD	9.40 GH	2.60 GH	27.65 CDE
18	3019	129 BCDE	148 EFG	91 GH	59 BCD	8.60 DEF	44 DE	10.60 FG	2.90 GH	27.35 CDE
19	3021	121 CDEF	164 BCD	103 DEFG	57 BCD	10.90 BCD	41 DE	9.40 GH	2.70 GH	28.72 CDE
20	3022	123 CDEF	155 DEFG	109 CDEF	68 BC	8.20 FG	39 DEF	10.60 FG	3.20 FGH	30.18 BCD
21	3023	140 AB	184 A	89 GH	54 BCDE	9.00 DE	46 CDE	11.90 EFG	3.50 EFG	29.41 CDE
22	3024	115 DEF	159 BCDE	93 FGH	51 BCDE	8.70 DEF	32 EFG	10.50 FG	3.10 FGH	29.52 CDE
23	3025	133 BCD	163 BCD	115 BCD	69 BC	9.40 DE	48 CDE	10.30 FG	2.90 GH	28.15 CDE
24	3026	126 CDE	169 ABC	106 DEFG	42 DEF	9.90 CDE	54 BCD	13.90 DEF	3.40 FGH	24.46 DE
25	3027	118 DEF	157 BCDE	96 FGH	55 BCD	9.50 CDE	48 CDE	17.30 AB	5.30 BC	30.63 BCD
26	3028	130 BCDE	177 AB	90 GH	59 BCD	10.80 BCD	52 BCD	10.10 FG	2.70 GH	26.73 CDE
27	3029	134 BED	148 EFG	93 FGH	42 DEF	9.50 BCD	47 CDE	10.40 FG	2.60 GH	25.00 CDE
28	3030	139 B	151 DEFG	105 DEFG	29 EFG	10.40 CD	58 BC	9.40 GH	2.20 GHI	23.40 DE
29	3032	109 FGH	142 FGH	101 EFG	73 AB	10.90 BCD	48 CDE	14.80 CDEF	5.60 AB	37.83 BC
30	3039	122 CDEF	167 BCD	98 EFG	41 DEF	9.40 DE	47 CDE	10.30 FG	2.10 GHI	20.38 DE
31	3061	139 B	152 DEFG	89 GH	29 EFG	11.50 ABC	43 DE	15.40 CDE	3.50 EFG	22.72 DE
32	3062	113 DEFG	154 DEFG	95 FGH	54 BCDE	9.10 DE	40 DE	11.10 EFG	2.90 GH	26.12 CDE
33	3063	135 BC	168 ABC	104 DEFG	59 BCD	9.60 CDE	37 DEF	11.90 EFG	4.60 CDE	38.65 BC
34	3064	138 B	178 AB	110 CDEF	63 BC	11.20 BC	44 DE	10.30 FG	3.10 FGH	30.09 BCD
35	3065	118 DEFG	154 DEFG	117 BCD	56 BCD	9.40 DE	58 BC	10.60 FG	3.70 EFG	34.90 BC
36	3066	124 CDEF	163 BCD	91 GH	68 BC	9.70 CDE	59 BC	9.80 GH	2.40 GHI	24.48 DE
37	3067	122 CDEF	168 ABC	122 AB	61 BCD	9.10 DE	37 DEF	10.70 FG	3.10 FGH	28.97 CDE
38	3068	129 CDE	161 BCDE	100 EFG	50 BCDE	8.90 DEF	39 DEF	10.40 FG	3.00 FGH	28.84 CDE
39	3069	120 DEF	180 AB	124 AB	25 EFG	9.90 CDE	37 DEF	9.50 DEFG	2.30 FGH	24.21 CDE
40	3070	127 CDE	147 EFG	96 FGH	64 BC	9.30 DE	42 DE	10.50 FG	2.60 GH	24.76 DE
41	3073	138 BC	178 AB	113 BCD	37 EF	9.10 DE	57 BC	15.10 CDE	4.30 DEF	28.47 CDE
42	3074	136 BCD	153 DEFG	119 ABC	53 BCDE	8.70 DEF	48 CDE	13.50 DEF	3.90 EFG	28.88 CDE
43	3075	139 B	169 ABC	104 DEFG	28 EFG	10.30 CD	43 DE	9.50 GH	1.90 IJ	17.89 EF
44	3076	123 DEF	162 BCD	88 GH	61 BCD	9.70 CDE	46 CDE	16.30 BCD	3.80 EFG	23.31 DE
45	3077	129 CDE	167 BCD	125 A	35 EF	10.70 BCD	47 CDE	11.60 EFG	2.30 GHI	19.82 EF
46	3078	127 CDE	151 DEFG	114 BCD	56 BCD	9.20 DE	54 BCD	10.90 EFG	1.80 J	16.51 EFG
47	3079	125 DEF	164 BCD	111 CDEF	29 EFG	10.30 CD	57 BC	10.30 FG	2.90 GH	28.15 CDE
48	3081	139 B	162 BCD	98 EFG	30 EFG	9.70 CDE	49 CDE	10.60 FG	3.20 FGH	30.18 BCD
49	3082	121 DEFG	168 ABC	101 EFG	75 A	12.30 A	52 BCD	17.50 A	5.90 A	33.71 BCD
50	3083	114 EFGH	146 EFG	96 FGH	65 BC	9.00 DE	48 CDE	15.50 CDE	4.70 CDE	30.32 BCD
51	3084	120 DEFG	152 DEFG	92 FGH	40 AB	9.70 CDE	43 DE	9.70 GH	1.90 IJ	15.46 EFG
52	3085	138 BC	157 BCDE	86 GH	51 BCDE	11.0 BC	42 DE	10.30 FG	2.30 GHI	22.33 DE
53	3086	135 BCD	143 FGH	98 EFG	55 BCD	10.50 BCD	46 CDE	9.90 FGH	2.10 GHI	21.21 DE
54	3088	123 DEF	146 EFG	112 CDEF	58 BCD	10.30 CD	34 EFG	13.70 DEF	3.50 EFG	25.54 CDE
55	3091	129 DEFG	170 ABC	109 CDEF	63 BC	9.50 CDE	47 CDE	10.40 FG	2.20 GHI	21.15 DE
56	3092	111 EFGH	145 EFG	98 EFG	56 BCD	10.80 BCD	38 DEF	12.00 DEF	3.10 FGH	25.83 CDE

