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Determination of extent of variability in wheat germplasm using augmented randomized block design

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Abstract

Low level of gene pool variation exhibited by modern wheat cultivars may be due to the use of narrow genetic base in breeding programmes and also due to environment conditions. The presence of ample genetic diversity in the base material causes better chance of evolving desirable plant types. Yield is a complex polygenic character and is resultant of interactions of several genetic and environmental factors, hence it requires continuous improvement involving the diverse material. The present investigation was carried out in *rabi* season, 2015-16 at N.E. Borlaug Crop Research Centre, G. B. Pant Univ. of Agriculture & Technology, Pantnagar. The experimental materials for the present investigation comprised of 180 germplasm accessions and four checks, namely, WH 1105, DPW 621-50, PBW 343 and Agra Local. These genotypes were evaluated in augmented block design and observations were recorded for 15 characters *viz.*, days to 75% heading, days to maturity, plant height, number of tillers per meter, peduncle length, spike length, number of spikelets per spike, number of grains per spike, grain weight per spike, 1000 grain weight, biological yield, grain yield, harvest index, protein content and test weight. Variance (mean sum of squares) was found highest for biological yield followed by grain yield. The coefficient of variability was found to be the highest for grain yield and lowest for test weight. On the basis of findings of the study, six desirable donors for each character were identified on the basis of character mean. IC-532150, IC-82219, IC-753957, IC-58012 and IC-532931 were found to be the most promising donor genotypes for grain yield. These genotypes can be used for future breeding programme to improve the yield potential of the variety. For other characters, genotypes can be picked up from different groups, formed on the basis of their ranking

Keywords: Wheat, genetic variability, augmented RBD, agro-morphological traits, quality traits

Introduction

Wheat (*Triticum aestivum* L. em. Thell) is an allohexaploid crop ($2n = 6x = 42$) belonging to family Graminae (Poaceae). Owing to high nutrient content and suitability to all agro-ecological regions, wheat is considered as the king of all cereals crops. It contributes almost 1/3rd of the total food grain production all over the globe and is a critical source of energy, protein and dietary fiber in human nutrition. It provides 20 per cent of energy and 25 per cent of protein in human diet. Besides, it is an essential crop on account of the real estate, it possesses high profitability and productivity and coveted position it holds in the global food grain trade.

Grain yield is a complex trait and highly influenced by many genetic factors and environmental fluctuations. The success of a breeding programme depends upon the presence of genetic variability in a material in hand. Therefore, the assessment and use of genetic variability in desired direction is crucial in any crop improvement programme.

Evaluation of genetic diversity among adapted, elite germplasm can provide predictive estimates of genetic variation among segregating progeny for pure-line cultivar development. Knowledge about germplasm diversity and genetic relationships among breeding material could be an invaluable aid in crop improvement strategies (Mohammadi *et al.* 2012) [7] and study of the genetic diversity in bread wheat is important for breeding and genetic resource conservation programs.

Precise information on the nature and degree of genetic diversity helps the plant breeder in choosing the diverse parents for purposeful hybridization. Several genetic diversity studies have been conducted on different crop species based on quantitative and qualitative traits in order to select genetically distant parents for hybridization. The more genetic diverse the

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parents, more are the chances of obtaining higher heterotic expression in F_1 's and broad spectrum of variability in segregating population. Naik *et al.* (2014) [8] reported that the character contributing maximum to the divergence should be given greater emphasis for deciding the type of cluster for purpose of further selection and the choice of parents for hybridization. Considering such importance of genetic diversity for crop improvement programmes, the present investigation was carried out to analyze the genetic diversity for various agro-morphological and quality traits in a large germplasm pool of 180 lines of wheat.

Materials and Methods

The present investigation was conducted at the N.E. Borlaug Crop Research Centre, G.B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand; during *Rabi* season 2015-2016 and quality analysis in wheat laboratory, Department of Genetics and Plant Breeding, G.B. Pant University of Agriculture and Technology, Pantnagar.

The experimental material consisted of 180 germplasm lines of bread wheat along with four prominent checks (WH 1105, DPW 621-50, PBW 343 and Agra Local) obtained from National Bureau of Plant Genetic Resources (NBPGR), New Delhi. The germplasm lines along with checks were evaluated during *Rabi* season of 2015-2016. The experiment was carried out in an Augmented Randomized Block Design with each block containing 35 test entries and 4 checks (randomly allocated) with the total of 39 genotypes in each block. Each genotype was sown in two rows of 2 meter length with a row spacing of 20 cm. Recommended package of practices was followed to grow the normal healthy crop.

Observations were recorded on different qualitative and quantitative traits *viz.*, days to 75% heading, days to maturity, plant height (cm), peduncle length (cm), number of tillers per running meter, spike length (cm), number of spikelets per spike, number of grains per spike, grain weight per spike (g), 1000 grain weight (g), biological yield (g), grain yield per plot (g), harvest index (%) and quality traits including protein content (%) and test weight (kg/hl)

For augmented block design analysis of variance was done by using the method given by Federer (1961 and 1975) [4,5].

Least significant differences (LSD's) were computed using the variance in the following way:

$$1. \text{ For the check means} = t \sqrt{\frac{2MSE}{b}}$$

$$2. \text{ For the two adjusted new selections in the same block} = t \sqrt{2MSE}$$

$$3. \text{ For two adjusted new selections in different blocks} = t \sqrt{\frac{2MSE(c+1)}{c}}$$

$$4. \text{ For an adjusted genotype against check means} = t \sqrt{\frac{MSE(b+1)(c+1)}{bc}}$$

For all LSD's, the 't' value at ($p=0.05$) and error degree of freedom will be used. The analysis gave adjusted values for all characters in each genotype. Further, classificatory analysis was done on these adjusted values of variables.

Results and Discussion

The knowledge about nature and amount of genetic diversity is of utmost importance for a systematic breeding effort. The presence of ample genetic diversity in the base material causes better chance of evolving desirable plant types. Yield is a complex polygenic character and is resultant of

interactions of several genetic and environmental factors hence it requires continuous improvement involving the diverse material.

