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Estimation Combining Ability for Grain Yield and it's attributing Traits in Macaroni Wheat (*Triticum durum* Desf.)

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***Abstract*— *The goal of the current study to estimate the combining ability and gene effects for grain yield and its attributing traits in Macaroni wheat (Triticum durum Desf.). During Rabi 2023-24, eight lines and four testers were used in an attempt to make crossovers utilizing a line × tester mating scheme. In Rabi 2024–2025, the 32 hybrids that were produced, along with 12 parents and one standard check (GW 1339), were examined at the Wheat Research Station, Junagadh Agricultural University, Junagadh, using a randomized block design with three replications. The analysis of variance for combining ability revealed that the mean square due to lines and testers were significant for all the characters except mean square due to testers for plant height and 100-grain weight. Likewise, mean squares due to line × tester interaction was also found significant for all characters under investigation except plant height. For every individual in the study, the influence of specific gene combinations (SCA) on their traits was more significant than the general influence of their parents (GCA). This was further supported by the ratio of $\sigma^2_{gca}/\sigma^2_{sca}$ was less than unity for all characters confirmed the preponderance of non-additive gene action for all the traits. The estimates of gca effect indicated that among the lines, MACS 3949, GW 1348, MPO 1357 and HD 4758 were found to be good general combiners for grain yield per plant, while GDW 1255 and NIDW 1158 identified as good general combiner for this trait among testers. Parent UAS 475 was found to be good general combiners for early maturity due to negative and significant gca effects for days to anthesis and days to maturity. For grain yield per plant out of 32 crosses 11 were evaluated for their sca effects exhibited significant and favourable sca effects. Among them, the highest sca effects was manifested by the cross GW 1348 × GDW 1255 followed by HD 4758 × WHD 965 and HI 8841 × HI 8737.*

***Keywords*— Triticum durum Desf., combining ability, gene action**

I. INTRODUCTION

Wheat is a most extensively grown food crop in the world. Wheat is prized for its high nutritious content. Approximately 32% of all cereal growing land worldwide is planted with wheat, which is cultivated throughout a variety of latitudes. India's major wheat-growing states include Uttar Pradesh, Madhya Pradesh, Punjab, Haryana, Rajasthan, Maharashtra and Gujarat.

In India, farmers cultivated 31.83 million hectares, yielding 113.29 million tons with an average productivity of 3559 kg per hectare. While Gujarat accounted for 1.24 million hectares of land, 3.77 million tonnes of production and 3027 kg of productivity per hectare (Anon., 2024). In India there are six mega wheat-growing environments i.e. North-Western Plains Zone (NWPZ), North-Eastern Plains Zone (NEPZ), Central Zone (CZ), Peninsular Zone (PZ), Northern Hills Zone (NHZ) and Southern Hills Zone (SHZ) (Anon., 2007).

The durum wheat is higher in protein, β-carotene and vital micronutrients like iron and zinc, so it offers greater nutrition (ZukGolaszewska *et al*., 2016). Durum wheat contains high level of folate. which is much important during pregnancy time. The glycemic index of durum wheat pasta is substantially lower than that of regular wheat pasta. Regular pasta causes a quicker spike in blood sugar (GI 68) compared to pasta made from durum wheat, which leads to a more gradual rise (GI 47). Durum wheat is a potentially for maintaining the health of our eyes because it contains roughly twice as much lutein than bread wheat.

The choice of parents to be incorporated in hybridization programme is a crucial step for breeders, particularly if the aim is improvement of complex quantitative characters, such as grain yield and its components. The use of parents of known superior genetic worth ensures much better success. Geneticists need to thoroughly analyze the genes of current plant varieties and new promising lines to identify the best ones for future breeding programs or direct release as new crop types after testing. Nature and magnitude of heterosis is one of the important aspects for selection of right parents for crosses and also help in identification of superior cross combinations that produce desirable transgressive segregants in advanced generations.

