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Genetic variability among wheat genotypes based on Agro-morphological traits under restricted irrigated conditions

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Abstract
Present study was carried out with thirty six promising wheat genotypes to study nature and magnitude of genetic variability and selection strategies to improve the grain yield in wheat using association analyses. Genotypes were evaluated using a randomized complete block design with three replications. Observations were recorded on randomly selected plants for days to 50% heading, days to maturity, plant height (cm), number of tillers/plant, number of ear/plant, number of spikelets/ear, ear length (cm), peduncle length (cm), biological yield/plant (g), grain yield/plant (g), thousand grain weight (g), harvest index (%), relative water content (%), canopy temperature (ºC), chlorophyll content index, protein content (%), wet gluten (%) and sedimentation value (ml). Analysis of variance showed sufficient amount of variability in the existing material for all traits studied. Number of ear/plant and ear length showed highest genotypic and phenotypic coefficient of variation. High heritability coupled with high genetic advance was recorded for thousand grain weight and ear length. Among the significant inter-relationships, the plant height showed significant positive association with grain yield/plant and wet gluten; number of tillers/plant with number of ear/ plant, number of spikelet/ear, 1000- grain weight, canopy temperature and sedimentation value; number of tillers/plant with 1000- grain weight, canopy temperature and sedimentation value; number of spikelet/ ear with ear length, chlorophyll content and protein content and ear length with harvest index and chlorophyll content at both phenotypic and the genotypic levels. Whereas, biological yield/plant showed negative significant correlation with 1000-grain weight and grain yield per plant with relative water content. Path coefficient analysis revealed that the magnitude of positive direct effect on grain yield/ plant was highest through harvest index, followed by biological yield/plant and number of tiller/plant; whereas days to maturity, followed by protein content, number of spikelets/ear, number of ear/plant and chlorophyll content exhibited high, but negative direct effect on grain yield per plant, thereby indicated that these were main contributors to the grain yield.

Keywords: Wheat, genetic variability, correlation coefficient, path analysis

Introduction
Wheat a self pollinated crop originated from West Asia is considered as the second most important cereal crop in the world. It belongs to genus '*Triticum*' of poaceae family and there are 17 different species out of which only three species are cultivated throughout the world, including *Triticum aestivum* (bread wheat) in 95%, Triticum *durum* (macaroni wheat) in 4%, and *Triticum dicocum* (emmer wheat) in1% areas in India. India is the world's second largest wheat producer with an area of 29.55 mha, production of 101.20 mt and average national productivity of 3424 kg/ha. Madhya Pradesh is third largest producer of wheat, accounting for 16% of production and 18% of the area under cultivation. In Madhya Pradesh, it is grown in an area of 5.52 mha with production of 17.35 million tones and 3143 kg/ha productivity (Anonymous, 2018-19) [3].
Wheat is very sensitive to high temperature and moisture stress and therefore, resulted in low productivity. Under scenario of climate change, Madhya Pradesh is a need of drought tolerant and low moisture genotypes for sustainable productivity of wheat. There is great scope to increase wheat production in very late sown conditions by breeding more efficient plant types adaptable to restricted irrigated condition. At present, breeding of wheat for such specific situation including identification of potential genotypes and related attributes on variability, association and co-inheritance keeps immense values. The estimation of genetic parameters and the co-heritance that help to decide breeding strategies may vary with environmental conditions and set up of experimental genotypes. Hence, it is essential to conduct studies in different environment for selection of suitable genotypes. Keeping these things in the view, an effort has been made in the present study to evaluate a set of promising genotypes with the objectives, to estimate the variability, heritability and genetic advance for yield and yield

components traits. Similarly, an attempt was also made to analyze grain yield and its attributing traits of wheat by correlation and path coefficient analysis.