57	3093	132 BCDE	150 DEFG	110 CDEF	65 BC	9.10 DE	46 CDE	10.50 FG	2.90 GH	27.61 CDE
58	3095	128 CDE	165 BCD	104 DEFG	46 DEF	9.50 CDE	49 CDE	14.30 CDEF	4.10 DEF	28.67 CDE
59	3096	124 CDE	149 EFG	95 FGH	42 DEF	10.60 BCD	52 BCD	11.60 EFG	3.40 FGH	29.31 BCD
60	3097	139 B	167 BCD	104 DEFG	58 BCD	10.40 CD	50 BCD	10.40 FG	2.80 GH	26.92 CDE
61	3098	117 DEFG	151 DEFG	93 FGH	45 DEF	8.90 DEF	44 DE	10.70 EFG	3.20 FGH	29.90 BCD
62	3121	122 CDEF	149 EFG	91 GH	59 BCD	9.30 DE	43 DE	9.70 EFG	2.30 GHI	23.71 DE
63	3128	126 CDEF	158 BCDE	99 EFG	43 DEF	9.70 CDE	48 CDE	10.10 FG	2.40 GHI	23.76 DE
64	3129	120 DEF	166 BCD	108 CDEF	57 BCD	9.50 CDE	36 DEF	10.90 EFG	2.77 GH	25.41 CDE
65	3130	128 CDE	163 BCD	116 BCD	66 BC	9.70 CDE	54 BCD	14.60 CDEF	3.60 EFG	24.65 DE
66	3131	132 CD	169 ABC	93 FGH	31 EF	10.10 CD	57 BC	12.40 DEF	2.50 GH	20.16 DEF
67	3132	125 CDE	152 DEFG	92 FGH	53 BCDE	10.60 BCD	42 DE	11.30 DEFG	3.70 EFG	32.74 BCD
68	3133	135 BC	158 BCDE	113 BCD	60 BCD	9.90 CDE	27 FG	10.70 EFG	2.40 GHI	22.42 DE
69	3134	133 BCD	150 DEF	104 DEFG	64 BC	9.50 CDE	44 DE	16.30 BCD	4.30 DEF	26.38 CDE
70	3135	130 BC	153 DEF	118 ABC	38 EF	9.70 CDE	61 AB	14.70 CDE	3.70 EFG	25.17 CDE
71	3138	123 CDE	167 BCD	105 DEFG	59 BCD	9.30 DE	57 BC	11.10 EFG	2.50 GH	22.52 DE
72	3139	136 BC	143 FGH	108 CDEF	53 BCDE	10.20 CD	52 BCD	16.50 BCD	3.90 EFG	23.63 DE
73	3141	138 BC	147 EFG	116 BCD	59 BCD	10.00 CD	59 BC	10.40 FG	2.80 GH	26.92 CDE
74	3142	126 DEF	153 DEFG	87 GH	22 EFG	8.70 DEF	43 DE	10.50 DEF	2.20 FGH	20.95 CDE
75	3143	137 BC	164 BCD	103 DEFG	55 BCD	9.90 CDE	47 CDE	9.90 GH	2.10 GHI	21.21 DE
76	3144	132 BCD	166 BCD	97 FGH	64 BC	8.90 DEF	32 EFG	10.30 FG	1.85 J	14.17 G
77	3145	137 BCD	168 ABC	114 BCD	65 BC	10.70 BCD	53 BCD	10.40 FG	2.10 GHI	20.19 DEF
78	3146	131 CDE	165 BCD	111 CDEF	54 BCDE	9.30 DE	44 DE	11.50 DEFG	2.70 GH	23.47 DE
79	3147	126 CDEF	172 ABC	89 GH	32 EF	9.00 DE	49 CDE	11.90 DEF	2.50 GH	21.00 DE
80	3148	129 CDEF	147 EFG	100 EFG	56 BCD	9.40 DE	21 I	16.40 BCD	4.20 DEF	25.60 CDE