II. MATERIALS AND METHODS

The field experiment was conducted at Wheat Research Station, Junagadh Agricultural University, Junagadh during *Rabi,* 2023-24 and 2024-25. This region has a typical sub-tropical climate. The soil of the experimental site was medium black, alluvial in origin and poor in organic matter. The experimental material of present study was comprised of 32 elite hybrids developed by crossing eight lines and four testers in line × teste mating design along with one standard check (GW 1339). DDW 48, GW 1348, HD 4758, HI 8841, MACS 3949, MPO 1357, RAJ 3307 and UAS 475 used as lines and GDW 1255, HI 8737, WHD 965 and NIDW 1158 used as testers. The genotypes were collected from Wheat Research Station, Junagadh Agricultural University, Junagadh.

The crossing programme was carried out during *Rabi,* 2023-24 at Wheat Research Station, Junagadh Agricultural University, Junagadh. At the same time, the male and female parents were selfed to get pure seeds of parents for the experiment. The experimental material consisting of 45 entries, including 12 parents, 32 crosses and one standard check (GW 1339) were tested in randomized block design with three replications during *Rabi,* 2024-25. A single row plot of 2.5 m was allotted randomly to each entry. The row-to-row and plant-to-plant distance was kept 22.5 cm and 10 cm, respectively.

Five competitive plants per genotype in each replication in each environment were selected randomly for recording observations on plant height (cm), number of effective tillers per plant, length of main spike (cm), number of spikelets per main spike, number of grains per main spike, 100-grain weight (g), grain yield per plant(g), biological yield per plant (g) and harvest index (%) (except days to anthesis, grain filling period and days to maturity) and their average values were used in the statistical analysis.

III. RESULTS AND DISCUSSION

3.1 Analysis of variance for combining ability and gene action

The analysis of variance for combining ability for all the twelve traits is presented in Table 1. The analysis of variance for combining ability revealed that the mean square due to lines and testers were significant for all the characters except mean square due to testers for plant height and 100-grain weight. Likewise, mean squares due to line × tester interaction was also found significant for all characters under investigation except plant height.

The SCA variations were greater than the GCA variances for every character in the study, according to the magnitude of the GCA and SCA variants. This suggested that non-additive gene action plays a significant role in the inheritance of these traits. This was further supported by the ratio of $\sigma^2_{gca}/\sigma^2_{sca}$ was less than unity for all characters confirmed the preponderance of non-additive gene action for all the traits. The predominance of non-additive gene action for grain yield and its attributing traits was also reported by Riaz *et* *al.* (2021), Mousa *et al.* (2022), Rauf *et al.* (2023) and Talpur *et al.* (2024).

3.2 Estimation of general combining ability effects

The estimation of general combining ability effects revealed that for days to anthesis DDW 48, MACS 3949 and UAS 475 among the lines, whereas HI 8737 among the testers were found good general combiners. For grain filling period lines *viz.,* HD 4758, MPO 1357 and RAJ 3307, whereas among testers, GDW 1255 considered as good combiner. Lines *viz.,* RAJ 3307 and UAS 475 were good general combiners for days to maturity, whereas GDW 1255 as tester parent. The lines GW 1348 and HI 8841 registered good general combiners, while none of the testers was good combiner for plant height. The lines *viz.,* GW 1348, HD 4758, MACS 3949 and MPO 1357 excretes good general combining effects for number of effective tillers per plant. Lines HD 4758 and MPO 1357 whereas in tester GDW 1255 exhibited good general combiners for length of main spike. The lines, HD 4758 and MACS 3949, while NIDW 1158 among the testers were considered as good general combiners for number of spikelets per main spike. The estimation of general combining ability effect indicated that good combiners for number of grains per main spike were HD 4758 and MACS 3949, among the lines, whereas NIDW 1158 among the parents. For a 100-grain weight, lines GW 1348 and MACS 3949 as well as no tester parents demonstrated good overall combining effects. For grain yield per plant, among the lines, GW 1348, HD 4758, MACS 3949 and MPO 1357 were identified as good general combiners, GDW 1255 and NIDW 1158 were identified as good general combiners among the testers. For biological yield per plant, good general combining effect was registered in three lines GW 1348, HD 4758 and MACS 3949; GDW 1255 and NIDW 1158 testers. For harvest index two lines MPO 1357 and RAJ 3307 and testers, WHD 965 and NIDW 1158 were considered as good general combiners. (Table 2)