In the present investigation, the analysis of variance was carried out for 16 characters *viz.*, days to 75% heading, days to maturity, plant height, number of tillers per meter, peduncle length, spike length, number of spikelets per spike, number of grains per spike, grain weight per spike, 1000 grain weight, biological yield, grain yield, harvest index, protein content and test weight of genotypes in augmented block design (Table 1). The analysis of variance depicted significant differences among genotypes for all the characters studied. Variance (mean sum of squares) was found highest for biological yield followed by grain yield, number of tillers per meter, peduncle length, plant height, test weight and days to maturity. The adjusted means are presented in Table 2:

The basic requirement for any crop improvement programme is the availability of genetic variation. Greater the variability in the experimental material, higher is the chance of recovering improved lines. The above mentioned results of the present investigation reveal the abundance of genetic variability in the germplasm pool (180 lines) of wheat for all the characters. Biological yield, grain yield and number of tillers per meter exhibited maximum variance followed by peduncle length, plant height, test weight and days to maturity. Low amount but significant variance was showed by ear length, grain weight per spike and protein content. These results are in agreement with the findings of Kumar and Kumar (1983) [6], Shah *et al.* (2003) [9], Asif *et al.* (2004) [1] and Baranwal *et al.* (2012) [3]. Traits like grain yield, number of tillers per meter must be given due importance while practicing selection in wheat improvement programmes.

Estimation of variability

The mean, range of variation and least significant differences for various characters studied during the course of investigation are mentioned in Table 3. The character-wise results are discussed below:

Days to 75% heading

Days to 75% heading ranged from 82.20 to 104.01 with general mean of 91.24 days. Coefficient of variation was found to be 2.78 per cent. Minimum number of days to 75% heading were recorded in IC-82219 (82.20) followed by IC-78924 (82.26) and IC-73351 (83.20), whereas the maximum was found in genotype IC-79005 (104.01).

Days to maturity

This character ranged from 120.9 to 152.4 days with general mean of 134.87 days. Coefficient of variation for this character was found to be 3.18 per cent. Genotype IC-78924 took least number of days to maturity (120.9 days) followed by IC-534430 and IC-532472 (122.9 days). The maximum number of days to maturity were taken by the genotype IC-38870 (152.4 days).

Plant height (cm)

Plant height ranged from 72.35 to 149.35 cm with general mean of 105.42. The coefficient of variation for this character was found to be 8.11 per cent. The most dwarf genotype was found to be IC-78938 (72.35 cm) followed by IC-55636 (73.22 cm) and IC-534820 (80.35 cm). The tallest genotype was IC-61836 (149.35 cm).

Number of tillers per meter

It varied from 28.75 to 242.75 with a general mean of 116.43. Coefficient of variation for this character was observed to be 20.6 per cent. The genotype IC-73683 produced maximum number of tillers (242.75) followed by IC-532373 (217) and IC-594790 (201).

Peduncle length (cm)

The character showed a range from 17.14 to 74.43 cm with a mean value of 41.08 cm. Coefficient of variation for this character was observed to be 10.16 per cent. Peduncle length was highest for genotype IC-75353 (74.43 cm) and lowest for IC-532809 (17.14 cm).

Spike length (cm)

It ranged from 7.40 to 17.84 cm with genotype IC-532409 showing smallest ear (7.40 cm) and genotype IC-60208 showing the maximum ear length (17.84 cm). The coefficient of variation for this trait was found to be 8.87 per cent.

Number of spikelets per spike

The trait showed a general mean of 20.82 with a range from 12.90 to 28.60. The genotypes IC-138729 and IC-73497 had highest number of spikelets per spike (28.60) whereas, the lowest were found for the genotype IC-534870 (12.90). The coefficient of variation for this character was 9.79 per cent.

Number of grains per spike

It ranged from 16.20 to 81.42 with a mean value of 48.10. The coefficient of variation for the character was found to be 8.56%. The genotype IC-532245 exhibited highest number of grains per spike (81.42) followed by IC-532212 (79.07) and IC-55636 (78.62).

Grain weight per spike (g)

The trait showed a general mean of 2.18 g with a range from 0.77 to 5.30 g. The genotype IC-78962 exhibited highest grain weight per spike (5.30 g) followed by IC-79056 (5.26 g) and IC-75321 (4.50 g). The coefficient of variation for this character was found to be 17.52 per cent.

Thousand grain weight (g)

1000 grain weight ranged from 20.27 to 67.40 g with general mean of 40.26 g. The coefficient of variation for this character was found to be 8.19 per cent. The maximum 1000 grain weight was exhibited by the genotype IC-532931 (67.39 g) followed by IC-138846 (61.00 g) and IC-5324208 (60.70 g) whereas; the lowest value was exhibited by genotype IC-28637 (20.27 g).

Biological yield (g)

Biological yield ranged from 223.90 to 2632.40 grams per meter with a mean value of 995.47. Coefficient of variation was found to be 15.14 per cent. Maximum biological yield was recorded in the genotype IC-532150 (2632.40) followed by IC-82219 (2532.40) and IC-532420 (2294.90).

Grain yield (g)

This trait showed a general mean of 273.31 g with a range from 77.85 to 964.00 g. The coefficient of variation for this character was found to be 27.47 per cent. Maximum grain yield was recorded in the genotype IC-532150 (964.60 g) followed by IC-82219 (883.60 g) and IC-753957 (587.85 g).

Harvest Index (%)

Harvest index ranged from 10 to 68% with general mean of 29%. The coefficient of variation for this character was found to be 18.62 per cent. The maximum harvest index was exhibited by the genotype IC-532152 (68%) followed by IC-79022 (65%) and IC-75354 (63%).

Test weight (Kg/hl)

It ranged from 61.10 to 88.11 Kg/hl with genotype IC-532420 having maximum value followed by IC-532463 (82.91 Kg/hl) and IC-532952 (82.58 Kg/hl). The lowest hectoliter weight was recorded in genotype IC-73650. The coefficient of variation for this character was found to be 2.63 per cent.

Protein content (%)

The mean value of this character was found to be 11.67% with a range of 9.32 to 14.88%. Genotype IC-208906 exhibited highest protein content followed by IC-73650 (14.48%) and IC-75353 (14.12%). The coefficient of variation for this character was found to be 4.82%.