Materials and Methods

A total of 36 promising genotypes (Received from IIWBR, Karnal) were planted in randomized completely block design with three replications at Seed Breeding Farm, Department of Plant Breeding and Genetics, College of Agriculture, JNKVV, Jabalpur (Madhya Pradesh) during Rabi 2017-18. The experiment was conducted with recommended agronomic practices, for restricted irrigation condition, where only one irrigation was given at 45 DAS. At the time of maturity, five plants of each genotype from each replication were selected. The data were recorded from the randomly selected plants from the field for various quantitative characters *viz*., days to 50% heading, days to maturity, plant height (cm), number of tillers/plant, number of ear/plant, number of spikelets/ear, ear length (cm), peduncle length (cm), biological yield/plant (g), grain yield/plant (g), thousand grain weight (g), harvest index (%), relative water content (%), canopy temperature (ºC), chlorophyll content index, protein content (%), wet gluten (%) and sedimentation value (ml). The mean performance of individual genotypes was embayed for statistical analysis.

Analysis of variance to test the significance for each trait was estimated as per methodology given by Panse and Sukhatme 1967 [19]. Genotypic and phenotypic coefficients of variation (GCV and PCV) were calculated by the formula given by Burton, 1952 [5], heritability in broad sense (h^2) by Burton and Vane 1953 [4] and genetic advance given by Johnson *et al*., 1955 [10]. Correlation coefficient and path coefficient was worked out as method suggested by Al-Jibouri *et al*., 1958 [2] and Dewey and Lu, 1959 [6], respectively.

Results and Discussion

The analysis of variance showed highly significant differences among the genotypes for all the traits studied (table 1), thereby suggesting the presence of considerable amount of variability among the 36 cultivars of wheat evaluated in the present study. Similar findings were also reported by Pawar *et al*., 2002 [20] and Kalimullah *et al*., 2012 [11]. The presence of large amount of variability might be due to diverse source of materials taken as well as environmental influence affecting the phenotypes.

The character possessing high genotypic coefficient of variation (GCV) value has better scope of improvement through selection. Since, the extent of variability is measured by genotypic (GCV) and phenotypic coefficient of variance (PCV) which provides information about relative amount of variation in different characters. A perusal of coefficient of variation revealed that the highest estimate of genotypic (GCV) and phenotypic coefficient of variation (PCV) was observed in case of number of ear/plant (18.62% and 22.94%) and ear length (21.05% and 22.31%). Similar findings have been also reported by Rajpoot *et al*., 2015 [24]. Moderate estimate of GCV and PCV were recorded for number of tillers/plant (18.88% and 21.30%), peduncle length (19.23% and 20.90%), harvest index (16.12% and 17.22%), grain yield/plant (15.44% and 16.73%), ear weight (11.42% and 14.83%), number of spikelets/ear (9.40% and 11.11%), chlorophyll content (9.75% and 10.36%) and thousand grain weight (10.15% and 10.30%). Report of Tiwari *et al*., 2017 [32] for peduncle length, grain yield/plant, ear weight and Mecha *et al*., 2016 [16] for test weight support our results for GCV and PCV in wheat population. While, other traits *viz*., canopy temperature, wet gluten, sedimentation value, relative water content, biological yield/plant, protein percent, plant height, days to 50% heading and days to maturity exhibited low phenotypic and genotypic coefficient of variation. This indicated low variability for such traits among genotypes. Kumar *et al*., (2003) [13] revealed low PCV and GCV for days to 50% heading and days to maturity and Singh *et al*., 2015 [28] for starch content.

The proportion of genetic variability which is transmitted from parents to offspring is reflected by heritability (Lush, 1940) [14]. In this context, the high estimates of heritability were recorded for 1000-grain weight, sedimentation value, relative water content, plant height, wet gluten content, ear length, chlorophyll content, days to 50% heading, harvest index, grain yield/plant, days to maturity, peduncle length, biological yield/plant, canopy temperature, number of tillers/plant and number of spikelets/ear, while moderate for number of ear/plant and ear weight. Rajshree and Singh (2018) [25]; Rahman *et al.*, 2016 [23] and Dutamo *et al.*,2015[8] also reported high heritability values for canopy temperature, spike length, 1000 grain weight, grain yield per plot and harvest index which in fact demonstrated the presence of additive genes effect indicating effectiveness of selection for the improvement of these traits. Selection will be more effective for those traits having high heritability, because these traits are governed predominantly by additive gene action and could be improved through individual plant selection. Whereas, low heritability indicated that the traits were highly influenced by environmental effect and genetic improvement through selection will be difficult due to effect of environment. Johnson *et al*., (1955) [10] showed that a character exhibiting high heritability may not necessarily give high genetic advance. It can be found out with greater degree of accuracy when heritability in conjunction with genetic advance is studied by Dudley and Moll, 1968 [7]. Thus a character possessing high heritability along with high genetic advance will be valuable in the selection programme. High heritability coupled with high genetic advance as percent mean were observed for 1000- grain weight, ear length, harvest index, peduncle length and number of tillers/plant. Similar kind of results were also reported by Dutamo *et al*., 2015 [8] for 1000 grain weight and harvest index; Ghallab *et al*., 2016 [9] for 1000 grain weight and Rajshree and Singh, 2018 [25] for number of tillers/plant and harvest index. It indicated predominance of additive gene action. Therefore, direct selection for such trait would be effective. The traits days to maturity and days to 50% heading showed high heritability in conjunction with low genetic advance suggested predominance of non-additive gene action, hence direct selection for such traits would mislead the expected result.