Table 1 Analysis of variance for combining ability and variance components for grain yield and its attributing traits in durum wheat

Source	d.f.	Days to anthesis	Grain filling period	Days to maturity	Plant height	Number of effective tillers per plant	Length of main spike
Replications	2	2.697**	0.375	3.885**	7.163	0.342	0.207
Lines	7	32.994**	28.166**	5.375**	53.598*	15.321**	1.170**
Testers	3	13.819**	21.305**	13.736**	30.685	8.587**	1.219**
Lines × Testers	21	25.708**	36.742**	11.926**	30.774	6.205**	1.334**
Error	62	0.536	0.331	0.595	18.304	0.167	0.229
Variance Components							
σ^2_l		2.704	2.319	0.398	2.941	1.262	0.078
σ^2_t		0.553	0.873	0.547	0.515	0.350	0.041
σ^2_{sca} (σ^2_{lt})		8.390**	12.136**	3.777**	4.156	2.012**	0.368**
σ^2_{gca}		1.270	1.355	0.497	1.324*	0.654**	0.053
$\sigma^2_{gca}/\sigma^2_{sca}$		**0.151**	**0.111**	**0.131**	**0.318**	**0.325**	**0.145**

*, ** Significant at 5% and 1% against error, respectively

+, ++ Significant at 5% and 1% levels, respectively against line × tester interaction

The estimation of genetic variance contributed by lines (σ^2l) and testers (σ^2t)

Table 1 Cont…

Source	d.f.	Number of spikelets per main spike	Number of grains per main spike	100-grain weight	Grain yield per plant	Biological yield per plant	Harvest index
Replications	2	1.750	5.790	0.919**	0.914	0.881	4.861
Lines	7	13.745**	70.709**+	0.898**	101.290**+	2125.200**++	359.699**
Testers	3	11.274**	81.472**	0.189	42.623**	875.204**	277.965**

Lines x Testers	21	6.105**	27.076**	0.395**	38.443**	320.772**	285.474**
Error	62	1.082	5.094	0.137	1.226	10.576	9.958
Variance Components							
σ^2_l		1.055	5.467*	0.063	8.338*	176.218**	29.145
σ^2_t		0.424	3.182	0.002	1.724	36.026	11.166
σ^2_{sca} (σ^2_{lt})		1.674**	7.327**	0.086**	12.405**	103.398**	91.838**
σ^2_{gca}		0.634**	3.944**	0.022*	3.929**	82.757**	17.159
$\sigma^2_{gca}/\sigma^2_{sca}$		**0.379**	**0.538**	**0.262**	**0.316**	**0.800**	**0.186**

*, ** Significant at 5% and 1% against error, respectively

+, ++ Significant at 5% and 1% levels, respectively against line × tester interaction

The estimation of genetic variance contributed by lines ($\sigma^2 l$) and testers ($\sigma^2 t$)

Table 2 General combining ability effects of parents for grain yield and its attributing traits in durum wheat

Sr. No.	Parents	Days to anthesis	Grain filling period	Days to maturity	Plant height	Number of effective tillers per plant	Length of main spike
Lines							
1	DDW 48	-0.604**	0.750**	0.146	1.740	-1.910**	-0.161
2	GW 1348	-0.188	0.250	0.063	3.157*	1.423**	0.174
3	HD 4758	2.646**	-2.250**	0.296	1.378	0.723**	0.354*
4	HI 8841	0.729**	0.583**	1.313**	-3.798**	-0.277*	-0.071
5	MACS 3949	-2.438**	2.333**	-0.104	-0.077	0.506**	-0.027
6	MPO 1357	0.979**	-1.333**	-0.354	-0.688	0.856**	0.357*
7	RAJ 3307	0.813**	-1.417**	-0.604**	-0.880	-0.027	-0.019
8	UAS 475	-1.938**	1.083**	-0.854**	-0.833	-1.294**	-0.606**
	SE (g_i)	0.211	0.166	0.222	1.235	0.118	0.138
Testers							
1	GDW 1255	0.021	-1.083**	-1.063**	-1.165	0.548**	0.286**
2	HI 8737	-1.063**	1.208**	0.146	1.513*	-0.827**	-0.140
3	WHD 965	0.354**	-0.167	0.188	-0.428	0.298**	-0.215*
4	NIDW 1158	0.688**	0.042	0.729**	0.080	-0.019	0.070
	SE (g_i)	0.149	0.117	0.157	0.873	0.083	0.097
***, ** Significant at 5% and 1% against error, respectively**							

