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Research Article

Physicochemical and Genetic Analysis for Grain Yield and its Contributing Traits in Macaroni Wheat (*Triticum durum* desf.) Over the Environments

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Abstract

Present investigation was conducted to estimates combining ability effects and components of gene action for 15 metric traits in durum wheat. Results revealed significant variation among parents crosses and parents v/s F_1s for all the characters. Analysis of variance for combining ability depicted the role of both additive and non-additive gene effects. Component of gene action also indicated preponderance of SCA variance that reveals non-additive (H) nature of gene effects for most of the traits. On the basis of GCA effects, parents viz., HI-8663, HI-8498, PDW-274 and PDW-233 were found good general combiner, while based on SCA effects, the crosses HI-8663 × PDW-274, PDW-274 × PDW-233 and HI-8498 × HI-8663 identified as superior having good × good general combiners for grain yield. Hence, these parents and crosses may be used in durum wheat multiple crossing programme using simple pedigree method.

Keywords: Additive and Non-additive, Combing ability, Durum wheat and Gene effects

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Introduction

Macaroni wheat [*Triticum durum*, (2n=4x=28, genomes AABB)] is one of the ancient staple food grain crop consumed by human being. The grain protein content of durum wheat is an important trait for the nutritional value of grain and the technological properties of flour [1]. In India, durum wheat has the potential for both domestic consumption and export market, as it is used primarily for making special products such as couscous, macaroni and various types of bread [2]. India has special emphasis to improve productivity of wheat under harsh environments like drought and high temperature at the time of maturity [3]. New climatic conditions might induce plant terminal growth stress resulting from a more pronounced heat and drought stress during the late stages of the wheat growth cycle [4]. Thus, early maturity is an important breeding objective in durum wheat under semi- arid conditions. Earliness minimizes the effect of terminal heat and drought stresses on plant, as short-cycle cultivars grow mostly under more favorable conditions than their long-cycle counterparts [5]. Grain yield and some other traits controlling stress tolerance are complex polygenic characters, sensitive to environmental changes, showing low response to selection [6]. Improvements of such traits rely upon identification of genetically superior and suitable genotypes and their exploitation through crossing programme, such as biparental mating or diallel selective mating and pedigree method, which exploit both additive and non-additive gene effects, simultaneously, could be useful in the improvement of grain yield and its components in durum wheat. With this perspective, the present investigation was taken to estimate the general and specific combining ability variance, effects and gene action for seed yield and its contributing characters in macaroni wheat.

Material and Method

The experimental material of present study was composed of ten genetically diverse durum wheat genotypes viz., PDW-291, HI-8498, HI-8663, WH-896, RAJ-1555, PDW-274, PDW-233, PDW-314, NIDW-295 and HI-8737. These genotypes were crossed in half diallel mating design. The investigation using 45 F_1s and 10 parents were laid out in randomized block design with three replications in each environment at three different dates of sowing as E_1 (early), E_2 (normal) and E_3 (late) at Instructional Research Farm, College of Agriculture, SKRAU, Bikaner during *Rabi* 2018-19. Each genotype was grown in a double row of 3 m length with 22.50 x 10 cm^2 spacing. Five plants were randomly selected for taking observation of plant height, flag leaf length, flag leaf area, number of productive tillers per plant, spike length, number of grains per spike, grain weight per spike, biological yield per plant, harvest index, test weight and grain yield per plant. While, phonological traits like days to 50% heading and days to maturity were recorded on whole plot basis. However quality trait protein content was estimated from a random sample of grain from bulk grain harvested from five selected plants of each replication of the experiment [7]. The mean data were subjected to statistical analysis for analysis of variance [8] and combining ability and effects [9] using Model-1 and Method-2.

