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Assessment of Genetic Variability and Morphological Characterization of Wheat Cultivar under South Eastern Plain of Rajasthan

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ABSTRACT

Background: Wheat is the prime and staple food in the world as well as India and it is grown in peninsular zone of India. The production of wheat was suffered due to biotic and abiotic factors in the country. Therefore, the present study was focused on assessing the genetic variability and morphological characterization among the cultivar under south eastern plain of Rajasthan.
Methods: Thirty-two cultivars of wheat were evaluated in RBD with four replications during *rabi* season 2022-23 at AICRP on Seed (Crops), Agriculture University, Kota, Rajasthan.
Result: Significant differences were observed among the cultivars for all traits studied. A wide range of variation was noted for most of these traits. The phenotypic variance for most traits closely matched the corresponding genotypic variance, indicating minimal environmental influence on their expression. High broad-sense heritability (%) combined with substantial genetic advance as a percentage of the mean was observed for traits such as biological yield per plant (g), number of grains per spike, harvest index (%) and grain yield per plant (g), suggesting these traits would respond well to selection. Grain yield per plant (g) showed a significant positive correlation at both phenotypic and genotypic levels with biological yield per plant (g) (0.744; 0.709), test weight (g) (0.436; 0.402) and days to maturity (0.249; 0.230). Biological yield per plant (g) had the strongest direct positive effect on grain yield per plant (g) at both levels (1.478; 1.282), followed by harvest index (%) (0.880; 0.904). These traits are recommended as key selection criteria for improving yield and ensuring stable performance in wheat cultivars.

Key words: Character association, Genetic advance, Genetic variability, Heritability, Path coefficient analysis.

INTRODUCTION

Wheat, originally from Southwest Asia in the region known as the Fertile Crescent, has been cultivated in India for over 5,000 years, with evidence from the Mohenjo-daro excavations. As of 2022-23, wheat is grown on 33.72 million hectares in India, yielding 112.74 million tonnes (Anonymous, 2023). However, the national wheat productivity, at 33.44 quintals per hectare, remains lower than that of developed nations, both in terms of quality and quantity. This low productivity is largely attributed to the effects of biotic and abiotic stressors.

To address this, there is an urgent need to develop resilient, high-yielding wheat varieties. The natural variability found in wild wheat populations provides breeders with a valuable resource for selecting cultivars with improved yield and stability. However, selection based solely on phenotype can be misleading, as environmental factors often influence the expression of traits. Thus, morphological characterization is an essential first step in describing and classifying cultivars.

The backbone of any breeding program lies in the magnitude of genetic variability within a crop, which plays a critical role in determining traits and transmitting them to future generations (Singh and Upadhyay, 2013; Bhandari *et al*., 2017). Understanding genetic parameters is essential for selecting cultivars that combine high yield with stable performance. The combination of high genetic advance with high heritability provides ideal conditions for effective selection (Larik *et al*., 2000).

For improving quantitative and qualitative traits, it is crucial to study the interrelationship between various traits, as selecting for one trait can impact others. Character association analysis helps in understanding the cause-and-effect relationships between yield and its components (Khan *et al*., 2003). It quantifies the interrelationships among yield components and identifies whether their influence on yield is direct or operates through other pathways (Meena *et al*., 2015). This study aims to select

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cultivars based on their yield potential and stability within the studied wheat populations.

MATERIALS AND METHODS

The experimental material was received from different AICRP centres of the country (Table 1). The thirty-two cultivars of wheat crop were sown in randomized block design (RBD) with four replications at AICRP on Seed (Crops), Mechanized Agriculture Farm, Ummedganj, Kota, Rajasthan during *rabi* season 2022-23. In each replication, there was a five row of each cultivar with a row length of 5.0 meter. All the recommended agronomic cultural practices and plant protection measures were followed during crop gestation period. The following observations were recorded on ten randomly selected plants from each cultivar and each replication eliminating border and unhealthy plant for twelve characters *viz*. days to 50 (%) flowering, days to maturity, number of tillers in 1 square meter area, plant height at maturity (cm), spike length (cm), biological yield per plant (g), number of grains per spike, number of spikelets per spike, number of grains per spikelet, test weight (g), grain yield per plant (g) and harvest index (%) except days to 50 (%) flowering (days) and days to maturity (days) recorded on the plot basis.