The results showed that the coefficient of variation (CV) was found to be highest for grain yield (27.47) followed by number of tillers per meter (20.6), harvest index (18.62), grain weight per spike (17.52) and biological yield (15.14).

Least significant difference between means of two check varieties (CM)

It was found to be highest for biological yield (218.46) followed by grain yield (108.49), number of tillers per meter (34.71), plant height (12.34) and days to maturity (6.18). The other characters exhibited quite lesser values of CM.

Least significant difference between the adjusted value of two selections in the same block (AVSB)

It was found to be highest for biological yield (546.16) followed by grain yield (271.23), number of tillers per meter (86.79), plant height (30.84), days to maturity (15.45), peduncle length (15.04) and number of grains per spike (14.99).

Least significant difference between the adjusted value of two selections in the different blocks (AVDB)

This was observed to be highest for biological yield (488.5) followed by grain yield (242.59), number of tillers per meter (77.62), plant height (27.59), days to maturity (13.82), peduncle length (13.46) and number of grains per spike (13.41).

Least significant difference between an adjusted selection value and a check mean (AVAC)

It was found to be highest for biological yield (423.05) followed by grain yield (210.09), number of tillers per meter (67.22), plant height (23.89), days to maturity (11.97), peduncle length (11.65) and number of grains per spike (11.62).

From the above results, it is clear that a wide range of variation was observable in the genotypes for most of the characters. A high magnitude of coefficient of variability was recorded for characters like biological yield, grain yield, number of tillers per meter, plant height, days to maturity, peduncle length and number of grains per spike. These results are in concordance with the reports of Bametha (1989) [2], Singh (1989) [11], Sultana and Malik (2005) [12], Shankarrao *et al.* (2010) [10].

Table 1: Analysis of variance for different characters in germplasm of wheat using Augmented RBD

a	Characters	Mean Sum of Squares (df)		
		Block (4)	Check (3)	Error (12)
1	Days to 75% heading	96.55**	11.64	7.56
2	Days to maturity	159.93**	16.33	21.63
3	Plant height (cm)	284.80*	613.15**	86.21
4	No. of tillers per meter	3456.26*	4405.92**	364.34
5	Peduncle length (cm)	609.12**	70.30	20.51
6	Spike length(cm)	8.99**	2.09	1.24
7	No. of spikelets per spike	116.54**	1.92	1.92
8	No. of grains per spike	115.65**	48.99	20.37
9	Grain weight per spike (g)	7.88**	0.94*	0.18
10	Thousand grain weight (g)	104.04**	54.49*	12.95
11	Biological yield (g)	387325.47**	339618.87	79460.91
12	Grain yield (g)	22695.41*	4988.27	5273.64
13	Harvest index	0.05**	0.0012	0.0035
14	Test weight (Kg/hl)	196.87**	6.92	4.73
15	Protein content (%)	3.32**	0.46	0.37

**Significantly different at 1% level of significance; *Significantly different at 5% level of significance

Table 2: Adjusted means of different genotypes of wheat evaluated under Augmented Randomized Block Design

Genotypes	Days to 75% heading	Days to maturity	Plant height (cm)	Number of tillers	Peduncle length (cm)	Spike length (cm)	Number of spikelet per spike	Number of grains per spike	Grain weight per spike (g)	1000-grain weight (g)	Protein content (%)	Hectoliter weight (Kg/hl)	Biological yield (g)	Harvest index	Grain yield (g)
IC-78962	95.763	139.400	106.663	139.250	33.185	12.503	20.400	69.798	5.301	39.004	11.628	81.338	407.900	0.446	201.850
IC-82189	90.763	137.400	123.413	133.250	40.185	11.003	21.100	25.398	2.467	53.731	9.807	81.458	401.900	0.563	255.850
IC-79022	98.013	142.400	114.913	107.250	28.185	11.503	23.100	66.798	4.001	36.061	11.798	81.828	364.900	0.657	275.850
IC-41504	92.763	140.400	98.913	123.250	30.685	10.403	20.400	56.398	3.491	51.304	10.778	79.468	297.900	0.561	193.850
IC-532952	90.763	134.400	105.913	143.250	40.685	9.753	20.400	49.598	2.825	44.653	11.818	82.588	515.900	0.495	281.850
IC-138868	90.513	132.400	105.413	112.250	34.685	10.253	23.100	58.398	2.835	38.276	13.508	80.408	277.900	0.438	137.850
IC-82162	94.263	137.400	95.913	138.250	31.285	12.503	27.100	61.598	3.601	32.463	12.018	79.568	777.900	0.432	363.850
IC-138846	95.013	138.400	139.913	162.250	42.185	9.753	18.400	21.398	3.189	61.004	12.288	73.128	577.900	0.522	331.850
IC-78851	95.763	139.400	97.913	148.250	32.185	10.753	23.100	46.198	2.067	31.308	12.098	76.008	287.900	0.566	189.850
IC-79082	100.263	145.400	105.579	139.250	34.085	11.536	21.100	69.398	3.737	45.483	12.058	80.898	1777.900	0.237	455.850
IC-59555	92.763	139.400	107.913	133.250	39.185	10.003	20.400	40.198	1.949	32.840	12.638	77.208	737.900	0.461	368.850
IC-78812	96.013	145.400	100.413	137.250	34.185	12.003	19.100	41.398	2.459	44.361	12.498	79.188	1120.900	0.276	326.850
IC-532128	96.763	146.400	108.413	111.250	40.185	13.503	20.400	20.398	2.037	49.889	12.018	74.428	1173.900	0.206	259.850
IC-532463	94.263	137.400	120.913	109.250	39.185	12.253	21.100	53.398	2.899	42.954	12.218	82.918	1249.900	0.164	221.850
IC-532296	101.763	147.400	88.913	146.250	37.185	13.753	21.100	43.398	2.501	43.343	12.838	74.598	1266.900	0.097	133.850
IC-75394	93.513	136.400	127.413	165.250	53.685	12.503	21.100	55.398	2.773	60.346	12.638	76.828	979.900	0.189	197.850
IC-532384	94.763	137.400	103.413	133.250	38.185	11.503	20.400	38.548	3.351	44.733	13.248	78.068	989.900	0.189	199.850
IC-59553	92.013	134.400	114.913	128.250	29.685	9.253	21.100	37.698	2.401	47.059	13.938	76.898	817.900	0.159	135.850
IC-753957	95.763	139.400	130.413	143.250	45.685	10.003	19.100	68.128	3.035	35.943	12.358	82.268	1651.900	0.332	587.850
IC-532066	94.763	137.400	109.413	136.250	38.685	12.003	19.100	33.598	1.707	31.784	13.568	77.938	877.900	0.229	213.850
IC-36857	91.763	132.400	131.413	83.250	44.685	11.503	25.100	23.398	1.061	42.816	13.498	81.288	737.900	0.237	185.850