Table 2 Cont.....

Sr. No.	Parents	Number of spikelets per main spike	Number of grains per main spike	100-grain weight	Grain yield per plant	Biological yield per plant	Harvest index
Lines							
1	DDW48	-0.602*	-1.021	-0.159	-4.525**	-15.090**	-2.841**

2	GW1348	-0.069	-0.171	0.269*	2.615**	11.645**	-4.968**
3	HD4758	2.265**	5.313**	-0.010	1.633**	24.621**	-8.737**
4	HI8841	-0.852**	-1.854**	-0.192	-2.093**	-3.998**	1.237
5	MACS3949	0.665*	1.346*	0.404**	3.781**	6.522**	0.317
6	MPO1357	0.165	0.013	0.203	1.905**	-4.223**	8.703**
7	RAJ3307	-0.569	-1.554*	-0.098	-0.849*	-8.297**	4.486**
8	UAS475	-1.00**	-2.071**	-0.418**	-2.466**	-11.180**	1.804
	SE (g_i)	0.300	0.651	0.107	0.319	0.938	0.9110
Testers							
1	GDW1255	0.206	0.621	0.105	0.785**	8.748**	-4.850**
2	HI8737	-0.860**	-2.296**	-0.094	-1.975**	-3.328**	0.406
3	WHD965	-0.127	-0.413	-0.049	0.365	-4.595**	2.993**
4	NIDW1158	0.781**	2.087**	0.038	0.824**	-0.826	1.451*
	SE (g_i)	0.212	0.460	0.075	0.226	0.663	0.644
**** Significant at 5% and 1% against error, respectively**							

Table 3 Specific combining ability effects for days to anthesis, grain filling period, days to maturity and plant height in durum wheat

Sr. No.	Hybrids	Days to anthesis	Grain filling period	Days to maturity	Plant height
1	DDW 48 × GDW 1255	0.646	-1.750**	-1.104*	-2.796
2	DDW 48 × HI 8737	-6.604**	7.292**	0.683	2.263
3	DDW 48 × WHD 965	2.646**	0.333	2.979**	3.140
4	DDW 48 × NIDW 1158	3.313**	-5.875**	-2.563**	-2.608
5	GW 1348 × GDW 1255	1.563**	-1.250	0.313	1.921
6	GW 1348 × HI 8737	2.313**	-0.875*	1.438*	0.986
7	GW 1348 × WHD 965	-3.104**	0.500	-2.604**	1.080
8	GW 1348 × NIDW 1158	-0.771	1.625**	0.854	-3.987
9	HD 4758 × GDW 1255	-0.604	3.917**	3.313**	-1.117
10	HD 4758 × HI 8737	-0.188	-1.375**	-1.563**	-1.441
11	HD 4758 × WHD 965	1.729**	-1.000**	0.729	-3.367
12	HD 4758 × NIDW 1158	-0.938*	-1.542**	-2.479**	5.925*
13	HI 8841 × GDW 1255	0.979*	-2.917**	-1.938**	0.466
14	HI 8841 × HI 8737	1.063*	1.125**	2.188**	-0.835
15	HI 8841 × WHD 965	-1.688**	0.500	-1.188**	-4.051
16	HI 8841 × NIDW 1158	-0.354	1.292**	0.938*	4.421
17	MACS 3949 × GDW 1255	1.813**	-1.667**	0.146	-0.815
18	MACS 3949 × HI 8737	-3.438**	2.708**	-0.729	-2.743
19	MACS 3949 × WHD 965	-0.854*	1.750**	0.896*	2.805