The recorded replication wise mean data of each cultivar for each character has been subjected to analysis of variance (ANOVA), as suggested by Goulden (1959) and the test of significance was worked out by referring to the standard "F" table suggested by Snedecor and Cochlan (1967). The genotypic and phenotypic coefficient of variance were calculated as per the method suggested by Burton and Devane in 1953 and were classified as suggested by Sivasubramaniam and Madhava 1973. Heritability in a broad sense was calculated as per the formula suggested by Allard 1960 and expressed in percent as Low (<30%), moderate (30-60%) and high (>60%). The genetic advance as percent mean was categorized into low (<10), moderate (10-20) and high (>20) as per the formula suggested by

Table 1: List of thirty-two cultivar of wheat used under study.

Cultivars	Notification year	Source
GW 503	1990	AICRP on Seed (Crops), AU, Kota
Lok-1	1982	AICRP on Seed (Crops), AU, Kota
GW 173	1994	AICRP on Seed (Crops), AU, Kota
Raj 4238	2016	AICRP on Wheat and Barley Improvement, RARI, Durgapura, Jaipur
PBW 502	2004	PAU, Ludhiana
GW 496	1990	AICRP on Seed (Crops), AU, Kota
WH 147	1980	CCSHAU, Hisar
GW 366	2007	AICRP on Seed (Crops), AU, Kota
HI 1544	2008	IARI RS, Indore
Raj 1482	1983	AICRP on Wheat and Barley improvement, RARI, Durgapura, Jaipur
PBW 343	1996	PAU, Ludhiana
GW 322	2002	AICRP on Seed (Crops), AU, Kota
Raj 4079	2011	AICRP on Wheat and Barley Improvement, RARI, Durgapura, Jaipur
GW 273	1998	AICRP on Seed (Crops), AU, Kota
Raj 3077	1989	AICRP on Wheat and Barley Improvement, RARI, Durgapura, Jaipur
C 306	1978	AICRP on Seed (Crops), AU, Kota
HW 2004	1997	AICRP on Seed (Crops), AU, Kota
Raj 3765	1996	AICRP on Wheat and Barley Improvement, RARI, Durgapura, Jaipur
Raj 4037	2014	AICRP on Wheat and Barley Improvement, RARI, Durgapura, Jaipur
UP 2338	1995	AICRP on Seed (Crops), AU, Kota
GW 366	2007	AICRP on Seed (Crops), AU, Kota
HD 2278	1984	AICRP on Seed (Crops), AU, Kota
GW 190	1994	AICRP on Seed (Crops), AU, Kota
Sujata	1983	AICRP on Seed (Crops), AU, Kota
HD 2967	2014	AICRP on Seed (Crops), AU, Kota
WH 542	1992	CCSHAU, Hisar
DL 803-3	1995	AICRP on Seed (Crops), AU, Kota
GW 201	1985	AICRP on Seed (Crops), AU, Kota
HD 2781	2002	AICRP on Seed (Crops), AU, Kota
PBW 215	1991	PAU, Ludhiana
UP 319	1974	AICRP on Seed (Crops), AU, Kota
HD 2687	1999	AICRP on Seed (Crops), AU, Kota

Johnson *et al*. (1955). Character association (Searle *et al*. 1961 and Snedecor and Cochlan,1967) and Path coefficient analysis (Wright, 1934 and Dewey and Lu, 1952) were calculated as per statistical method.

RESULTS AND DISCUSSION

Analysis of variance and *per se* performance of wheat cultivar

The analysis of variance revealed the existence of significant differences among the cultivar studied for all the characters *viz*. days to 50 (%) flowering, days to maturity, number of tillers in 1 square meter area, plant height at maturity (cm), spike length (cm), biological yield per plant (g), number of grains per spike, number of spikelets per spike, number of grains per spikelet, test weight (g), grain yield per plant (g) and harvest index (%) indicating the presence of considerable amount of genetic variability in the genetic material (Table 2). Hence, there is a scope for the selection of potential cultivars for the breeding program. The similar results were reported by Meena *et al*. (2015); Mittal *et al*. (2021) and Singh and Singh (2022).