Results and Discussion

The pooled analysis of variance (ANOVA) for combining ability over the environments is presented in **Table 1**. The mean squares due to parents, general combining ability (GCA) and hybrids, specific combining ability (SCA) were found significant for all the 15 characters studied, which revealed significant difference present between parents for GCA and crosses for SCA. Thus, it indicates the role of both additive and non-additive (dominance and epistasis) gene effects for all the characters. The results were in conformity with reports of [10], [11], [12], [16] and [17]. The interaction components results from GCA × Environment and SCA × Environment mean squares were also significant for all the characters except flag leaf area for both GCA × Environment and SCA × Environment, indicating that the influence of environment on both σ^2 GCA and σ^2 SCA.

Table 1 Pooled ANOVA and components of gene action for combining ability over the environments

Characters	Source of variation with degree of freedom						Components of gene action		
	Env [2]	GCA [9]	SCA [45]	GCA×E [18]	SCA×E [90]	Pooled error [324]	σ^2 GCA	σ^2 SCA	σ^2 GCA/ σ^2SCA
Days to 50% heading	2792.93**	7.99**	4.33**	3.77**	1.95*	1.20	0.18	1.04	0.18
Days to maturity	2088.57**	46.75**	8.91**	5.47**	2.68**	0.81	1.27	2.70	0.47
Plant height (cm)	3366.18**	19.67**	4.50**	7.52**	5.65**	1.77	0.49	0.90	0.54
Flag leaf length(cm)	56.32**	6.12**	3.87**	1.86*	1.30*	0.96	0.14	0.96	0.14
Flag leaf area (cm^2)	203.63**	10.48**	7.05**	0.91	1.71	1.75	0.24	1.76	0.13
Number of productive tillers per plant	216.25**	10.53**	6.76**	0.81*	0.65*	0.41	0.28	2.11	0.13
Spike length (cm)	7.04**	4.98**	1.49**	0.34**	0.29**	0.11	0.13	0.45	0.29
Grain filling period	740.72**	32.83**	21.92**	2.08*	2.29**	1.09	0.88	6.94	0.12
Number of grains per spike	798.37**	404.76**	127.40**	23.63**	25.47**	1.32	11.20	42.02	0.26
Grain weight per spike (g)	1.91**	1.47**	0.45**	0.08**	0.09**	0.01	0.04	0.14	0.27
Biological yield per plant (g)	2485.83**	27.79**	40.14**	8.90**	13.67**	1.33	0.73	12.93	0.05
Harvest index (%)	113.77**	98.61**	116.03**	16.90**	29.42**	3.07	2.65	37.65	0.07
Test weight (g)	182.45**	145.25**	44.18**	8.30**	9.09**	0.96	4.00	14.40	0.27
Protein content (%)	13.91**	0.32**	0.61**	0.16**	0.22**	0.01	0.008	0.19	0.04
Grain yield per plant (g)	501.66**	15.62**	27.38**	3.16**	3.34**	0.30	0.42	9.02	0.04

* and ** represents significant at 5% and 1% level of significance, respectively

Perusal of Table 1 represented that the amount of σ^2sca was greater than their corresponding σ^2gca for almost characters on pooled environments, which reflected preponderance of non-additive gene action in the inheritance of these traits. This might be possible due to parental lines involved in present investigation had high selection efficiency for these traits. Similar results of pre dominance of SCA variances over GCA variances have also been observed and informed by some workers in wheat [11] and [13]. The ratio of GCA and SCA variances were less than unity revealed high estimates of non-additive (H) components for most of the characters on pooled over environments [14] and [15]. On the other hand days to maturity in E_1 and plant height in E_2 and over environment exhibited additive genetic variance.

