*Available online at* www.ijpab.com

DOI: http://dx.doi.org/10.18782/2320-7051.7664

**ISSN: 2582 – 2845**

*Ind. J. Pure App. Biosci.* (2019) *7*(4), 217-224

*Research Article*

Indian Journal of Pure & Applied Biosciences

# Combining Ability Analysis for Grain Yield and Its Components in Durum Wheat (*Triticum durum* Desf.)

**Nidhi A. Bajaniya[1], A. G. Pansuriya[1*], D. M. Vekaria[1], Chandrakant Singh[1] and J. J. Savaliya[2]**

[1]Wheat Research Station, Junagadh Agricultural University, Junagadh-362001, Gujarat

[2]Oilseeds Research Station, Junagadh Agricultural University, Manavadar-362630, Gujarat

*Corresponding Author E-mail: agpansuriya@jau.in

Received: 25.06.2019 | Revised: 29.07.2019 | Accepted: 6.08.2019

## ABSTRACT

*Combining ability was studied using a line × tester (10 × 4) analysis in durum wheat (Triticum durum Desf.). The analysis of variance for combing ability and the estimates of variance components indicated that the mean squares due to lines were significant for all characters which revealed significant contribution of lines towards general combining ability variance components for most of traits. The mean squares due to testers were also found significant for all the characters except number of spikelets per main spike, grain filling period and 100- grain weight suggesting the larger contribution of testers towards component of gca variance. The mean sum of squares due to lines × testers interaction observed significant for all yield attributing traits which revealed the significant contribution of hybrids for specific combining ability variance components. The best general combiners for various characters were DBPY 2012-06 for grain yield per plant, MACS 4054 for days to heading, 100-grain weight, grain yield per plant, biological yield per plant and harvest index, UAS 428 for plant height, grain filling period and number of grains per main spike, GW 2010-275 for length of main spike and number of spikelets per main spike, UPD 2949 days to maturity and WHD 960 for number of effective tillers per plant. The best specific combiner was GDW 1255 × UPD 2949 for grain yield per plant.*

***Keywords:*** *Triticum durum Desf., General combining ability, Specific combining ability*

## INTRODUCTION

Durum or macaroni wheat (*Triticum durum Desf.*), (2n=4x=28, genomes AABB), is one of the ancient staple food grain crop consumed by human beings. Wheat is grown over a range of latitudes and known for its remarkable adaptation to a wide diversity of environments. It occupies about 32 per cent of the total acreage under cereals in the world. Bread wheat is mostly preferred for making chapatti's/breads because of its binding properties of gluten; whereas, durum wheat is highly valued for preparation of macaroni, spaghetti, vermicelli and noodles. Macaroni wheat till recently were confined to only rainfed areas of Central and Peninsular India.

**Cite this article:** Bajaniya, N.A., Pansuriya, A.G., Vekaria, D.M., Singh, C., & Savaliya, J.J. (2019). Combining Ability Analysis for Grain Yield and Its Components in Durum Wheat (*Triticum durum* Desf.), *Ind. J. Pure App. Biosci. 7*(4), 217-224. doi: http://dx.doi.org/10.18782/2320-7051.7664

However, being responsive to higher fertilizer application and development of rust resistant high yielding varieties encouraged cultivation of durum wheat under irrigated conditions.

For improving the genetic yield potential of the varieties and hybrids, choice of right type of parents for hybridization is important. This emphasises the importance of testing the parents for their combining ability and their hybrids for manifestation of hybrid vigour, because many-a-times the high yielding parents may not combine well to give good hybrids. Therefore, the success of the useful gene combinations organized in the form of high combining lines and isolation of valuable sources of germplasm is necessary. From this, breeder will extract necessary background information with respect to genetic basis of grain yield and its components, nature of gene action and general and specific combining ability of elite parents and their crosses, respectively in the plant breeding programme.