81	3149	138 BCD	156 BCDE	106 DEFG	62 BCD	9.70 CDE	46 CDE	10.60 EFG	1.90 IJ	17.92 EF
82	3150	124 DEF	154 DEFG	91 GH	49 DEF	8.90 DEF	42 DE	10.70 EFG	2.90 GH	27.10 CDE
83	3153	119 EFG	168 ABC	94 FGH	70 AB	11.80 AB	43 DE	13.10 DEF	3.20 FGH	24.42 DE
84	3154	138 BC	154 DEFG	98 EFG	55 BCD	9.50 CDE	49 CDE	12.70 CDE	3.20 FGH	25.19 CDE
85	3157	111 EFGH	163 BCD	87 GH	58 BCD	10.30 CD	60 BC	10.50 FG	2.30 GHI	21.90 DE
86	3165	129 DEF	160 BCDE	117 ABC	53 BCDE	9.70 CDE	57 BC	17.40 AB	5.50 AB	31.60 BCD
87	3173	135 BCD	169 ABC	101 EFG	19 H	8.10 G	46 CDE	10.40 FG	2.20 GHI	21.15 DE
88	3186	137 BC	151 DEFG	89 GH	46 DEF	10.10 CD	32 EFG	9.80 GH	2.10 GHI	21.42 DE
89	3194	131 CDE	174 AB	115 BCD	48 DEF	8.80 DEF	44 DE	10.70 EFG	2.50 GH	23.36 DE
90	3196	124 DEF	168 ABC	103 DEFG	54 BCDE	9.90 CDE	43 DE	11.60 DEFG	3.50 EFG	30.17 BCD
91	3208	129 CDEF	179 AB	97 FGH	58 BCD	9.60 CDE	49 CDE	10.70 EFG	2.40 GHI	22.42 DE
92	3218	120 DEFG	165 BCD	94 FGH	67 BC	9.00 DE	46 CDE	14.20 CDEF	3.70 EFG	26.05 CDE
93	3219	132 CDE	158 BCDE	96 FGH	63 BC	9.50 CDE	53 BCD	11.60 DEFG	3.10 FGH	26.72 CDE
94	3222	127 CDE	152 DEFG	104 DEFG	56 BCD	10.70 BCD	56 BC	10.50 FG	2.70 GH	25.71 CDE
95	3226	130 BCD	163 BCD	105 DEFG	69 BC	9.50 CDE	41 DE	10.20 FG	2.40 GHI	23.52 DE
96	3227	132 BCD	166 BCD	84 HI	42 DEF	9.90 CDE	50 BCD	13.40 DEF	3.20 FGH	23.88 DE
97	3229	135 BC	152 DEFG	91 GH	35 EF	10.50 BCD	38 DEF	12.70 DEFG	2.40 GHI	23.30 DE
98	3230	135 BC	154 DEFG	97 FGH	55 BCD	9.50 CDE	46 CDE	10.50 FG	2.80 GH	26.66 CDE
99	3233	121 DEFG	148 EFG	92 FGH	48 DEF	9.10 DE	51 BCD	9.50 GH	2.30 GHI	24.21 CDE
100	3235	129 CDE	144 FGH	102 EFG	54 BCDE	9.30 DE	39 DEF	9.40 GH	2.45 GHI	26.06 CDE
Check	PS. 2015	122 BC	157 BCDE	105 BCD	53 BCDE	9.80 CDE	48 DEF	14.60 CDE	4.80 CDE	32.87 BCD
Check	NARC-2011	126 BCD	162 DEFG	111 BCD	59 BCD	10.30 ABC	53 DE	15.40 BCD	5.10 DEF	33.11 CDE
LSD 0.05		3.53	4.10	2.45	12.54	3.98	8.36	6.76	2.19	1.38
CV %		4.56	2.17	9.65	6.34	1.34	3.65	4.98	7.43	10.51