20	MACS 3949 × NIDW 1158	2.479**	-2.792**	-0.313	0.753
21	MPO 1357 × GDW 1255	-2.938**	3.000**	0.063	0.696
22	MPO 1357 × HI 8737	4.146**	-6.292**	-2.146**	1.408
23	MPO 1357 × WHD 965	0.396	-0.917**	-0.521	2.522
24	MPO 1357 × NIDW 1158	-1.604**	4.208**	2.604**	-4.626
25	RAJ 3307 × GDW 1255	1.896**	-0.583	1.313**	0.968
26	RAJ 3307 × HI 8737	-1.688**	2.125**	0.438	0.530
27	RAJ 3307 × WHD 965	0.896*	-1.500**	-0.604	1.257
28	RAJ 3307 × NIDW 1158	-1.104*	-0.042	-1.146*	-2.754
29	UAS 475 × GDW 1255	-3.354**	1.250**	-2.104**	0.677
30	UAS 475 × HI 8737	4.396**	-4.708*8	-0.313	-0.167
31	UAS 475 × WHD 965	-0.021	0.333	0.013	-3.386
32	UAS 475 × NIDW 1158	-1.021*	3.125**	2.104**	2.876
SE (S_{ij})±		**0.422**	**0.332**	**2.470**	**2.470**
Range of sca effects		**-6.604 to 4.396**	**-6.292 to 7.292**	**-2.604 to 3.313**	**-4.626 to 5.925**
No. of crosses with significant and desirable sca effects		**11**	**14**	**10**	**0**

*, ** Significant at 5% and 1% against error, respectively

Table 4 Specific combining ability effects for number of effective tillers per plant, length of main spike, number of spikelets per main spike and number of grains per main spike in durum wheat

Sr. No.	**Hybrids**	**Number of effective tillers per plant**	**Length of main spike**	**Number of spikelets per main spike**	**Number of grains per main spike**
1	DDW 48 × GDW 1255	0.652**	-0.412	-0.023	-0.754
2	DDW 48 × HI 8737	1.427**	0.107	0.510	0.962
3	DDW 48 × WHD 965	-0.365	-0.045	1.177	2.213
4	DDW 48 × NIDW 1158	-1.715**	0.350	-1.665**	-2.421
5	GW 1348 × GDW 1255	1.185**	1.273**	2.044**	3.863**
6	GW 1348 × HI 8737	-2.640**	-0.295	-1.023	-1.488
7	GW 1348 × WHD 965	-0.298	-0.420	-0.356	-0.438
8	GW 1348 × NIDW 1158	1.752**	-0.558*	-0.665	-1.938
9	HD 4758 × GDW 1255	-0.048	-0.607*	-1.023	-2.754*
10	HD 4758 × HI 8737	-1.673**	-0.261	-1.956**	-4.637**
11	HD 4758 × WHD 965	1.935**	-0.420	-0.356	-0.854
12	HD 4758 × NIDW 1158	-0.215	1.288**	3.335**	8.246**
13	HI 8841 × GDW 1255	-0.115	-0.396	-0.173	0.012