The per se performance of the cultivars, as presented in Table 3, exhibited significant differences, indicating ample variability across all the traits studied. These traits include days to 50% flowering, days to maturity, number of tillers per square meter, plant height at maturity (cm), spike length (cm), biological yield per plant (g), number of grains per spike, number of spikelets per spike, number of grains per spikelet, test weight (g), grain yield per plant (g) and harvest index (%). This variability was observed among the cultivars evaluated in the southeastern plains of Rajasthan. The results revealed that days to 50 (%) flowering ranged 48.0 (GW-173) to 66.0 (C-306) with average value of 57.0 days, days to maturity varied 114.0 (GW-173) to 142.0 (PBW-215) with the mean value of 121.49 days, number of tillers in 1 square meter area 235.0 (C-306) to 356.0 (Raj-4037) with average value of 297.29, plant height at maturity (cm) was observed minimum in 64.0 (GW-503) and maximum in 103.0 (Sujata) with average value of 88.76, spike length (cm) from 8.0 (GW 503) to 11.0 (Raj-4079) with the mean value of 9.34, biological yield per plant (g) ranged 62.0 (GW-496) to 156.0 (GW-503) with average value of 104.44, number of grains per spike from 36.0 (Raj-3765)-67.0 (Raj-1482) with the mean value of 48.31, number of spikelets per spike ranged 10.0 (Raj-4037) to 23.0 (GW-273) with the average value of 17.85, number of grains per spikelet was observed lowest in 3.0 (Raj-3765) and higher 4.0 (GW-503) with 3.16 mean value, test weight (g) from 31.0 (GW-322) to 42.0 (Raj-4238) with the mean value of 35.00, grain yield per plant (g) ranged 26.0 (Raj-3765) to 51.0 (HD-2781) with the average value of 40.78 and harvest index (%) varied 31.0 (PBW-343) to 58.0 (Raj-4079) with the mean value of 40.23 under studied. The similar results were reported by earlier Poonam *et al.* (2018) and Singh and Rajpoot (2021).

Table 2: Analysis of variances (ANOVA) for twelve characters in wheat.

S.V.	d. f.	C-1	C-2	C-3	C-4	C-5	C-6	C-7	C-8	C-9	C-10	C-11	C-12
Replication	3	2.15	4.26	70.13	18.20	0.66	21.06	19.84	2.90	0.58	13.82	5.81	0.37
Cultivar	31	56.65**	164.09**	5442.26**	326.72**	3.39**	2554.98**	302.38**	20.32**	0.72**	27.41**	181.90**	210.23**
Error	93	1.07	1.70	29.25	6.91	0.65	15.14	7.93	2.00	0.27	5.45	3.78	6.23

*and ** represent 5% and 1% level of significant, respectively.

Character details: C-1: Days to 50 (%) flowering, C-2: Days to maturity, C-3: Number of tillers in 1 square meter area, C-4: Plant height at maturity (cm), C-5: Spike length (cm), C-6: Biological yield per plant(g), C-7: Number of grains per spike,C-8: Number of spikelet's per spike,C-9: Number of grain per spikelet, C-10: Test weight (g), C-11: Grain yield per plant (g) and C-12: Harvest index (%).

Table 3: *per se* performance of wheat cultivar for twelve characters under study.