Biological yield (tons/ha)

Biological yield showed significant variation. The differences in mean variation was due to highly genetic variation in experimental genotypes. Biological yield ranged from 9.30 to 17.50 tons/ha. The maximum (17.50 tons/ha) and minimum (9.30 tons/ha) biological yield was observed for genotypes 3082 and 3004 respectively. Other genotypes like 3165, 3013 and 3148

were also recorded as a promising with high biological yield 17.40, 16.80 and 16.40 tons/ha respectively. Similar results were showed by varieties PS. 2015 and NARC-2011 used as a checks (Table 2). These outcomes are in great harmony with the findings of Ishaq [12] where biological yield was reported from 11.80 to 16.66 tons/ha in twenty wheat genotypes. Masood [16]

recorded significant variation for biological yield in different wheat landraces.

Grain yield (tons/ha)

Grain yield is one of the important and most desirable parameter of crop plant. It is quantitative trait which greatly affected by various genetic and environmental factors. Grain yield usually depends on other yield related physiological characters of plant. Variation in grain yield are due to genetic diversity of plant materials studied. In the present experiment highly significant variation was recorded for grain yield. The observed genetic variation in grain yield, under the same experimental conditions, represents the high diversity in genetic makeup of wheat genotypes studied. The grain yield ranged from 1.80 to 5.90 tons/ha (Table 2). The line 3082 gave the highest yield (5.90 tons/ha) and was superior amongst all genotypes. Grain yield of two other promising lines 3032 and 3015 was recorded up to 5.60 and 5.10 tons/ha respectively. These lines were statistically at par with high yielding varieties PS. 2015 and NARC-2011 used as checks in the experiment. In contrast, least grain yield was produced by line 3078 (1.80 tons/ha) and 3004 (1.90 tons/ha) which was considered poor genotypes in this experiment. Overall, the genotypes 3082, 3032 and 3015 were the most promising and superior throughout the experiment and therefore, it is suggested that these genotypes may be included in future wheat breeding program. Similar results of grain yield were found by Ishaq [12], Cheema [17], Masood [16], Jaradat [15], Ali [21] and Ehdaie [22].

Harvest index (%)

Harvest index was measured in percent by a formula such as grain yield/biological yield x 100. The harvest index ranged from 14.17 to 44.73 % as shown in table 2. Genotype 3015 was observed with highest (44.73 %) harvest index while germplasm 3144 showed minimum (14.17 %) harvest index.

Variation in harvest indices were due to differences in biological and grain yield of tested genotypes. Genotypes with more harvest index and more grain yield were considered superior genotypes. As stated above the genotypes 3082, 3032 and 3015 showed promising results and performed efficiently among all genotypes tested in this experiment.

Conclusion

From the genetic variability analysis of 100 different wheat genotypes, it is concluded that the germplasms 3082, 3032 and 3015 remained superior in term of yield production as well as in other important yield components. It is, therefore suggested that these lines may be brought forward and included in wheat breeding program across the various ecological zones of the country.

Authors' contributions

Conceived and designed the experiments: M Ghaffar, Performed the experiments: M Ghaffar, Analyzed the data: S Khan & W Khan, Contributed materials/ analysis/ tools: M Ghaffar, Wrote the paper: S Khan, M Ghaffar & W Khan.

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