The GCA effect and SCA effects of the crosses were estimated for those characters, which had significant value of respective variance of the combining ability analysis. The parents having significant GCA effect in desired direction, non-significant GCA effect and significant GCA effect in undesired direction were classified as good, average and poor general combiner, respectively. Same pattern was also followed for crosses. Maximum and minimum values of GCA effects (represented in **Table 2** on pooled basis) for different character were lies between -0.70 (HI-8498) to 0.64 (PDW-314) for days to 50% heading; -1.37 (RAJ-1555) to 2.00 (HI-8663) for maturity; -0.86 (PDW-314) to 1.41 (WH-896) for plant height; -0.63 (WH-896) to 0.74 (PDW-291) for flag length; -0.75 (PDW-314) and 0.93 (PDW-291) for flag leaf area; -0.90 (NIDW-295) and 0.57 (PDW-274) for tillers plant^{-1}; -0.64 (PDW-314) to

0.69 (HI-8663) for spike length; -1.75 (WH-896) to 0.92 (HI-8663) for grain filling period; -6.00 (PDW-314) to 6.18 (HI-8663) for number of grains spike^{-1}; -0.34 (PDW-314) to 0.40 (HI-8663) for grain weight spike^{-1}; -1.44 (RAJ-1555) and 1.63 (PDW-274) for biological yield per plant; -2.98 (WH-896) to 2.26 (RAJ-1555) for harvest index; -3.38 (PDW-314) to 4.05 (HI-8663) for test weight; -0.13 (PDW-233) to 0.16 (WH-896) for protein content and -0.78 (PDW-314) to 0.65 (HI-8663) for grain yield per plant.

Table 2 General combining ability (GCA) effects in durum wheat on pooled environments

Parents	**Days to 50% heading**	**Days to maturity**	**Plant height (cm)**	**Flag leaf length (cm)**	**Flag leaf area (cm^2)**	**Number of productive tillers per plant**	**Spike length (cm)**	**Grain filling period**	**Number of Grains per spike**	**Grain weight per spike (g)**	**Biological yield per plant (g)**	**Harvest index (%)**	**Test weight (g)**	**Protein content (%)**	**Grain yield per plant (g)**
GCA effects															
PDW-291	-0.34	-0.76**	-0.19	0.65	0.93**	0.47**	0.20**	0.07	1.91**	0.05*	0.64**	-2.02**	0.50*	0.07**	-0.46**
HI-8498	-0.70**	1.17**	-0.63*	0.50	0.42*	0.46**	0.21**	0.38*	1.05**	0.08**	0.30	0.94**	0.86**	-0.05*	0.50**
HI-8663	0.22	2.00**	0.13	0.24	0.50*	0.57**	0.69**	0.92**	6.18**	0.40**	0.13	1.50**	4.05**	0.03	0.65**
WH-896	0.61**	-0.87**	1.41**	-0.36	-0.24	-0.24*	-0.39**	-1.75**	-3.65**	-0.23**	-0.43*	-2.98**	-2.36**	0.16**	-1.14**
RAJ-1555	-0.23	-1.37**	1.12**	0.52	0.43*	0.07	0.09	-1.37**	1.05**	0.05*	-1.44**	2.26**	0.57**	-0.09**	0.06
PDW-274	0.32	0.62**	-0.37	0.08	-0.16	0.57**	-0.07	0.24	0.31	0.008	1.63**	-0.18	0.11	-0.08**	0.65**
PDW-233	0.23	0.65**	-0.55*	-0.26	-0.32	0.06	0.12*	0.70**	1.77**	0.08**	0.58*	1.17**	0.74**	-0.13**	0.65**
PDW-314	0.64**	0.41*	-0.86**	-0.45	-0.75**	-0.73**	-0.64**	0.84**	-6.00**	-0.34**	-0.92**	-0.90*	-3.38**	0.02	-0.78**
NIDW-295	-0.22	-0.54**	-0.06	-0.39	-0.27	-0.90**	-0.26**	0.67**	-2.00**	-0.10**	-0.53*	-0.64*	-0.97**	0.09**	-0.40**
HI-8737	-0.53*	-1.32**	0.03	-0.53	-0.52*	-0.33**	-0.03	-0.73**	-0.62**	-0.005	-0.03	0.85*	-0.11	-0.02	0.25*
Minimum	**-0.70**	**-1.37**	**-0.86**	**-0.36**	**-0.75**	**-0.90**	**-0.64**	**-1.75**	**-6.00**	**-0.34**	**-1.44**	**-2.98**	**-3.38**	**-0.13**	**-0.78**
Maximum	**0.64**	**2.00**	**1.41**	**0.74**	**0.93**	**0.57**	**0.69**	**0.92**	**6.18**	**0.40**	**1.63**	**2.26**	**4.05**	**0.16**	**0.65**
SE (g_i) ±	0.17	0.14	0.21	0.37	0.20	0.10	0.05	0.16	0.18	0.01	0.18	0.27	0.15	0.01	0.08
SE (g_i-g_j) ±	0.25	0.21	0.31	0.55	0.31	0.15	0.07	0.24	0.27	0.02	0.27	0.41	0.23	0.02	0.13