## MATERIALS AND METHODS

The experimental material of the study consisted of ten lines i.e., MPO 1215, PDW 233, UAS 428, GW 2010-275, HD 4730, MACS 4054, DDW 23, DBPY 2012-06, GDW 1255, HI 8498 and four testers i.e. UPD 2949, DDW 39, WHD 960, PBND 4826, one standard check (HI 8737) and their 40 $F_1$s. The $F_1$s were made by crossing ten lines with four testers in line × tester mating design. These crosses were further evaluated along with their parents and check, HI 8737 in randomized block design with three replications. Twelve morphological characters namely, days to heading, days to maturity, plant height (cm), number of effective tillers per plant, length of main spike (cm), number of spikelets per main spike, grain filling period (days), number of grains per main spike, 100-grain weight (g), grain yield per plant (g), biological yield per plant (g) and harvest index (%) were observed during this study. The mean values of analysis of variance and the estimation of combining ability variances and its effects for all the characters of parents and their hybrids were analysed as per Model-1, Method-2 of Griffing (1956), while, the magnitude of *gca* and *sca* variances were estimated by Potence ratio (Romero & Frey, 1973) and Predictability ratio (Baker, 1978).

## RESULTS AND DISCUSSION

The analysis of variance for combining ability and the estimates of variance components indicated that the mean squares due to lines were significant for all the characters studied. This indicated significant contribution of lines towards general combining ability variance components for all the traits. The mean sum of squares due to testers were also significant for all the characters, suggesting fair contribution of testers towards component of general combining ability variance. The mean sum of squares due to line × testers interaction were also significant for all the yield attributing traits which revealed the significant contribution of hybrids for specific combining ability variance components (Table-1).

The magnitude of *sca* variance were higher than the *gca* variance for the characters, *viz*., days to heading, days to maturity, plant height, number of effective tillers per plant, length of main spike, number of spikelets per main spike, grain filling period, number of grains per main spike, 100-grain weight, grain yield per plant, biological yield per plant and harvest index which indicated preponderance of non-additive gene action in the inheritance of these traits (Table-1). Therefore, selection from transgressive segregants for these traits in early generations would be effective for developing the superior varieties in wheat breeding programme. This was further supported by low magnitude of $\sigma^2$gca/ $\sigma^2$sca ratios. Preponderance of non-additive variance in expression of these traits in wheat have also been reported by Sharma and Garg, (2005) and Singh et al. (2013), for days to heading; Sharma and Garg, (2005), Vanpariya et al. (2006), and Singh et al. (2013), for days to maturity; Sharma and Garg, (2005), Singh et al. (2013), and Patel et al. (2018), for plant height; Chowdhary et al. (2007), Sami et al. (2010), Lohithaswa et al. (2013), Barot et al.

(2014), Pansuriya et al. (2014), Kerkhi et al. (2015), Ahmad et al. (2017), and Jatav et al. (2017), for number of effective tillers per plant; Vanpariya et al. (2006), Dhandhal et al.(2006), Sami et al. (2010), Lohithaswa et al. (2013), Barot et al. (2014), Pansuriya et al.(2014), Kerkhi et al. (2015), Ahmad et al. (2017), and Jatav et al. (2017), for length of main spike; Vanpariya et al. (2006), Dhandhal et al. (2006), Sami et al. (2010), Barot et al.(2014), Pansuriya et al. (2014), Kerkhi et al. (2015), and Ahmad et al. (2017), for number of spikelets per main spike; Chowdhary et al. (2007), Lohithaswa et al. (2013), Pansuriya et al. (2014), and Kerkhi et al. (2015), for number of grains per main spike; Dhandhal et al. (2006), Lohithaswa et al. (2013), Barot et al. (2014), Pansuriya et al. (2014), and Ahmad et al. (2017), for 100-grain weight; Sharma and Garg (2005), Vanpariya et al. (2006), Singh et al. (2013), for grain yield per plant; Singh et al., Singh et al.(2013), for biological yield per plant and Vanpariya et al. (2006), and Singh et al. (2013), for harvest index. In view of these studies, it could be concluded that grain yield is a complex character as compared to its components. Thus, as the quantitative character becomes complex, the contribution of non-additive gene action would be more. Under such situation, it would be worthwhile to resort the breeding methodologies, such as biparental mating and diallel selective mating instead of conventional pedigree or backcross techniques which would leave the non-fixable components of genetic variances which are usually exploited for yield and its components.