Cultivars	C-1	C-2	C-3	C-4	C-5	C-6	C-7	C-8	C-9	C-10	C-11	C-12
GW 503	53.00	119.50	240.25	64.00	7.65	156.00	63.50	18.50	3.75	37	49.75	31.99
Lok-1	51.00	118.50	256.00	85.75	10.13	119.00	41.75	17.25	3.25	36	41.75	35.07
GW 173	47.50	114.00	293.00	93.00	9.78	77.50	52.75	20.75	3.75	38	32.75	42.24
Raj 4238	53.75	122.00	348.00	71.00	9.30	104.75	44.25	17.50	3.25	42	47.00	44.93
PBW 502	61.00	129.00	258.00	74.00	10.13	94.00	62.50	21.50	3.75	37	32.00	34.14
GW 496	54.50	115.50	310.00	89.00	10.90	62.25	54.50	17.50	3.75	34	35.00	56.36
WH 147	52.50	119.00	257.50	85.00	9.13	102.25	55.50	19.25	3.50	35	41.00	40.08
GW 366	55.00	117.00	286.00	93.25	8.38	67.25	36.75	16.75	3.25	37	32.50	48.32
HI 1544	55.50	122.25	258.50	96.50	9.50	78.00	46.75	17.25	3.75	34	42.00	53.86
Raj 1482	53.00	120.00	286.00	88.50	9.43	94.25	66.50	18.00	3.75	34	33.25	35.26
PBW 343	59.00	127.00	286.25	91.00	9.78	102.00	49.50	20.25	3.50	35	32.00	31.36
GW 322	54.00	117.25	257.50	98.25	10.63	87.50	59.25	20.50	3.50	31	34.50	39.46
Raj 4079	55.00	117.50	272.00	86.00	11.38	75.25	49.00	18.25	3.25	35	43.25	57.59
GW 273	54.00	125.00	280.00	93.00	10.95	121.75	65.75	22.75	3.50	32	43.75	35.95
Raj 3077	61.00	119.00	286.00	83.00	9.40	74.00	42.75	19.00	3.00	32	30.00	40.58
C 306	65.75	127.00	234.75	103.00	9.25	106.00	43.50	16.50	3.00	33	40.25	37.98
HW 2004	64.25	126.00	255.50	102.00	10.75	136.00	49.75	19.25	2.75	32	44.00	32.37
Raj 3765	56.00	118.50	354.00	87.00	8.40	77.00	35.75	15.25	2.50	33	26.00	33.78
Raj 4037	59.00	118.00	356.00	83.25	10.05	79.50	41.00	9.88	2.75	37	34.75	43.75
UP 2338	59.00	114.00	335.00	86.75	8.50	96.50	43.00	16.00	3.00	38	36.00	37.31
GW 366	57.75	120.50	340.00	91.00	8.78	141.25	42.00	17.25	2.75	36	47.50	33.74
HD 2278	58.00	116.00	345.00	82.50	8.95	145.00	43.50	19.25	3.25	34	47.50	32.79
GW 190	57.50	116.00	335.50	96.00	8.68	95.00	43.00	17.00	2.75	32	41.75	43.94
Sujata	58.00	121.00	330.50	103.00	8.25	102.75	39.00	16.25	2.50	31	42.00	40.93
HD 2967	59.00	132.00	341.00	82.75	8.85	93.25	40.00	17.00	3.00	33	44.75	48.07
WH 542	58.00	118.75	305.00	89.00	9.30	97.50	43.00	16.25	2.50	36	49.50	50.80
DL 803-3	57.00	118.50	300.00	93.50	8.45	98.00	42.00	17.00	2.50	32	44.25	45.17
GW 201	57.50	121.00	311.00	94.00	8.80	136.00	58.00	19.00	3.25	39	50.00	36.79
HD 2781	59.00	122.00	344.00	82.00	9.73	139.25	57.75	19.00	3.50	36	51.00	36.63
PBW 215	62.00	142.00	258.00	98.00	8.78	137.50	47.00	18.00	2.75	37	47.50	34.55
UP 319	59.00	137.00	312.50	97.00	8.75	126.75	44.50	16.75	3.00	31	44.75	35.34
HD 2687	57.50	117.00	280.50	78.25	8.05	119.00	42.00	16.50	2.75	35	43.00	36.14
Mean	57.00	121.49	297.29	88.76	9.34	104.44	48.31	17.85	3.16	35.00	40.78	40.23
Range	48-66	114-142	235-356	64-103	8-11	62-156	36-67	10-23	3-4	31-42	26-51	31-58
CD	1.68	2.12	8.77	4.26	1.31	6.31	4.57	2.29	0.84	3.79	3.15	4.05
CV	1.82	1.07	1.82	2.96	8.65	3.73	5.83	7.92	16.34	6.74	4.77	6.21