Table 1: Estimation of mean, range and different genetic parameters for different traits

Characters	Range	Mean	GCV (%)	PCV (%)	CV	h2 (bs)	GA %
Days to 50% heading	61-76	67.53	4.96	5.29	1.86	88.00	9.56
Days to maturity	111-121	116.75	2.46	2.67	1.04	85.0	4.66
Plant height (cm)	90-112	98.41	6.72	6.93	1.71	94.0	13.41
Number of tillers/plant	4-10	7.44	18.89	21.31	9.86	79.0	34.49

Number of ears/ plant	4-10	6.68	18.63	22.94	13.39	66.0	31.15
Number of spikelets/ ear	15-21	17.85	9.40	11.11	5.92	72.0	16.39
Ear length (cm)	7-15	10.09	21.01	22.32	7.55	89.0	40.72
Ear weight (g)	2-4	2.62	11.43	14.84	9.46	59.0	18.13
Peduncle length (cm)	9-25	15.71	19.24	20.91	8.18	85.0	36.47
Biological yield/ plant (g)	37-49	43.66	6.78	7.37	2.88	85.0	12.86
Grain yield/ plant (g)	9-18	13.29	15.44	16.73	1.77	85.0	29.36
1000 grain weight (g)	36-58	42.98	10.15	10.31	6.07	97.0	20.60
Harvest index (%)	21-45	30.54	16.12	17.23	4.38	88.0	31.09
Canopy temperature (ºC)	18-27	22.45	9.18	10.17	3.51	82.0	17.07
Chlorophyll content (SPAD 502)	34-53	44.64	9.75	10.36	1.94	89.0	18.90
Relative water content (%)	54-78	66.74	8.20	8.43	5.85	95.0	16.44
Protein content (%)	12-14	13.01	4.26	7.24	2.78	35.0	5.17
Wet glutin (%)	27-38	31.19	8.57	9.01	1.81	91.0	16.79
Sedimentation value (ml)	41-56	48.83	8.45	8.64	6.44	96.0	17.02

GCV=Genotypic coefficient of variation, PCV= Phenotypic coefficient of variation, h^2(bs) =Heritability (broad sense), GA = Genetic advance

Correlation coefficients at phenotypic and genotypic levels are presented in the table 2. Significant and positive correlations were observed between days to 50 % heading and days to maturity both at phenotypic and genotypic levels. A significant and positive correlation existed for grain yield/plant and wet gluten with plant height. Similar findings were observed by Singh *et al*., 2014 [26]; Khames *et al*., 2016 [12] and Singh *et al*., 2017 [29]. Number of tillers/plant showed positive significant correlation with number of ear/ plant, number of spikelet/ear, 1000- grain weight, canopy temperature and sedimentation value. However, at genotypic level, the number of tillers/plant presented a negative significant correlation with ear weight and relative water content but significant positive with 1000- grain weight, canopy temperature and sedimentation value. Similar, findings were observed by Singh *et al*., 2014 [26]; Khames *et al*., 2016 [12]; Singh *et al*., 2017 [29]; Prasad and Pandey, 2001 [22] and Phougat *et al*., 2017 [21]. The number of spikelet/ear showed positive and significant correlation with ear length, chlorophyll content and protein content. Ear length was significantly correlated with harvest index and chlorophyll content at both levels, except the negative significant correlation with biological yield/plant at the genotypic level. The biological yield/plant showed positive and significant correlation with grain yield/plant, while negative significant with 1000- grain weight at both the phenotypic and the genotypic levels. The grain yield per plant revealed significant positive association with plant height, biological yield/plant, canopy temperature and chlorophyll content, whereas negative with relative water content at both the levels. Selection for these characters can directly be followed for immediate yield improvement under restricted irrigated conditions.