The summary of general combining ability effects of the parents revealed that none of the parents was found to be good general combiner simultaneously for all the characters (Table-2). General combining ability effects of the parents revealed that lines MACS 4054, HI 8498, DBPY 2012-06, GDW 1255, DDW 23 and testers PBND 4826 was found to be good general combiners for days to heading. For days to maturity, female parents HD 4730 and PDW 233 and male parent UPD 2949 were registered as good general combiners. The good general combining ability effect was expressed by the female parents HD 4730 and UAS 428 and male parent UPD 2949 for plant height. The estimate of general combining ability effect revealed that females DBPY 2012-06, MACS 4054 and GDW 1255 and male parents DDW 39 and WHD 960 have good general combining ability effects for number of effective tillers per plant. Female parents GW 2010-275 and GDW 1255 and male parents PBND 4826 showed significant positive general combining ability effects for length of main spike. For number of spikelets per main spike female parent GW 2010-275 and male parent PDW 233 registered as good general combiners. For grain filling period, female parents PDW 233, UAS 428 and HD 4730 showed significant negative general combining ability effects. Female parents *viz.*, UAS 428, GDW 1255 and HI 8498 and male parents PBND 4826 and WHD 960 were emerged as good general combiners for number of grains per main spike. For 100-grain weight, female parents HD 4730, HI 8498 and MACS 4054 were registered with good general combining ability. For grain yield per plant, female parents *viz.*, DBPY 2012-06, MACS 4054, MPO 1215 and GDW 1255 and male parent DDW 39 showed significant positive general combining ability effect. For biological yield per plant, female parents MACS 4054 and DBPY 2012-06 and male parent DDW 39 showed significant positive general combining ability effect. Female parents DBPY 2012-06 and MACS 4054 and male parent DDW 39 were observed as good general combiners for harvest index.

As regard to specific combining ability effects (Table-3), 10 crosses exhibited significant positive specific combining ability effects for grain yield per plant. The highest *sca* effect for grain yield per plant was exhibited by the cross GDW 1255 × UPD 2949 (good × average) followed by HI 8498 × WHD 960 (average × average), DBPY 2012-06 × WHD 960 (good × average). Considering the desired *sca* effects, the best cross combination were DBPY 2012-06 × WHD 960 for days to heading, GDW 1255 × DDW 39 for days to maturity, GDW 1255 × WHD 960 for plant height, DWPY 2012-06 × WHD 960 for number of effective tillers per plant, UAS 428 × PBND 4826 for length of main spike, HI 8498 × PBND 4826 for number of spikelets per main spike, MPO 1215 × WHD 960 for grain filling period, HI 8498 × DDW 39 for number of grains per main spike, GDW 1255 × PBND 4826 for 100-grain weight, GDW 1255 × UPD 2949 for grain yield per plant, DBPY 2012-06 × WHD 960 for biological yield per plant and HI 8498 × WHD 960 for harvest index.

The *gca* effects of the parents and *sca* effects of their crosses in the present study indicated that the crosses between two good general combiners were not always the best in their *sca* effects. The best specific cross combinations for different characters in present study were the combinations of good × good, good × average, average × average, average × poor and poor × poor general combiners. The marked desirable specific combining ability effects in crosses between poor × poor combiners includes HI 8498 × WHD 960 for days to maturity, PDW 233 × PBND 4826 for harvest index, poor × average combiner e.g., MPO 1215 × WHO 960 for number of spikelets per main spike, good × average e.g., HD 4730 × UPD 2949 for 100-grain weight, GDW 1255 × PBND 4826 for number of tillers per plant, GDW 1255 × UPD 2949 and DBPY 2012-06 × WHD 960 for grain yield per plant, good × good e.g., MACS 4054 × DDW 39 for biological yield per plant, HD 4730 × DDW 39 for plant height and good × poor e.g., DBPY 2012-06 × WHD 960 for days to heading, DDW 233 × PBND 4826 for days to maturity and UAS 428 × UPD 2949 for number of grains per main spike. The cross combinations showing high and involving both or at least one good general combiners, suggesting dominance type of gene action. Thus, identification of specific parental combination of producing the higher transgressive effects can be of greater value for development of nutritionally rich durum wheat varieties. These results are in accordance with the findings of Gami and co-workers (Gami et al., 2011).