IC-82835	101.763	147.400	120.413	119.250	35.185	13.003	21.100	43.398	2.351	39.855	13.078	79.988	585.900	0.255	157.850
IC-532948	91.763	133.400	100.413	184.250	26.685	12.303	19.100	67.198	2.901	34.417	11.308	73.358	661.900	0.323	229.850
IC-532311	101.763	147.400	106.413	103.250	37.185	12.253	20.400	42.398	2.983	55.816	10.858	78.078	807.900	0.296	255.850
IC-532315	89.763	146.400	114.413	154.250	33.685	13.253	21.100	34.398	2.001	39.718	12.958	76.448	1169.900	0.206	259.850
IC-75321	96.763	140.400	111.413	175.250	24.935	13.953	23.100	49.398	4.501	38.217	11.218	76.168	1057.900	0.187	211.850
IC-532966	96.763	144.400	128.913	104.250	46.385	11.153	20.400	50.198	3.741	42.447	12.578	79.838	639.900	0.323	221.850
IC-104547	98.763	143.400	101.413	148.250	37.685	13.253	21.100	46.398	2.563	41.961	13.328	76.628	691.900	0.297	219.850
IC-38870	100.763	152.400	99.413	134.250	37.685	10.503	15.100	30.398	1.733	35.883	11.568	77.618	1177.900	0.230	291.850
IC-75356	97.763	139.400	120.413	137.250	46.685	13.253	23.100	39.398	2.593	49.996	12.768	79.678	555.900	0.262	153.850
IC-79005	104.013	150.400	122.913	113.250	40.685	9.503	21.100	17.398	0.771	44.949	11.918	77.318	223.900	0.329	79.850
IC-532376	95.763	139.400	107.413	133.250	31.185	11.753	23.100	44.198	2.453	41.483	13.718	78.228	815.900	0.348	305.850
IC-82247	94.263	137.400	102.913	123.250	35.685	11.253	21.100	36.398	2.025	38.261	12.398	74.848	593.900	0.329	209.850
IC-532967	95.013	138.400	103.913	123.250	38.185	12.253	23.100	56.398	3.323	48.304	11.558	76.798	275.900	0.479	151.850
IC-79036	95.763	139.400	109.913	128.250	38.935	10.753	22.100	42.998	2.381	40.919	11.168	75.218	315.900	0.323	109.850
IC-75359	100.263	145.400	99.163	121.250	44.685	12.003	25.100	50.098	2.622	40.195	11.848	77.418	633.900	0.340	231.850
IC-75317	90.700	132.650	100.050	145.250	42.635	10.828	22.900	40.998	1.178	37.928	12.775	77.860	668.400	0.409	251.600
IC-55588	98.200	142.650	102.500	122.250	51.035	10.178	23.600	26.198	2.058	36.320	12.295	76.240	760.400	0.371	263.600
IC-532308	91.200	134.650	113.150	187.250	57.535	10.728	20.900	30.198	3.186	32.320	12.095	80.820	1264.400	0.385	455.600
IC-532336	94.450	137.650	95.450	103.250	56.785	8.628	23.600	46.198	3.898	45.820	11.995	76.560	942.400	0.349	309.600
IC-58012	88.450	129.650	106.550	68.250	53.535	9.578	21.600	53.198	2.864	53.229	12.725	81.870	1232.400	0.435	499.600
IC-78938	89.200	136.650	72.350	96.250	41.085	9.428	19.600	44.998	3.922	40.055	14.115	77.770	704.400	0.444	285.600
IC-534562	94.450	137.650	97.150	92.250	64.935	14.278	21.600	61.598	2.500	46.863	13.485	73.190	2176.400	0.179	366.600
IC-532279	93.200	138.650	96.350	144.250	54.435	11.378	21.600	54.198	1.958	27.356	12.385	76.370	1222.400	0.184	221.600
IC-75353	94.200	140.650	131.350	96.250	84.435	14.278	21.600	32.998	2.308	27.033	14.125	78.130	1292.400	0.210	263.600
IC-532313	91.200	134.650	125.350	131.250	74.235	12.278	22.900	36.398	1.488	33.996	13.085	78.520	1692.400	0.181	293.600
IC-532330	89.450	132.650	116.350	121.250	60.185	11.278	18.900	35.198	2.082	35.961	10.955	73.870	1132.400	0.291	313.600
IC-82210	86.450	128.650	103.350	133.250	60.935	11.378	19.600	56.398	1.974	33.277	11.545	71.240	1232.400	0.225	268.600
IC-532732	90.950	134.650	107.350	110.250	60.935	10.678	15.600	40.798	1.758	42.383	10.955	78.370	932.400	0.371	323.600
IC-532855	87.200	129.650	99.350	168.250	60.435	12.178	20.900	34.198	2.442	44.005	11.245	71.560	1082.400	0.289	298.600
IC-55601	86.450	128.650	129.850	111.250	73.935	9.378	23.600	55.198	1.960	40.049	13.645	73.870	1134.400	0.325	348.600
IC-32586	90.950	134.650	85.350	104.250	47.935	10.728	17.600	51.798	2.472	33.810	12.405	62.530	1134.400	0.236	259.600
IC-59577	87.200	129.650	97.350	102.250	56.085	9.678	25.600	58.598	1.428	38.365	11.305	75.420	750.400	0.234	175.600
IC-82219	82.200	130.650	136.350	134.250	67.435	11.378	24.900	34.198	2.018	35.320	11.545	73.340	2532.400	0.371	883.600
IC-532800	90.950	134.650	106.850	86.250	55.935	12.278	27.600	43.198	1.212	41.171	11.545	74.280	732.400	0.371	253.600
IC-61836	89.200	128.650	149.350	143.250	68.435	11.278	24.900	27.598	1.300	35.798	11.095	73.370	1732.400	0.235	385.600
IC-73351	83.200	127.650	123.850	135.250	63.435	11.228	22.900	32.798	1.608	33.162	11.135	74.470	1332.400	0.246	313.600
IC-532112	87.200	129.650	90.850	113.250	56.435	10.078	21.600	41.198	2.714	33.876	10.995	73.480	1132.400	0.271	293.600
IC-532931	87.950	130.650	112.850	141.250	58.435	13.078	19.600	35.198	1.038	67.397	11.185	77.830	1332.400	0.374	467.600
IC-532390	88.700	131.650	101.350	83.250	58.435	13.778	21.600	18.198	1.928	36.474	11.395	75.440	1432.400	0.282	383.600
IC-534481	92.450	136.650	115.350	103.250	63.435	10.278	22.900	39.798	1.672	42.293	14.025	76.360	1232.400	0.177	215.600
IC-534432	90.950	134.650	93.150	88.250	57.435	11.028	21.600	29.198	3.134	48.017	13.865	74.320	1332.400	0.226	289.600
IC-78867	91.700	135.650	99.517	129.250	38.835	10.311	17.600	65.198	2.156	44.320	11.455	77.970	1632.400	0.203	317.600
IC-534820	90.200	133.650	80.350	121.250	30.435	8.778	15.600	50.798	1.832	38.013	11.315	74.370	1032.400	0.354	343.600
IC-82461	86.450	128.650	95.850	133.250	42.935	9.028	18.600	45.198	1.896	35.708	13.115	75.470	1932.400	0.237	433.600
IC-35057	85.700	127.650	94.850	104.250	41.435	10.428	17.600	44.998	2.136	37.165	11.795	74.420	1022.400	0.470	443.600
IC-532963	93.200	141.650	80.850	148.250	30.785	8.378	18.600	57.198	1.358	33.730	10.955	76.590	532.400	0.358	178.600