Path coefficient analysis measures the direct influence of one variable upon the other, and permits separation of correlation coefficients into components of direct and indirect effects. Partitioning of total correlation into direct and indirect effects provide actual information on contribution of characters and thus form the basis for selection to improve the yield. Path coefficient analysis was carried out using coefficient of all the traits with grain yield per plant (table 3). Maximum direct effect on grain yield/ plant was contributed mostly by harvest index (1.003), followed by biological yield/plant (0.437) and number of tiller/plant (0.081). This means that a slight increase in one of the above traits may directly contribute to seed yield. Similar results were observed by Phougat *et al*., 2017 [21]; Singh and Dwivedi, 2002 [30]; Mohammed *et al*., 2011 [17] and Singh *et al*., 2012 [27] for harvest index and biological yield/plant; Singh *et al*., 2003 [31] for biological yield/plant and number of tillers/plant; Majumder *et al*., 2008 [15] for harvest index; Yadav *et al*., 2006 [33] for number of tillers/plant; Ali and Abdulla, 2016 [1] for biological yield/plant; Neeru *et al*., 2017 [18] for tiller/m and Zare *et al*., 2017 [34] for harvest index.

On the other hand, the maximum negative direct effect was exhibited by days to maturity (-0.068), followed by protein content (-0.060), number of spikelets/ear (-0.048), number of ear/plant (-0.047) and chlorophyll content (-0.035). The rest of the traits showed moderate to low positive or negative direct effect on grain yield per plant. Majority of indirect effects of various independent traits *via* other traits were extremely low of either signs. There were only few characters had higher to moderate positive indirect effects. Harvest index exerted high indirect effect on grain yield/plant via. days to 50% heading, number of tillers/plant, number of ear/plant; biological yield/plant via. number of tillers/plant, number of ear/plant; days to maturity via. number of spikelets/ear, days to 50% heading; 1000 grain weight via. protein content and number of ear/plant via. ear weight and protein content on grain yield/plant. Hence these indirect effects should also be kept in the mind while selection for better yield.

Table 2: Genotypic (upper) and phenotypic (below) correlation coefficients among nineteen traits of wheat

		DH	DM	PH	NTPP	NEPP	NSPE	EL	EW	PL	BYPP	GYPP	TGW	HI	CT	CC	RWC	PP	WGP	SDS
DH	G		0.758**	-0.060	0.198*	0.066	0.271	0.229*	-0.079	0.045	-0.011	-0.042	0.124	0.146	-0.163	0.147	-0.112	0.041	-0.073	0.114
	P		0.77**	-0.03	0.15	0.04	0.25**	0.23*	-0.04	0.06	-0.03	-0.03	0.13	0.13	-0.13	0.13	-0.11	0.02	-0.06	0.11
DM	G			0.190*	0.095	-0.015	0.239*	0.252**	0.107	-0.106	0.041	-0.001	-0.075	-0.039	-0.045	0.426**	-0.197	0.126	0.177	-0.053
	P			0.18	0.05	-0.02	0.24*	0.23*	0.06	-0.08	0.01	0.01	-0.04	-0.04	-0.03	0.38**	-0.11	0.11	0.16	-0.03
PH	G				-0.001	0.01	0.073	0.099	-0.016	0.035	-0.237*	0.232*	0.004	-0.059	0.148	0.061	0.079	0.034	0.219*	-0.080
	P				0.01	-0.001	0.02	0.07	0.02	0.09	-0.20*	0.22*	-0.01	-0.08	0.11	0.05	-0.04	0.02	0.21*	-0.09
NTPP	G					0.958**	0.280**	0.133	-0.381**	0.060	0.072	0.164	0.446**	-0.028	0.217*	0.059	-0.286**	-0.096	-0.088	0.495**
	P					0.86**	0.25**	0.12	-0.18	0.08	0.09	0.14	0.34***	-0.05	0.19*	0.03	-0.15	-0.09	-0.07	0.39**
NEPP	G						0.127	0.101	-0.304**	0.071	0.133	0.075	0.499**	0.025	0.215*	-0.038	-0.214*	-0.088	0.001	0.579**
	P						0.16	0.08	-0.17	0.05	0.16	0.07	0.39***	0.01	0.19*	-0.04	-0.05	-0.07	0.02	0.47**