A number of parents showing good GCA effects for grain yield and its contributing traits over environments for three or more traits were PDW-291 for maturity, flag leaf length, flag leaf area, number of productive tillers per plant, spike length, number of grains per spike, grain weight per spike, biological yield per plant, test weight and protein content; HI-8498, HI-8663 for flag leaf area, number of productive tillers per plant, spike length, grain filling period, number of grain per spike, grain weight per spike, harvest index, test weight and grain yield per plant; PDW-233 for spike length, grain filling period, number of grain per spike, grain weight per spike, biological yield per plant, harvest index, test weight and grain yield per plant; for quality attributing trait protein content were NIDW-295, PDW-291 and WH-896. However, GCA effects in negative direction is desirable for days to heading and days to maturity was HI-8737 and for dwarf plant height was PDW-314, PDW-233 and HI-8737 (Table 2). In wheat, parents having good general combining ability were corroborative with the findings [10], [11], [13] and [16]. On the basis of high *per se* performance and high general combining ability effects for majority of the characters, which is due to existence of gene attributed to additive and additive × additive gene interaction effects. Therefore, these parents could be used in hybridization programme for accumulation of favorable alleles in a single genetic background.

Table 3 Range of SCA effects, Number of crosses showing SCA effects and best three crosses based on SCA effects