IC-75341	89.200	127.650	99.850	155.250	35.935	7.928	18.600	28.598	2.304	39.209	11.525	71.430	1232.400	0.230	273.600
IC-532150	86.450	128.650	100.100	92.250	42.935	9.028	15.600	45.198	1.328	45.341	12.375	76.690	2632.400	0.389	964.600
IC-66548	83.450	124.650	97.350	135.250	53.435	8.378	18.900	50.448	1.078	25.422	11.265	74.660	1732.400	0.199	328.600
IC-532394	85.700	127.650	104.350	130.250	55.935	9.028	19.600	16.198	1.662	49.320	12.325	75.210	1032.400	0.154	163.600
IC-78845	84.950	126.650	120.850	118.250	48.435	9.778	15.600	32.798	1.163	43.053	11.505	73.280	832.400	0.292	233.600
IC-59580	87.513	127.900	125.725	135.000	38.810	12.178	23.400	28.823	2.315	40.760	11.715	75.526	1284.900	0.187	227.850
IC-104581	88.263	128.900	96.225	94.000	36.310	13.178	24.100	63.823	2.201	36.426	10.935	76.576	884.900	0.327	289.850
IC-532087	84.513	123.900	90.475	141.000	26.310	9.328	20.100	54.423	3.321	40.837	11.125	73.596	584.900	0.383	233.850
IC-55636	85.263	124.900	73.225	119.000	32.310	14.678	21.400	78.623	1.927	42.707	11.095	74.426	1284.900	0.285	355.850
IC-532832	89.513	125.900	104.725	126.000	43.310	14.678	20.100	39.823	2.099	49.542	12.175	79.316	1084.900	0.318	339.850
IC-60244	86.763	126.900	109.725	76.000	42.910	7.927	20.100	42.023	1.403	51.195	11.035	76.726	684.900	0.341	239.850
IC-59193	91.263	132.900	93.225	122.000	41.310	13.178	17.400	34.223	2.107	41.470	11.505	72.926	784.900	0.277	219.850
IC-532208	93.513	135.900	88.225	66.000	28.310	9.627	20.100	57.023	2.627	37.120	11.095	74.426	584.900	0.223	137.850
IC-79651	86.513	129.900	112.225	94.000	42.810	13.678	18.100	60.223	2.093	44.204	12.975	77.726	1026.900	0.290	293.850
IC-79024	92.513	137.900	84.225	75.000	30.310	12.278	23.400	71.423	1.197	29.131	10.675	72.376	884.900	0.293	259.850
IC-78847	95.763	138.900	110.725	63.000	43.310	11.278	22.100	37.423	1.387	31.543	10.125	77.636	1084.900	0.236	249.850
IC-79086	91.263	132.900	109.725	76.000	39.810	13.678	20.100	45.923	1.789	29.778	10.915	74.236	1066.900	0.215	223.850
IC-82332	89.763	130.900	121.725	83.000	39.310	10.678	20.100	44.723	1.115	40.366	11.375	76.066	306.900	0.207	77.850
IC-534789	90.513	131.900	122.725	106.000	45.310	10.678	20.100	34.423	1.237	31.915	11.525	74.526	634.900	0.199	131.850
IC-118771	88.263	128.900	130.225	106.000	42.810	9.177	21.400	41.423	1.859	29.314	10.695	75.216	684.900	0.312	219.850
IC-532373	86.763	126.900	93.225	217.000	45.810	9.927	19.400	54.423	2.037	34.131	10.775	76.516	1584.900	0.281	425.850
IC-534430	87.513	122.900	96.725	107.000	41.810	10.228	18.100	45.423	2.777	45.605	10.605	74.286	1384.900	0.248	329.850
IC-118702	93.513	138.900	88.225	74.000	35.810	11.178	19.400	61.423	1.279	45.884	10.845	75.516	534.900	0.327	184.850
IC-78924	82.263	120.900	140.725	109.000	44.810	11.578	18.100	29.823	2.167	43.624	9.455	81.966	1734.900	0.231	377.850
IC-534784	96.513	139.900	93.725	55.000	32.810	12.578	22.100	70.423	1.297	39.107	10.605	73.866	584.900	0.257	157.850
IC-79056	85.263	124.900	89.725	123.000	32.560	10.278	18.100	38.423	5.267	33.509	12.105	75.176	1084.900	0.269	285.850
IC-532093	94.263	136.900	99.225	147.000	35.810	14.178	25.400	74.423	1.937	30.395	10.815	74.616	1384.900	0.270	359.850
IC-532435	88.263	128.900	83.225	141.000	26.810	12.678	24.100	54.673	2.419	35.488	10.595	75.636	1084.900	0.299	319.850
IC-145935	91.263	132.900	86.225	132.000	35.810	15.778	24.100	55.023	2.813	44.591	10.805	74.286	984.900	0.317	309.850
IC-82410	85.263	124.900	129.295	140.000	43.810	10.678	24.100	62.823	3.749	45.417	11.095	74.426	784.900	0.339	269.850
IC-532245	95.763	138.900	101.725	99.000	37.810	13.678	25.400	81.423	2.815	46.674	10.955	76.306	684.900	0.355	249.850
IC-532472	86.513	122.900	94.725	89.000	32.310	11.178	22.100	67.023	1.267	42.473	10.175	70.076	1184.900	0.323	375.850
IC-534810	87.513	127.900	102.725	117.000	34.810	17.678	24.100	39.023	1.537	32.108	11.225	72.366	484.900	0.307	159.850
IC-79027	87.513	127.900	89.975	86.000	32.810	10.428	19.400	38.173	1.823	40.654	11.125	73.596	384.900	0.377	159.850
IC-594790	89.013	129.900	122.725	201.000	37.910	12.428	20.100	41.823	2.311	44.273	10.695	72.186	784.900	0.439	349.850
IC-59727	89.763	130.900	106.225	94.000	39.310	12.678	20.100	48.423	1.389	48.678	10.855	74.596	684.900	0.455	319.850
IC-532194	93.513	135.900	99.225	79.000	35.810	13.678	20.100	35.423	3.109	39.491	11.555	81.596	734.900	0.387	289.850
IC-532213	92.763	134.900	99.725	108.000	39.810	13.178	20.100	62.823	2.299	50.400	10.735	75.406	1384.900	0.242	321.850
IC-534561	92.013	133.900	115.385	163.000	40.760	12.178	22.100	56.023	2.117	41.469	10.315	77.576	884.900	0.160	139.850
IC-212181	84.513	123.900	85.475	99.000	41.810	8.677	19.400	48.623	1.907	44.172	12.485	75.726	934.900	0.248	229.850
IC-79080	95.013	137.900	107.225	109.000	37.810	10.678	20.100	59.223	1.836	32.087	10.695	76.516	834.900	0.279	233.850
IC-75354	85.388	136.150	102.038	121.750	35.135	16.640	22.600	55.873	1.690	31.791	11.803	71.003	519.900	0.639	379.850
IC-104582	88.138	132.150	145.038	74.750	46.985	12.740	21.900	35.073	2.640	47.308	12.133	80.233	1169.900	0.166	177.850
IC-36699	87.388	131.150	116.538	97.750	34.385	11.740	22.600	52.873	2.304	49.247	12.393	78.353	469.900	0.275	129.850
IC-79995	86.638	130.150	111.988	146.750	40.185	11.540	18.600	57.673	2.016	39.060	10.853	76.003	969.900	0.338	333.850
IC-532446	88.138	132.150	96.638	64.750	43.135	13.740	19.900	60.273	1.890	32.438	12.143	73.873	519.900	0.282	147.850