NSPE	G						0.317**	-0.231*	0.156	-0.191*	0.137	0.049	-0.061	0.117	0.299**	-0.124	0.334**	0.109	-0.047
	P						0.28**	-0.12	0.09	-0.17	0.13	0.08	0.01	0.13	0.27**	-0.05	0.29**	0.08	-0.00
EL	G							-0.013	-0.136	-0.296**	0.084	0.084	0.276**	0.118	0.264**	-0.098	-0.005	-0.067	-0.043
	P							0.01	-0.14	-0.24	0.07	0.09	0.28**	0.15	0.267**	-0.00	-0.00	-0.043	-0.02
EW	G								-0.405**	-0.124	-0.009	0.019	0.179	0.011	0.030	-0.114	-0.138	-0.023	- 0.025
	P								-0.22*	-0.01	-0.00	-0.04	0.13	-0.00	0.00	-0.19	-0.07	-0.00	-0.04
PL	G									0.129	0.213*	-0.150	-0.166	-0.189*	0.216*	0.150	-0.035	-0.047	-0.102
	P									0.12	0.18	-0.13	-0.17	-0.19*	0.19*	0.00	-0.06	-0.04	-0.08
BYPP	G										0.235*	-0.269**	-0.144	0.144	0.060	-0.364**	-0.107	-0.074	0.164
	P										0.20*	-0.26**	-0.11	0.14	0.04	-0.13	-0.10	-0.05	0.18
GYPP	G											-0.033	0.022	0.285**	0.261**	-0.624**	-0.177	-0.157	0.083
	P											-0.02	0.01	0.26**	0.25**	-0.38**	-0.16	-0.16	0.08
TGW	G												0.450**	-0.310**	-0.207*	0.128	-0.045	0.101	0.904**
	P												0.38***	-0.25*	-0.16	0.12	-0.05	0.11	0.90**
HI	G													-0.231*	-0.146	0.183	0.158	-0.163	0.393**
	P													-0.16	-0.13	0.11	0.11	-0.14	0.33**
CT	G														0.269**	-0.326**	0.047	-0.021	-0.252**
	P														0.25**	-0.16	0.06	-0.02	-0.18
CC	G															0.052	0.099	0.197	-0.174
	P															0.02	0.11	0.19*	-0.14
RWC	G																0.446**	0.579**	-0.025
	P																0.21*	0.34**	0.07
PP	G																	0.453**	-0.096
	P																	0.41**	-0.09
WGP	G																		0.072
	P																		0.09

*, ** Significant at 5% and 1% respectively.

DH = Days to 50% heading, DM = Days to maturity, PH = Plant height (cm), NTPP = Number of tillers/plant, NEPP = Number of ear/plant, NSPE =number of spikelet/ear, EL = ear length (cm), EW = Ear weight, PL = Peduncle length (cm), BYPP=Biological yield/plant(g),TGW = 1000-grain weight (g), GYPP = Grain yield/plant (g), HI = Harvest index (%), CT = Canopy temperature (ºC), CC = Chlorophyll content (SPAD Units), RWC Relative water content (%), PP = Protein content %, WGP = Wet gluten %, SDS = Sedimentation value (ml)

Table 3: Path analysis (genotypic level) showing direct (bold values) and indirect effects on different traits in wheat