Character details: C-1: Days to 50 (%) flowering, C-2: Days to maturity, C-3: Number of tillers in 1 square meter area, C-4: Plant height at maturity (cm), C-5: Spike length (cm), C-6: Biological yield per plant(g), C-7: Number of grains per spike, C-8: Number of spikelet's per spike, C-9: Number of grain per spikelet, C-10: Test weight (g), C-11: Grain yield per plant (g) and C-12: Harvest index(%).

Genetic variability, heritability and genetic advance

The study of genetic variation parameters, *viz*., genotypic and phenotypic coefficient of variance (GCV and PCV), heritability and genetic advance as percent of the mean for different characters. In this study, the cultivars revealed a significant amount of variability for all the characters under studied (Table 4).

The highest values of genotypic and phenotypic coefficients of variation (GCV and PCV) were observed for biological yield per plant (g) (24.13; 24.41), suggesting that this trait is primarily governed by additive genes with minimal environmental influence. Moderate GCV and PCV values were recorded for traits such as the number of grains per spike (17.76; 18.69), harvest index (%) (17.75; 18.81), grain yield per plant (g) (16.36; 17.04), number of tillers per square meter (12.37; 12.51), number of spikelets per spike (11.99; 14.37), number of grains per spikelet (10.69; 19.53) and plant height at maturity (cm) (10.07; 10.50). Similar findings were previously reported by Bhoite *et al*. (2008) and Singh and Upadhyay (2013) in wheat and by Meena *et al*. (2013) in fennel.

The high GCV and PCV values for most traits suggest a broad range of variation, indicating potential for improvement through selection. However, the GCV values for all traits were lower than the corresponding PCV values, indicating that environmental factors contribute to some extent to the observed variability (Singh and Upadhyay, 2013). The lowest GCV and PCV values were recorded for days to maturity (5.24; 5.35), days to 50% flowering (6.54; 6.79), spike length (cm) (8.87; 12.39) and test weight (g) (6.76; 9.54), suggesting that improving these traits through simple selection may be challenging.

The heritability estimates devoid of environmental influence from the total variability indicate the accuracy with which superior segregants in a population can be selected by their phenotypic performance, thus making the selection more effective. The higher values of heritability (%) were exhibited in the study for number of tillers in 1 square meter area (97.89), biological yield per plant(g) (97.67), days to maturity (95.97), days to 50(%) flowering (92.85), grain yield per plant(g) (92.18), plant height at maturity(cm) (92.04), number of grains per spike (90.27), harvest index (%) (89.11) and number of spikelets per spike (69.63). However, heritability estimates itself is not an indication of the amount of genotypic progress that would result from selecting the superior segregants (Johnson *et al.,* 1955). The similar result was observed by (Singh and Rajpoot, 2021). The high heritability magnitude indicates the reliability with the higher chance of the genotype to be recognized by its phenotypic expression (Chandrababu and Sharma, 1999). Moderate heritability value was observed for spike length (cm) (51.27) and test weight (g) (91.97) and lowest for number of grains per spikelet (29.97) suggesting selection for these characters would not be effective due to predominant effects of non-additive genes in this population.

Genetic advance is an important selection parameter that helps to plant breeders in the selection of cultivar from a diverse population. Estimates of heritability with genetic advances are more reliable and meaningful individual consideration of the parameters (Nwangburuka and Denton, 2012). Maximum expected genetic advance as percentage of mean was observed on biological yield per plant (g) (49.12) followed by number of grains per spike (34.76), harvest index (%) (34.52), grain yield per plant(g) (32.36), number of tillers in 1 meter area (25.22) and number of spikelets per spike (20.61) indicating the presence of additive gene; while the moderate for days to maturity (10.58), number of grains per spikelets (12.06), days to 50 (%) flowering (12.98), spike length (cm) (13.08) and plant height at maturity (cm) (19.91). Test weight (g) was recorded lowest value. Similar results were found by Bhoite *et al*. (2008) in wheat and Singh *et al.* (2015) in pearl millet.