IC-532391	89.638	134.150	111.038	160.750	40.335	11.890	22.600	45.873	1.482	40.229	11.083	75.373	769.900	0.344	272.850
IC-79046	88.138	132.150	118.038	50.750	38.235	12.740	22.600	47.873	1.596	29.728	11.483	77.133	969.900	0.278	267.850
IC-82452	88.888	133.150	89.038	110.750	37.635	11.490	22.600	60.273	1.932	25.319	12.173	78.113	1069.900	0.368	403.850
IC-82403	89.638	134.150	107.838	84.750	36.235	13.240	22.600	50.673	1.814	37.128	12.293	73.653	419.900	0.405	187.850
IC-107942	90.388	135.150	97.788	114.750	42.135	14.640	22.600	59.673	2.536	29.317	10.603	72.823	1069.900	0.288	307.850
IC-138764	91.888	137.150	117.338	70.750	37.635	10.440	23.900	55.873	1.640	44.612	11.413	74.423	874.900	0.353	317.850
IC-36761	88.888	133.150	97.538	64.750	43.635	11.090	23.900	42.473	1.934	37.518	11.963	76.703	869.900	0.325	287.850
IC-532211	89.638	134.150	120.038	132.750	39.135	10.240	24.600	53.873	2.814	34.880	11.693	76.493	1169.900	0.251	287.850
IC-532053	90.388	140.150	80.538	64.750	25.785	8.440	25.900	64.873	2.272	42.607	10.063	75.273	569.900	0.253	141.850
IC-82281	88.138	132.150	119.038	166.750	35.135	9.440	24.600	49.273	2.352	45.307	12.553	74.183	1869.900	0.230	417.850
IC-82172	97.888	145.150	88.538	90.750	18.635	12.990	24.600	63.673	1.754	36.031	10.033	78.123	1769.900	0.205	347.850
IC-138729	89.388	131.150	94.538	70.750	31.635	12.340	28.600	56.473	1.676	29.955	13.323	73.553	469.900	0.355	177.850
IC-73497	88.888	133.150	97.038	88.750	34.635	13.290	28.600	38.473	2.592	42.567	10.113	78.293	1069.900	0.301	323.850
IC-59572	92.388	135.150	95.538	106.750	42.135	10.290	25.900	58.273	3.312	43.697	12.023	73.483	519.900	0.312	167.850
IC-532212	89.638	134.150	87.038	90.750	36.635	14.940	27.900	79.073	1.676	41.150	11.843	73.703	1319.900	0.294	387.850
IC-78738	98.638	146.150	87.238	73.750	34.635	12.240	14.600	43.273	2.066	39.100	11.723	75.333	269.900	0.455	147.850
IC-78779	94.138	140.150	104.538	105.750	41.135	15.940	20.600	37.273	1.682	54.834	11.763	75.813	969.900	0.276	265.850
IC-73650	92.638	138.150	106.538	174.750	60.635	15.240	20.600	49.873	1.410	32.602	14.483	61.103	769.900	0.209	151.850
IC-31242	96.388	143.150	126.538	82.750	57.635	14.440	27.900	40.673	2.646	33.415	11.653	69.473	1269.900	0.269	337.850
IC-60208	91.138	136.150	105.038	64.750	36.635	17.840	19.200	57.073	1.964	45.614	11.723	78.333	1249.900	0.334	421.850
IC-55129	90.388	135.150	112.538	78.750	37.635	13.740	21.200	53.473	2.574	35.725	11.483	71.933	419.900	0.292	125.850
IC-79001	94.388	133.150	129.038	101.750	61.635	14.840	20.600	60.073	1.732	42.040	11.393	78.153	769.900	0.360	287.850
IC-60203	95.638	142.150	111.038	28.750	43.135	10.140	17.900	42.073	2.464	40.145	10.293	72.703	427.900	0.381	177.850
IC-73663	88.138	132.150	143.538	130.750	56.135	10.940	20.600	54.273	2.294	44.613	11.173	74.273	1319.900	0.260	337.850
IC-532809	88.888	133.150	91.038	104.750	17.135	14.040	26.600	55.873	2.784	40.179	12.823	73.333	873.900	0.290	253.850
IC-532123	89.638	134.150	95.038	36.750	37.635	10.640	18.600	60.473	1.598	45.300	11.023	74.573	769.900	0.278	213.850
IC-534322	91.138	136.150	124.038	138.750	41.635	7.790	19.900	33.473	1.682	46.824	11.603	79.573	1069.900	0.263	277.850
IC-534435	86.638	130.150	90.038	64.750	33.135	11.940	20.600	45.473	1.852	35.892	10.973	73.463	969.900	0.259	247.850
IC-78857	87.388	131.150	118.538	110.750	45.635	10.540	19.900	56.673	1.968	31.614	12.633	74.723	969.900	0.305	297.850
IC-78820	93.388	139.150	94.038	85.750	31.635	11.540	22.600	45.273	2.354	42.557	11.883	75.843	921.900	0.357	337.850
IC-107371	91.888	137.150	85.038	136.750	34.135	10.740	18.600	54.873	2.482	42.057	11.873	75.643	819.900	0.325	271.850
IC-532927	85.388	127.900	107.475	98.750	34.435	13.603	21.600	62.110	2.616	43.075	12.610	74.913	994.900	0.288	281.850
IC-199660	97.388	143.900	87.475	82.750	26.435	13.103	23.600	47.510	1.572	34.120	13.280	75.723	694.900	0.205	136.850
IC-82410	86.888	129.900	128.975	100.750	35.935	10.903	17.600	51.910	1.980	39.180	11.900	78.393	1494.900	0.195	310.850
IC-28637	87.638	130.900	137.475	128.750	42.435	10.003	19.600	41.710	0.808	20.274	12.390	79.853	1194.900	0.142	184.850
IC-64230	91.388	135.900	99.475	144.750	32.435	11.303	19.600	55.310	2.260	41.885	11.240	73.783	1644.900	0.241	414.850
IC-82177	92.138	136.900	94.475	136.750	32.435	10.553	19.600	51.210	1.868	37.501	10.300	76.133	1294.900	0.255	336.850
IC-532933	92.888	137.900	90.475	136.750	29.268	10.069	18.900	69.710	2.762	40.477	11.310	74.843	2194.900	0.190	456.850
IC-532933	93.638	138.900	97.975	138.750	37.435	13.703	16.900	44.710	1.772	40.819	11.310	78.203	694.900	0.201	134.850
IC-75318	90.638	134.900	91.975	98.750	30.935	13.203	21.600	56.110	2.286	41.754	10.570	72.053	794.900	0.177	140.850
IC-532307	89.888	133.900	103.475	148.750	35.935	9.303	15.600	44.710	1.464	33.819	11.510	72.613	1494.900	0.193	306.850
IC-78789	84.138	132.900	93.975	112.750	32.435	11.303	18.900	44.510	1.552	35.982	10.690	72.443	544.900	0.316	151.850
IC-208906	93.138	143.900	92.975	128.750	31.935	9.903	20.900	46.110	2.408	53.578	14.880	75.663	934.900	0.178	170.850
IC-75436	92.138	134.900	109.975	107.750	42.935	13.903	18.900	68.710	2.764	41.097	12.180	78.423	1494.900	0.218	341.850
IC-53134	98.138	144.900	113.975	93.750	43.935	12.903	17.600	66.910	2.748	41.966	9.320	74.293	694.900	0.313	201.850
IC-532076	100.388	147.900	81.975	78.750	31.935	11.903	20.900	65.710	1.822	28.489	10.780	74.703	704.900	0.250	166.850