14	HI 8841 × HI 8737	0.194	-0.010	0.760	1.529
15	HI 8841 × WHD 965	-0.131	0.839**	0.094	0.046
16	HI 8841 × NIDW 1158	0.052	-0.433	-0.681	-1.588
17	MACS 3949 × GDW 1255	-1.698**	-0.653*	-2.023**	-2.454
18	MACS 3949 × HI 8737	1.677**	0.606*	1.710**	1.463
19	MACS 3949 × WHD 965	0.285	0.108	0.310	0.979
20	MACS 3949 × NIDW 1158	-0.265	-0.061	0.002	0.013
21	MPO 1357 × GDW 1255	0.152	0.143	-0.390	0.854
22	MPO 1357 × HI 8737	0.794**	-0.045	0.944	2.729*
23	MPO 1357 × WHD 965	-0.998**	0.030	-0.323	-0.554
24	MPO 1357 × NIDW 1158	0.052	-0.128	-0.231	-1.321
25	RAJ 3307 × GDW 1255	-0.765**	-0.034	-0.190	-0.688
26	RAJ 3307 × HI 8737	-0.056	-0.081	0.190	-0.171
27	RAJ 3307 × WHD 965	1.819**	-0.546	-0.723	-1.587
28	RAJ 3307 × NIDW 1158	-0.998**	0.662*	1.102	2.446
29	UAS 475 × GDW 1255	0.635**	0.686*	1.777*	3.629**
30	UAS 475 × HI 8737	0.277	-0.021	-0.756	-0.387
31	UAS 475 × WHD 965	-2.248**	0.454	0.177	0.196
32	UAS 475 × NIDW 1158	1.335**	-1.118**	1.198	-3.438**
SE (S_{ij})±		**0.236**	**0.276**	**0.600**	**1.303**
Range of sca effects		**-2.640 to 1.935**	**-1.118 to 1.288**	**-2.023 to 3.335**	**-4.637 to 8.246**
No. of crosses with significant and desirable sca effects		**10**	**6**	**4**	**4**

*, ** Significant at 5% and 1% against error, respectively

Table 5 Specific combining ability effects for 100-grain weight, grain yield per plant, biological yield per plant and harvest index in durum wheat

Sr. No.	Hybrids	100-grain weight	Grain yield per plant	Biological yield per plant	Harvest index
1	DDW 48 × GDW 1255	-0.134	-0.147	-5.781**	4.194*
2	DDW 48 × HI 8737	-0.162	4.810**	7.609**	3.755*
3	DDW 48 × WHD 965	0.323	-0.604	1.722	-0.215
4	DDW 48 × NIDW 1158	-0.027	-4.059**	-3.550	-7.73**
5	GW 1348 × GDW 1255	0.321	6.483**	-3.822*	13.558**
6	GW 1348 × HI 8737	-0.113	-5.457**	0.280	-9.141**
7	GW 1348 × WHD 965	-0.472*	-3.454**	-5.583**	-3.495
8	GW 1348 × NIDW 1158	0.264	2.428*	9.125**	-0.923
9	HD 4758 × GDW 1255	-0.397	-1.348*	-3.408	-1.174
10	HD 4758 × HI 8737	-0.381	-4.368**	8.935**	-2.359

11	HD 4758 × WHD 965	0.554*	5.272**	10.058**	-0.806
12	HD 4758 × NIDW 1158	0.234	0.444	-15.584**	4.339*
13	HI 8841 × GDW 1255	0.158	-2.362**	14.360**	-6.837**
14	HI 8841 × HI 8737	0.354	3.451**	-10.454**	12.414**
15	HI 8841 × WHD 965	-0.134	-0.779	-10.230**	4.914**
16	HI 8841 × NIDW 1158	-0.378	-0.310	6.324**	-10.491**
17	MACS 3949 × GDW 1255	-0.378	-3.666**	-6.243**	-2.567
18	MACS 3949 × HI 8737	0.712**	1.027	4.713*	-3.769*
19	MACS 3949 × WHD 965	-0.237	3.344**	12.920**	-2.453
20	MACS 3949 × NIDW 1158	0.097	-0.705	-11.389**	8.789**
21	MPO 1357 × GDW 1255	0.057	1.446*	4.806*	-5.466**
22	MPO 1357 × HI 8737	0.099	1.293*	-0.385	-3.032
23	MPO 1357 × WHD 965	-0.063	-2.370**	-1.305	-6.685**
24	MPO 1357 × NIDW 1158	-0.093	-0.369	-3.117	15.183**
25	RAJ 3307 × GDW 1255	0.328	-3.476**	8.647**	-14.906**
26	RAJ 3307 × HI 8737	-0.029	0.754	-10.380**	11.715**
27	RAJ 3307 × WHD 965	-0.081	1.297*	2.463	0.388
28	RAJ 3307 × NIDW 1158	-0.218	1.425*	-0.729	2.803
29	UAS 475 × GDW 1255	0.045	3.070**	-8.557**	13.199**
30	UAS 475 × HI 8737	-0.479*	-1.510*	-0.318	-9.583**
31	UAS 475 × WHD 965	0.119	-2.706**	-10.045**	8.353**
32	UAS 475 × NIDW 1158	0.315	1.145	18.920**	-11.968**
SE (S_{ij})±		**0.214**	**0.639**	**1.877**	**1.822**
Range of sca effects		**-0.479 to 0.712**	**-5.457 to 6.483**	**-15.584 to 18.920**	**-14.906 to 15.183**
No. of crosses with significant and desirable sca effects		**2**	**11**	**11**	**11**