High heritability coupled with high genetic advance percentage over mean was recorded on biological yield per plant (g), number of grains per spike, harvest index (%),

Table 4: Estimation of variance components for the twelve characters under study.

Characters	Coefficient of variance		Heritability in broad sense (h^2_{bs}) (%)	Genetic advance (GA)	GA as (%) of mean
	Genotypic	Phenotypic			
Days to 50 (%) flowering	6.54	6.79	92.85	7.40	12.98
Days to maturity	5.24	5.35	95.97	12.86	10.58
Number of tillers in 1 square meter area	12.37	12.51	97.89	74.98	25.22
Plant height at maturity (cm)	10.07	10.50	92.04	17.67	19.91
Spike length (cm)	8.87	12.39	51.27	1.22	13.08
Biological yield per plant (g)	24.13	24.41	97.67	51.30	49.12
Number of grains per spike	17.76	18.69	90.27	16.79	34.76
Number of spikelets per spike	11.99	14.37	69.63	3.68	20.61
Number of grains per spikelet	10.69	19.53	29.97	0.38	12.06
Test weight (g)	6.76	9.54	50.16	3.42	9.86
Grain yield per plant (g)	16.36	17.04	92.18	13.20	32.36
Harvest index (%)	17.75	18.81	89.11	13.89	34.52

Table 5: Genotypic (G) and phenotypic (P) character association between different characters in wheat.

Characters	Level	C-1	C-2	C-3	C-4	C-5	C-6	C-7	C-8	C-9	C-10	C-11	C-12
C-1	G	-	0.514**	0.014	0.265**	-0.085	0.227**	-0.280**	-0.193*	-0.611**	-0.143	0.121	-0.225*
	P	-	0.490**	0.015	0.244**	-0.084	0.213*	-0.252**	-0.185*	-0.322**	-0.143	0.102	-0.218*
C-2	G		-	-0.211*	0.203*	-0.021	0.355**	0.060	0.145	-0.104	0.093	0.249**	-0.282**
	P		-	-0.203*	0.186*	-0.020	0.341**	0.051	0.111	-0.071	0.086	0.230**	-0.267**
C-3	G			-	-0.126	-0.273**	-0.061	-0.426**	-0.468**	-0.484**	-0.080	0.050	0.090
	P			-	-0.120	-0.182*	-0.059	-0.400**	-0.382**	-0.262**	-0.077	0.044	0.083
C-4	G				-	0.172	-0.116	-0.194*	-0.004	-0.380**	-0.447**	-0.072	0.076
	P				-	0.088	-0.111	-0.176*	-0.006	-0.202*	-0.408**	-0.064	0.072
C-5	G					-	-0.312**	0.418**	0.288**	0.444**	-0.369**	-0.198*	0.306**
	P					-	-0.207*	0.367**	0.233**	0.332**	-0.257**	-0.152	0.194*
C-6	G						-	0.225*	0.234**	-0.099	0.458**	0.744**	-0.681**
	P						-	0.218*	0.207*	-0.062	0.431**	0.709**	-0.659**
C-7	G							-	0.677**	0.928**	0.250**	0.068	-0.220*
	P							-	0.598**	0.510**	0.233**	0.058	-0.210*
C-8	G								-	0.704**	0.112	0.049	-0.276**
	P								-	0.416**	0.078	0.038	-0.223*
C-9	G									-	0.297**	-0.192*	0.050
	P									-	0.147	-0.126	0.017
C-10	G										-	0.436**	-0.181*
	P										-	0.402**	-0.159
C-11	G											-	-0.040
	P											-	0.037
C-12	G												-
	P												-

*and ** represent significant at 5 (%) and 1 (%) level of significant, respectively.

Character details: C-1: Days to 50 (%) flowering, C-2: Days to maturity, C-3: Number of tillers in 1 square meter area, C-4: Plant height at maturity (cm), C-5: Spike length (cm), C-6: Biological yield per plant(g), C-7: Number of grains per spike,C-8:Number of spikelet's per spike, C-9:Number of grain per spikelet, C-10: Test weight (g), C-11: Grain yield per plant (g) and C-12: Harvest index (%).