IC-532420	91.388	135.900	111.475	110.750	39.435	11.403	22.900	56.310	3.348	60.705	10.430	88.113	2294.900	0.185	466.850
IC-532382	92.888	137.900	92.975	93.750	33.935	9.403	22.900	46.910	2.198	48.109	10.790	75.243	1004.900	0.169	176.850
IC-145969	96.638	142.900	100.475	143.750	33.435	9.403	17.600	43.010	1.968	47.082	10.690	78.063	994.900	0.171	176.850
IC-30276	91.138	127.900	104.475	93.750	42.935	14.903	16.900	54.910	2.008	37.543	12.900	72.093	1094.900	0.221	246.850
IC-78966	86.888	129.900	109.975	112.750	40.135	9.403	14.900	44.110	1.398	32.762	10.960	74.313	1494.900	0.243	376.850
IC-534870	87.638	130.900	96.175	80.750	35.935	8.653	12.900	37.110	1.048	29.394	10.570	80.603	394.900	0.445	138.850
IC-35063	93.138	133.900	87.475	78.750	34.935	12.403	21.600	61.910	2.660	43.934	9.970	76.213	744.900	0.236	168.850
IC-78826	92.888	137.900	91.675	158.750	37.435	11.903	24.900	41.310	1.360	34.067	11.310	75.403	1194.900	0.280	336.850
IC-79043	85.388	127.900	88.975	80.750	39.435	7.853	15.600	49.910	2.260	46.453	10.000	80.613	794.900	0.274	208.850
IC-532152	86.138	128.900	89.475	136.750	33.935	10.903	14.900	66.910	2.676	40.878	10.220	78.123	544.900	0.682	316.850
IC-82414	90.138	130.900	103.975	165.750	32.935	11.403	18.900	44.710	1.708	39.365	11.990	76.923	704.900	0.365	236.850
IC-138884	91.388	135.900	116.475	141.750	45.935	12.903	19.600	43.510	1.976	46.722	11.130	78.063	2194.900	0.176	426.850
IC-73661	90.638	134.900	103.975	154.750	42.935	14.403	19.600	50.710	1.764	35.794	11.000	75.063	1074.900	0.318	336.850
IC-532823	90.638	134.900	107.675	153.750	37.435	9.253	17.600	47.710	1.550	33.508	10.550	74.513	584.900	0.267	141.850
IC-532409	89.888	133.900	92.975	107.750	36.635	7.403	13.600	33.110	1.568	49.039	11.180	79.213	1494.900	0.235	366.850
IC-104587	87.638	130.900	128.975	127.750	47.435	11.403	18.900	46.710	1.844	40.622	11.450	78.573	1394.900	0.220	320.850
IC-82188	90.638	134.900	81.475	131.750	28.435	10.903	17.600	36.110	1.588	45.472	10.440	75.383	1094.900	0.105	130.850
IC-73683	88.138	127.900	124.475	242.750	38.035	12.403	15.600	34.460	1.788	53.607	12.100	79.083	1544.900	0.167	280.850
IC-79095	89.888	133.900	119.975	108.750	40.135	11.403	16.900	31.110	0.810	27.313	12.450	79.173	1244.900	0.166	220.850
IC-82260	97.388	143.900	113.475	161.750	43.435	10.903	19.600	54.110	1.804	34.281	11.110	77.663	1244.900	0.222	284.850
IC-532092	89.138	132.900	90.975	59.750	34.435	9.403	16.900	51.310	2.104	42.092	11.570	75.623	594.900	0.255	138.850
WH 1105	89.050	133.200	107.800	120.400	39.340	11.120	21.400	51.080	2.348	42.827	11.008	75.776	959.600	0.289	269.400
DPW 621-50	90.000	132.800	99.700	116.800	38.500	11.210	20.600	54.510	2.079	37.882	11.452	73.524	980.000	0.282	268.200
PBW 343	91.550	135.000	93.400	83.600	39.800	10.710	19.000	48.000	1.977	39.499	11.016	74.216	980.000	0.256	242.600
Agra Local	87.950	130.600	119.050	156.200	45.100	11.550	21.400	54.500	2.251	41.192	10.714	75.916	1260.000	0.263	318.200