Characters	Range of SCA effects	Number of crosses showing SCA effects	Crosses according to rank		
			1st	2nd	3rd
Days to 50% heading	-2.21 (PDW-291× WH-896) to 2.17 (PDW-291 × HI-8663)	3	PDW-291 × WH-896 (A × P)	HI-8663 × RAJ-1555 (P × A)	HI-8663 × NIDW-295 (P × A)
Days to maturity	-2.41 (WH-896 × PDW-233) to 3.26 (PDW-291 × PDW-233)	9	WH-896 × PDW-233 (A × P)	PDW-291 × HI-8663 (G × P)	HI-8498 × PDW-314 (P × P)
Plant height (cm)	-1.85 (HI-8498× NIDW-295) to 3.84 (HI-8663 × RAJ-1555)	3	HI-8498 × NIDW-295 (G × A)	HI-8663 × PDW-314 (P × G)	PDW-291 × RAJ-1555 (A × P)
Flag leaf length (cm)	PDW-291 × RAJ-1555 (-2.65) to RAJ-1555 × NIDW-295 (2.26)	9	RAJ-1555 × NIDW-295 (G × P)	PDW-274 × PDW-233 (A × A)	WH-896 × PDW-274 (P × A)
Flag leaf area (cm^2)	-3.39 (PDW-274 × HI-8737) to 3.24 (HI-8663 × PDW-274)	5	HI-8663 × PDW-274 (G × P)	PDW-291 × HI-8737 (G × P)	PDW-274 × PDW-233 (P × P)
Number of productive tillers per plant	-2.25 (PDW-291 × PDW-274) to 4.45 (PDW-291 × HI-8737)	8	PDW-291 × HI-8737 (G × P)	HI-8663 × PDW-274 (G × G)	HI-8498 × RAJ-1555(G × A)
Spike length (cm)	-1.30 (HI-8498 × PDW-274) to 1.97 (PDW-291 × HI-8737)	10	PDW-291 × HI-8737 (G × P)	PDW-274 × PDW-233 (P × G)	HI-8498 × RAJ-1555 (G × A)
Grain filling period	-5.55 (WH-896 × NIDW-295) to 4.76 (PDW-233 × HI-8737)	16	PDW-233 × HI-8737 (G × P)	PDW-291 × HI-8498 (A × G)	PDW-291 × WH-896 (A × P)
Number of grains per spike	-11.50 (HI-8498 × PDW-274) to 18.97 (PDW-291 × HI-8737)	13	PDW-291 × HI-8737 (G × P)	PDW-274 × PDW-233 (A × G)	HI-8663 × PDW-274 (G × A)
Grains weight per spike (g)	-0.68 (HI-8498 × PDW-274) to 1.20 (PDW-291 × HI-8737)	11	PDW-291 × HI-8737 (G × P)	PDW-274 × PDW-233 (A × G)	HI-8663 × PDW-274 (G × A)
Biological yield per plant (g)	-5.56 (PDW-291 × PDW-314) to 7.99 (HI-8663 × PDW-274)	16	HI-8663 × PDW-274 (A × G)	HI-8498 × RAJ-1555 (A × P)	PDW-291 × HI-8737 (G × P)
Harvest index (%)	-16.62 (RAJ-1555 × PDW-274) to 10.52 (PDW-291 × HI-8737)	20	PDW-291 × HI-8737 (P × G)	PDW-291 × RAJ-1555 (P × G)	PDW-274 × PDW-233 (P × G)
Test weight (g)	-7.00 (HI-8498 × PDW-274) to 11.04 (PDW-291 × HI-8737)	15	PDW-291 × HI-8737 (G × P)	PDW-274 × PDW-233 (A × G)	HI-8663 × PDW-274 (G × A)
Protein content (%)	-0.76 (PDW-291 × HI-8737) to 0.81 (PDW-291 × HI-8663)	22	PDW-291 × HI-8663 (G × A)	HI-8663 × WH-896 (A × G)	HI-8498 × NIDW-295 (P × G)
Grain yield per plant (g)	-5.73 (RAJ-1555 × PDW-274) to 6.93 (HI-8663 × PDW-274)	18	HI-8663 × PDW-274 (G × G)	PDW-291 × HI-8737 (P × G)	HI-8498 × HI-8663 (G × G)

The information pertaining to different aspects of SCA effect pooled over the environments was presented in **Table 3**. This table gives the information about top three crosses along number of crosses as depicted significantly in desired direction in SCA effects for different character. Ranged of SCA effects varied from -2.21 (PDW-291× WH-