Table 6: Genotypic (G) and phenotypic (P) path coefficient analysis showing direct and indirect effects of eleven characters on grain yield per plant in wheat.

Characters	Level	Direct effect	C-1	C-2	C-3	C-4	C-5	C-6	C-7	C-8	C-10	C-12
C-1	G	0.114	0.1139	-0.0031	0.0014	0.0262	0.0067	0.3361	0.0773	0.0134	-0.2660	0.0136
	P	-0.01	-0.0103	0.0201	0.0007	0.0011	0.0057	0.2733	-0.0051	-0.0036	0.0143	0.0031
C-2	G	-0.006	0.0586	-0.0060	-0.0215	0.0201	0.0017	0.5249	-0.0165	-0.0100	-0.0453	-0.0089
	P	0.041	-0.0050	0.0410	-0.0092	0.0008	0.0015	0.4373	0.0010	0.0021	0.0031	-0.0019
C-3	G	0.102	0.0016	0.0013	0.1022	-0.0125	0.0215	-0.0906	0.1176	0.0323	-0.2107	0.0076
	P	0.045	-0.0002	-0.0083	0.0454	-0.0005	0.0110	-0.0761	-0.0081	-0.0073	0.0116	0.0017
C-4	G	0.099	0.0302	-0.0012	-0.0129	0.0990	-0.0135	-0.1721	0.0537	0.0003	-0.1655	0.0427
	P	0.004	-0.0025	0.0076	-0.0055	0.0045	-0.0053	-0.1425	-0.0036	-0.0001	0.0090	0.0088
C-5	G	-0.079	-0.0096	0.0001	-0.0279	0.0170	-0.0787	-0.4607	-0.1156	-0.0199	0.1932	0.0353
	P	-0.06	0.0010	-0.0010	-0.0083	0.0004	-0.0605	-0.2658	0.0074	0.0083	-0.0147	0.0055
C-6	G	1.478	0.0259	-0.0021	-0.0063	-0.0115	0.0245	1.4785	-0.0622	-0.0162	-0.0432	-0.0438
	P	1.282	-0.0022	0.0140	-0.0027	-0.0005	0.0125	1.2816	0.0044	0.0040	0.0028	-0.0093
C-7	G	-0.276	-0.0319	-0.0004	-0.0435	-0.0192	-0.0329	0.3327	-0.2762	-0.0468	0.4043	-0.0239
	P	0.02	0.0026	0.0021	-0.0182	-0.0008	-0.0222	0.2798	0.0202	0.0115	-0.0226	-0.0050
C-8	G	-0.069	-0.0220	-0.0009	-0.0478	-0.0004	-0.0227	0.3458	-0.1871	-0.0691	0.3065	-0.0107
	P	0.019	0.0019	0.0046	-0.0173	0.0001	-0.0262	0.2658	0.0121	0.0192	-0.0185	-0.0017
C-9	G	0.436	-0.0695	0.0006	-0.0494	-0.0376	-0.0349	-0.1466	-0.2564	-0.0486	0.4356	-0.0284
	P	-0.044	0.0033	-0.0029	-0.0119	-0.0009	-0.0201	-0.0798	0.0103	0.0080	-0.0443	-0.0032
C-10	G	-0.095	-0.0163	-0.0006	-0.0081	-0.0442	0.0291	0.6776	-0.0690	-0.0077	0.1295	-0.0955
	P	-0.022	0.0015	0.0035	-0.0035	-0.0018	0.0156	0.5524	0.0047	0.0015	-0.0065	-0.0215
C-12	G	0.88	-0.0256	0.0017	0.0092	0.0076	-0.0241	-1.0075	0.0609	0.0191	0.0216	0.0173
	P	0.904	0.0022	-0.0109	0.0038	0.0003	-0.0117	-0.8444	-0.0042	-0.0043	-0.0008	0.0034

Residual effect of G= 0.0566 and P= 0.0394.