*, ** Significant at 5% and 1% against error, respectively

The lines GW 1348, HD 4758, MACS 3949, and MPO 1357 were effective in producing high grain yield per plant, and they passed this trait on to their offspring for number of effective tillers per plant, length of main spike, number of spikelets per main spike, number of grains per main spike, 100-grain weight and biological yield per plant. The testers GDW1255 and NIDW 1158 were good general combiners for grain yield per plant were also found good combiners for length of main spike, number of spikelets per main spike, number of grains per main spike and biological yield per plant. Therefore, the parents that performed well in general combing for grain yield were also performing well in general combing for one or more component characteristics. Hence, these parents may be exploited well in the future breeding programme for grain yield improvement in durum wheat. These finding were in accordance with Joshi and Kumar (2020), Kumar *et al.* (2021), Dudhat *et al.* (2022), Fouad *et al.* (2023), Reddy *et al.* (2023) and Fareed *et al.* (2024).

3.3 Estimation of specific combining ability effects

Here are the estimates of the specific combing ability (sca) effects of hybrids on yield and its attributing traits:

Out of 32 hybrids, 11 hybrids revealed significant negative sca effects for days to anthesis. The highest significant and negative sca effect was observed in cross DDW 48 × HI 8737 (-6.604) followed by MACS 3949 × HI 8737 (-3.438), UAS 475 × GDW 1255 (-3.354) and GW 1348 × WHD 965 (-3.104) (Table 3). For grain filling period (days), out of 32 hybrids, 14 hybrids exhibited significant negative sca effects. The highest significant and negative sca effects observed in cross MPO 1357 × HI 8737 (-6.292) followed by DDW 48 × NIDW 1158 (-5.875) and UAS 475

× HI 8737 (-4.708) (Table 3). 10 crosses exhibited significant and negative sca effects for early maturity. The highest significant and negative sca effect was observed in cross GW 1348 × WHD 965 (-2.604) followed by DDW 48 × NIDW 1158 (-2.563), HD 4758 × NIDW 1158 (-2.479), MPO 1357 × HI 8737 (-2.146) and UAS 475 × GDW 1255 (-2.104) indicating that they may be promising hybrids for exploiting earliness in durum wheat (Table 3). The ranged of sca effects for plant height in hybrids varied from -4.626 (MPO 1357 × NIDW 1158) to 5.925 (HD 4758 × NIDW 1158). None of the hybrids exhibited significant negative sca effects for dwarf plant height (Table 3). Out of 32 crosses, 10 crosses exhibited significant and positive sca effects for number of effective tillers per plant. The highest significant and positive sca effects was observed in cross HD 4758 × WHD 965 (1.935) followed by RAJ 3307 × WHD 965 (1.819), GW 1348 × NIDW 1158 (1.752) and DDW 48 × HI 8737 (1.427) indicating that they may be promising hybrids for number of effective tillers per plant (Table 4). The sca effect for length of main spike in hybrids, out of 32 crosses, six crosses exhibited significant and positive sca effects for length of main spike. The highest significant and positive sca effects were observed in cross HD 4758 ×