	DH	DM	PH	NTPP	NEPP	NSPE	EL	EW	PL	BYPP	TGW	HI	CT	CC	RWC	PP	WG	SDS
DH	0.028	0.021	-0.002	0.006	0.002	0.008	0.006	-0.002	0.001	0.000	-0.001	0.004	0.004	-0.005	0.004	-0.003	0.001	-0.002
DM	-0.052	-0.068	-0.013	-0.006	0.001	-0.016	-0.017	-0.007	0.007	-0.003	0.000	0.005	0.003	0.003	-0.029	0.013	-0.009	-0.012
PH	-0.003	0.009	0.045	0.000	0.000	0.003	0.004	-0.001	0.002	-0.011	0.010	0.000	-0.003	0.007	0.003	0.004	0.002	0.010
NTPP	0.016	0.008	0.000	0.081	0.078	0.023	0.011	-0.031	0.005	0.006	0.013	0.036	-0.002	0.018	0.005	-0.023	-0.008	-0.007
NEPP	-0.003	0.001	-0.001	-0.045	-0.047	-0.006	-0.005	0.014	-0.003	-0.006	-0.004	-0.024	-0.001	-0.010	0.002	0.010	0.004	0.000
NSPE	-0.013	-0.012	-0.004	-0.013	-0.006	-0.048	-0.015	0.011	-0.008	0.009	-0.007	-0.002	0.003	-0.006	-0.014	0.006	-0.016	-0.005
EL	0.002	0.002	0.001	0.001	0.001	0.002	0.008	0.000	-0.001	-0.002	0.001	0.001	0.002	0.001	0.002	-0.001	0.000	-0.001
EW	-0.002	0.002	0.000	-0.008	-0.006	-0.005	0.000	0.021	-0.009	-0.003	0.000	0.000	0.004	0.000	0.001	-0.002	-0.003	-0.001
PL	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
BYPP	-0.005	0.018	-0.103	0.031	0.058	-0.083	-0.129	-0.054	0.056	0.437	0.102	-0.118	-0.063	0.063	0.026	-0.159	-0.047	-0.032
TGW	0.001	0.000	-0.007	-0.005	-0.002	-0.004	-0.003	0.000	-0.006	-0.007	-0.030	0.001	-0.001	-0.008	-0.008	0.018	0.005	0.005
HI	0.124	-0.075	0.004	0.447	0.501	0.050	0.084	0.019	-0.151	-0.270	-0.033	1.003	0.452	-0.311	-0.207	0.129	-0.045	0.101
CT	0.001	0.000	0.000	0.000	0.000	0.000	0.001	0.001	-0.001	-0.001	0.000	0.002	0.004	-0.001	-0.001	0.001	0.001	-0.001
CC	0.006	0.002	-0.005	-0.008	-0.008	-0.004	-0.004	0.000	0.007	-0.005	-0.010	0.011	0.008	-0.035	-0.009	0.011	-0.002	0.001
RWC	0.007	0.020	0.003	0.003	-0.002	0.014	0.012	0.001	0.010	0.003	0.012	-0.010	-0.007	0.013	0.047	0.002	0.005	0.009
PP	0.007	0.012	-0.005	0.017	0.013	0.007	0.006	0.007	-0.009	0.022	0.037	-0.008	-0.011	0.020	-0.003	-0.060	-0.027	-0.035
WG	0.001	0.004	0.001	-0.003	-0.003	0.010	0.000	-0.004	-0.001	-0.003	-0.005	-0.001	0.005	0.001	0.003	0.014	0.030	0.014
SDS	-0.002	0.005	0.006	-0.002	0.000	0.003	-0.002	-0.001	-0.001	-0.002	-0.004	0.003	-0.004	-0.001	0.005	0.016	0.012	0.027
GYPP	0.114	-0.053	-0.080	0.495	0.580	-0.047	-0.043	-0.025	-0.102	0.164	0.083	0.904	0.393	-0.252	-0.174	-0.025	-0.096	0.072

DH = Days to 50% heading, DM = Days to maturity, PH = Plant height (cm), NTPP = Number of tillers/plant, NEPP = Number of ear/plant, NSPE =number of spikelet/ear, EL = ear length (cm), EW = Ear weight, PL = Peduncle length (cm), BYPP=Biological yield/plant(g),TGW = 1000-grain weight (g), GYPP = Grain yield/plant (g), HI = Harvest index (%), CT = Canopy temperature (ºC), CC = Chlorophyll content (SPAD Units), RWC Relative water content (%), PP = Protein content %, WGP = Wet gluten %, SDS = Sedimentation value (ml)

Conclusion

The existence of negative as well as positive direct/indirect effects by some trait on grain yield per plant *via*. one or other traits simultaneously, present a complex situation where a compromise is needed to attain proper balance of different yield components in determining ideotype for high grain yield in wheat under restricted irrigated conditions.

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