896) to 2.17 (PDW-291 × HI-8663) for 50% heading; -2.41 (WH-896 × PDW-233) to 3.26 (PDW-291 × PDW-233) maturity; -1.85 (HI-8498 × NIDW-295) to 3.84 (HI-8663 × RAJ-1555) for plant height; -2.65 (PDW-291 × RAJ-1555) to 2.26 (RAJ-1555 × NIDW-295) for flag leaf length; -3.39 (PDW-274 × HI-8737) to 3.24 (HI-8663 × PDW-274) for flag leaf area; -2.25 (PDW-291 × PDW-274) to 4.45 (PDW-291 × HI-8737) for tillers plant^{-1}; -1.30 (HI-8498 × PDW-274) to 1.97 (PDW-291 × HI-8737) for spike length; -5.55 (WH-896 × NIDW-295) to 4.76 (PDW-233 × HI-8737) for grain filling period; -11.50 (HI-8498 × PDW-274) to 18.97 (PDW-291 × HI-8737) for grains spike^{-1}; -0.68 (HI-8498 × PDW-274) to 1.20 (PDW-291 × HI-8737) for grain weight spike^{-1}; -5.56 (PDW-291 × PDW-314) to 7.99 (HI-8663 × PDW-274) for biological yield plant^{-1}; -16.62 (RAJ-1555 × PDW-274) to 10.52 (PDW-291 × HI-8737) for harvest index; -7.00 (HI-8498 × PDW-274) to 11.04 (PDW-291 × HI-8737) for test weight; -0.76 (PDW-291 × HI-8737) to 0.81 (PDW-291 × HI-8663) for protein content and -5.73 (RAJ-1555 × PDW-274) to 6.93 (HI-8663 × PDW-274) for grain yield plant^{-1}. Among the 45 crosses, the five cross combinations showed significant SCA effects over the environments for four or more characters with grain yield per plant (**Table 4**) which were HI-8663 × PDW-274, PDW-274 × PDW-233, HI-8498 × HI-8663, PDW-291 × HI-8737 and HI-8498 × PDW-233 for flag leaf area, number of productive tillers per plant, spike length, grain filling period, number of grain per spike, grain weight per spike, biological yield per plant, harvest index and test weight; it also observed that cross PDW-274 × PDW-233 for flag leaf area and HI-8498 × PDW-233 for days to maturity. These crosses had both the parents were good × good general combiners, indicating that these crosses had high SCA effects might be attributed due to the cumulative effects of the additive gene action. The transgressive segregants could be isolated in higher frequency from these crosses and could be successfully utilized to generate a pure breeding line in self-pollinated crop like wheat by using simply pedigree method of breeding. PDW-291 × HI-8737, such cross combination involving at least one good general combiner parent may produce transgressive segregants due to showing high SCA effects. Hence they were indicating interaction of additive × dominance effects. While some of the cross combinations were recorded to be high SCA effects, in which both the parents were poor general combiner. Therefore, good general combiner might not necessarily produce superior cross combination; nevertheless it might occur even from poor × poor combinations. Present findings supported the reports of previous workers done [11] and [13].

Table 4 Promising crosses with high *per se* performance and genetic parameters for grain yield on pooled environments

S. No.	Crosses	Mean grain yield per plant (g)	SCA	GCA P1	P2	Types of combination	Significant SCA effects for other traits
1.	HI-8663 × PDW-274	21.32	6.93**	0.65**	0.65**	(good × good)	FLA, Tillers, SL, GF, grains, GW, BY, HI, TW
2.	PDW-274 × PDW-233	19.93	5.53**	0.65**	0.65**	(good × good)	FLL, FLA, Tillers, SL, GF, grains, GW, BY, HI, TW
3.	HI-8498 × HI-8663	19.81	5.57**	0.50**	0.65**	(good × good)	FLA, Tillers, SL, GF, grains, GW, BY, HI, TW
4.	PDW-291 × HI-8737	19.80	6.92**	-0.46**	0.25**	(poor × good)	FLA, Tillers, SL, GF, grains, GW, BY, HI, TW
5.	HI-8498 × PDW-233	18.16	3.91**	0.50**	0.65**	(good × good)	DM, FLA, Tillers, SL, grains, GW, BY, HI, TW

Where, DM=days to maturity, PH= Plant height, FLA= flag leaf area, FLL=flag leaf length, Tiller = Number of productive tillers per plant, SL= Spike length, GF= Grain filling period, Grains= Number of grains per spike, GW= Grains weight per spike, BY= Biological yield per plant, HI= Harvest index, TW= test weight and GY= Grain yield per plant

Conclusions

From the present investigation, it is concluded that parents namely HI-8498, HI-8663 and PDW-233 were good general combiners for grain yield and its contributing characters; HI-8737 for days to heading and days to maturity. Cross combinations namely HI-8663 × PDW-274, PDW-274 × PDW-233 and HI-8498 × HI-8663 could be given weightage in durum crop improvement programme. Thus, studies of gene effects and genetic variance helps to understanding genetic potential of breeding material and enhancement of grain yield along quality parameters.

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