Table 3: Mean, range and least significant differences in diverse wheat germplasm available at GBPUA&T, Pantnagar

Characters	Genotypes		Checks				CV%	CM (5%)	AVDB (5%)	AVSB (5%)	AVAC (5%)
	Mean	Range	1	2	3	4					
Day to 75% heading	91.24	82.20 – 104.01	89.05	90.00	91.55	87.95	2.78	3.65	8.17	9.14	7.08
Days to maturity	134.86	120.90-152.40	133.20	132.8	135.00	130.60	3.18	6.18	13.82	15.45	11.97
Plant height (cm)	105.42	72.35 -149.35	107.80	99.70	93.40	119.05	8.11	12.34	27.59	30.84	23.89
No. of tillers per meter	116.43	28.75 - 242.75	120.40	116.80	83.60	156.20	20.6	34.71	77.62	86.79	67.22
Peduncle length (cm)	41.08	17.14 - 74.43	37.70	39.52	36.70	45.10	10.16	6.02	13.46	15.04	11.65
Spike length (cm)	11.57	7.40 - 17.84	12.23	11.80	10.71	11.77	8.87	1.48	3.32	3.71	2.87
No. of spikelets per spike	20.82	12.90 - 28.60	21.40	20.60	19.00	21.40	9.79	2.94	6.58	7.35	5.69
No. of grains per spike	48.10	16.20 -81.42	51.08	54.51	48.00	54.50	8.56	5.997	13.41	14.99	11.62
Grain weight per spike (g)	2.18	0.77 - 5.30	2.73	1.96	1.93	2.65	17.52	0.56	1.25	1.39	1.07
Thousand grain weight (g)	40.26	20.27 - 67.40	41.65	37.75	41.86	46.88	8.19	4.78	10.69	11.95	9.26
Biological yield (g)	995.47	223.90 - 2632.40	823.60	794.00	1232.00	1284.00	15.14	218.46	488.50	546.16	423.05
Grain yield (g)	273.31	77.85 - 964.60	269.40	268.20	242.60	318.20	27.47	108.49	242.59	271.23	210.09
Harvest Index (%)	29	10 - 68	29	28	26	26	18.62	0.079	0.18	0.196	0.15
Test Weight (kg/hl)	76.06	61.10 - 88.11	75.78	73.52	74.22	75.92	2.63	2.89	6.46	7.22	5.59
Protein content (%)	11.67	9.32 - 14.88	11.01	11.45	11.02	10.71	4.82	0.81	1.81	2.02	1.57

CM= Least significant difference between the mean of two check varieties; AVSB= Least significant difference between adjusted value of two selections in same block; AVDB= Least significant difference between adjusted value of two selections in different blocks; AVAC= Least significant difference between an adjusted selection value and a check mean.

The estimates of coefficient of variability were moderate for 1000-grain weight as also suggested by Sultana *et al.* (2005) [12].

High genetic variability in any crop improvement programme is always essential and useful for effective selection and genetic up gradation of concerned crop species. The results of the present investigation revealed that significant and high amount of variability is existing in the germplasm pool of wheat evaluated during the study. The desirable genotypes identified to be superior for particular characters can be crossed in several fashions with each other to accumulate as many desirable alleles as possible in the same genotype, popularly known as combination breeding.

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