Character details: C-1: Days to 50 (%) flowering, C-2: Days to maturity, C-3: Number of tillers in 1 square meter area, C-4: Plant height at maturity (cm), C-5: Spike length (cm), C-6: Biological yield per plant (g), C-7: Number of grains per spike,C-8:Number of spikelet's per spike,C-9: Number of grain per spikelet,C-10: Test weight (g) and C-12: Harvest index (%).

grain yield per plant(g), number of tillers in 1 meter area and number of spikelets per spike indicating selection for these characters would be more effective. High heritability indicated that these characters were little influenced by the environment and direct selection for these characters would be effective for further genetic improvement. Low heritability was observed for number of grains per spikelets which may be due to the character being highly influenced by environmental effects and genetic improvement through selection will be difficult due to masking effects of the environment on the genotypic effects. It can be concluded that characters such as biological yield per plant (g), number of grains per spike, harvest index (%), grain yield per plant (g), number of tillers in 1 meter area and number of spikelets per spike had higher GCV, PCV, heritability and genetic advance as per cent of the mean are agreeable for the selection and can be effectively used for genetic improvement of plant breeding programs.

Character association and Path coefficient analysis

For the improvement of any characters, the information on its association with other characters are very crucial because selection for particular characters invariably affect its associated characters. Character association analysis could be used as an important tool to bring information about appropriate cause and effects relationship between yield and its related characters (Khan *et al.,* 2003).

Days to 50(%) flowering had showed positive significant association with days to maturity (0.514; 0.490), plant height at maturity (cm) (0.265; 0.244) and biological yield per plant (g) (0.227; 0.213), days to maturity with biological yield per plant (g) (0.355; 0.341), grain yield per plant (g) (0.249; 0.230) and plant height at maturity (cm) (0.203; 0.186), spike length (cm) was showed with number of grains per spikelet (0.444; 0.332), number of grains per spike (0.418; 0.367) and number of spikelets per spike (0.288; 0.233), biological yield per plant (g) had positive association with grain yield per plant (g) (0.744; 0.709), test weight (g) (0.458;0.431), number of spikelets per spike (0.234; 0.207) and number of grains per spike (0.225; 0.218) number of grains per spike with number of grains per spikelets (0.928; 0.510), number of spikelets per spike (0.677; 0.598) and test weight(g) (0.250; 0.233), number of spikelets per spike with number of grains per spikelets (0.704; 0.416) and test weight (g) had positive association with grain yield per plant (g) (0.436; 0.402) at genotypic and phenotypic level (Table 5). Similar results were observed by (Singh and Upadhyay, (2013), Sen *et al*. (2013); Meena *et al*. (2015) and Singh and Singh (2022). The genotypic character association value for most of the characters were higher in magnitude than the corresponding phenotypic values showing the existence of inherent association among the attributes.

The path coefficient analysis was done with twelve characters using estimates of direct and indirect effects of eleven characters on grain yield per plant (g) (Table 6). Highest positive genotypic and phenotypic direct effects on grain yield per plant (g) were exhibited by biological yield per plant (g) (1.478; 1.282) followed by harvest index (%) (0.880; 0.904) and number of tillers in 1square meter area (0.102; 0.045) which supports the findings by Moghaddam *et al*. (1997). Hence, these traits could be considered in further selection procedures for obtaining higher grain yield. Test weight (g) and spike length (cm) had negative direct effect on grain yield per plant (g). Similar result was found (Singh *et al*., 2014 and Singh and Singh, 2022). Residual effect was G=0.0566, P = 0.0394 showing the variability in the grain yield in wheat was contributed by the characters studied in path analysis.

CONCLUSION

The substantial variation observed among the wheat cultivars for the studied traits indicates significant potential for genetic improvement through selective breeding. Notably, grain yield per plant exhibited positive correlations with other yield-related traits, suggesting that these characteristics can be effectively utilized as selection criteria to enhance grain yield in wheat. Furthermore, the direct positive effects of harvest index and the number of tillers per square meter on grain yield per plant underscore the possibility of improving these traits through targeted selection strategies.

Conflict of interest

All authors declare that they have no conflict of interest.

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