NIDW 1158 (1.288) followed by GW 1348 × GDW 1255 (1.273) and HI 8841 × WHD 965 (0.839) indicating that they may be promising hybrids for number of effective tillers per plant (Table 4). Four crosses exhibited significant and positive sca effects for number of spikelets per main spike. The highest significant and positive sca effect was observed in cross HD 4758 × NIDW 1158 (3.335) followed by GW 1348 × GDW 1255 (2.044), UAS 475 × GDW 1255 (1.777) and MACS 3949 × HI 8737 (1.710) (Table 4). Out of 32 crosses, four crosses exhibited significant and positive sca effects for number of grains per main spike. The highest significant and positive sca effects was observed in cross HD 4758 × NIDW 1158 (8.246) followed by GW 1348 × GDW 1255 (3.863), UAS 475 × GDW 1255 (3.629) and MPO 1357 × HI 8737 (2.729) indicating that they may be promising hybrids for number of grains per main spike (Table 4). The cross MACS 3949 × HI 8737 (0.712) and HD 4758 × WHD 965 (0.554) were identified as good specific combinations as they exhibit significant and positive sca effects for 100-seed weight. 11 crosses were identified as good specific combiners as they exhibit significant and positive sca effects for grain yield per plant. The most superior cross combiners were GW 1348 × GDW 1255 (6.483), HD 4758 × WHD 965 (5.272) and DDW 48 × HI 8737 for grain yield per plant (Table 5). Ten hybrids were identified as good specific combiners for biological yield per plant. The most superior cross combinations were UAS 475 × NIDW 1158 (18.920), MACS 3949 × WHD 965 (12.920) and HI 8841 × GDW 1255 (14.360) (Table 5). The spectrum of variability for sca effects in hybrids for harvest index was varied from -14.906 (RAJ 3307 × GDW 1255) to 15.183 (MPO 1357 × NIDW 1158). Out of 32 crosses, 11 crosses exhibited significant and positive sca effects for harvest index. The highest significant and positive sca effect was observed in cross MPO 1357 × NIDW 1158 (15.183) followed by GW 1348 × GDW 1255 (13.558) and HI 8841 × HI 8737 (12.414) indicating that they may be promising hybrids for number of spikelets per main spike (Table 5).

It is general observation that good cross combinations obtained between good × good and poor ones between poor × poor general combiners. But in the present study, superior cross combinations *viz.,* GW 1348 × GDW 1255 (good ×good), HD 4758 × WHD 965 (good × average) and DDW 48 × HI 8737 (poor × poor) general combiners for the characters under study indicates that good cross combinations are not always obtained by crossing between good general combiners.

With respect to specific combining ability effects, following conclusion could be drawn from the present study. No cross combination exhibited consistently high specific combining ability effects for all the characters studied. Crosses having high sca effects for grain yield also depicted high sca effects for yield attributing characters. The crosses exhibiting high sca effects did not always involve parents with high gca effects suggesting that interallelic interaction was important for characters. These findings are in agreement with the findings of Motawea (2017), Joshi and Kumar (2020) and Kumar *et al.* (2021).

IV. CONCLUSION

Majority of the parents exhibited good gca effect for different traits also had acceptable *per se* performance, which suggested that the *per se* performance can be considered as a reliable criterion for selecting parents for hybridization. In case of line × tester, three cross combinations *viz.*, GW 1348 × GDW 1255, HD 4758 × WHD 965 and DDW 48 × HI 8737 were found to be better specific combiners for grain yield per plant which were in combination of good × good, good × average and poor × poor combiners, respectively. Crosses with high sca effects for grain yield per plant also depicted high sca effects for important grain yield attributes *viz.,* length of main spike, number of spikelets per main spike, number of grains per main spike and 100-grain weight. The combining ability analysis revealed predominance of non-additive gene action for the inheritance of grain yield and its attributes. At present heterosis breeding is not feasible in wheat at commercial level, above three crosses could be exploited to isolate transgressive segregants in segregating generations to develop high yielding pureline in durum wheat.

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