In fact, in majority of cases, the best specific combinations for different characters were either poor × poor, good × poor, average × poor, average × average and *vice versa* general combiners. This suggested that information on *gca* effects should be supplemented by *sca* effects and hybrid performance of cross combinations to predict the transgressive type possibly made available in segregating generations. Selection is rapid if *gca* effects of parents and *sca* effects of crosses are in same direction. If crosses showing high *sca* effects involve at least one parent possessing good *gca* effect and high mean value, they could be exploited for practical breeding. Therefore, it is suggested that the selection of parents for further breeding programme should be based on *gca* effects and due consideration should be given to mean value of the cross combinations while selecting crosses for specific combining ability effects.

**Table 1: Analysis of variance for combining ability and variance components for different characters in durum wheat**

| Source | d.f. | Days to heading | Days to maturity | Plant height | Number of effective tillers per plant | Length of main spike | Number of spikelets per main spike |
|---|---|---|---|---|---|---|---|
| Replications | 2 | 3.05 | 1.23 | 3.51 | 0.97 | 0.24 | 1.79 |
| Lines | 9 | 108.53**++ | 29.51** | 81.12** | 12.39** | 1.15* | 7.66** |
| Testers | 3 | 24.30** | 58.10** | 89.06* | 7.27** | 6.22**+ | 1.62 |
| Lines× Testers | 27 | 30.84** | 31.28** | 50.65* | 6.15** | 1.46* | 4.09** |
| Error | 78 | 3.45 | 3.39 | 29.12 | 0.12 | 0.31 | 1.47 |
| **Variance Components** | | | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| $\sigma^2$l | 8.75 | 2.17 | 4.33 | 1.02 | 0.07 | 0.51 |
| $\sigma^2$t | 0.69 | 1.82 | 1.99 | 0.23 | 0.19 | 0.01 |
| $\sigma^2$lt | 9.13 | 9.29 | 7.17 | 2.00 | 0.38 | 0.87 |
| $\sigma^2$gca | 2.99 | 1.92 | 2.66 | 0.46 | 0.16 | 0.15 |
| $\sigma^2$sca | 9.13 | 9.29 | 7.17 | 2.00 | 0.38 | 0.87 |
| **$\sigma^2$gca/ $\sigma^2$sca** | **0.32** | **0.20** | **0.37** | **0.23** | **0.42** | **0.17** |

| Source | d.f. | Grain filling Period | Number of grains per main spike | 100-grain weight | Grain yield per plant | Biological yield per plant | Harvest index |
|---|---|---|---|---|---|---|---|
| Replications | 2 | 3.40 | 32.13 | 0.18 | 3.61 | 9.52 | 22.34 |
| Lines | 9 | 61.81**+ | 31.79** | 0.67** | 22.33** | 25.25** | 66.03** |
| Testers | 3 | 10.20 | 92.94** | 0.07 | 53.11**+ | 12.56* | 301.44** |
| Lines× Testers | 27 | 24.46** | 40.47** | 0.60** | 16.04** | 19.72** | 60.51** |
| Error | 78 | 11.39 | 8.89 | 0.06 | 0.79 | 4.46 | 9.52 |
| **Variance Components** | | | | | | | |
| $\sigma^2$l | | 4.20 | 1.90 | 0.05 | 1.79 | 1.73 | 4.70 |
| $\sigma^2$t | | -0.04 | 2.80 | 0.01 | 1.74 | 0.26 | 9.73 |
| $\sigma^2$lt | | 4.35 | 10.52 | 0.18 | 5.08 | 5.08 | 16.99 |
| $\sigma^2$gca | | 1.17 | 2.54 | 0.01 | 1.75 | 0.68 | 8.29 |
| $\sigma^2$sca | | 4.35 | 10.52 | 0.18 | 5.08 | 5.08 | 16.99 |
| **$\sigma^2$gca/ $\sigma^2$sca** | | **0.26** | **0.24** | **0.05** | **0.34** | **0.13** | **0.48** |

*,** 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 for different characters in durum wheat**

| Sr. No. | Parents | Days to heading | Days to maturity | Plant height | Number of effective tillers per plant | Length of main spike | Number of spikelets per main spike | Grain filling period | Number of grains per main spike | 100-grain weight | Grain yield per plant | Biological yield per plant | Harvest index |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Lines** | | | | | | | | | | | | | |
| 1 | MPO 1215 | 0.48 | 1.26* | -2.93 | -0.39** | -0.19 | -0.83* | -0.81 | -0.06 | -0.21** | 0.62* | 0.05 | 1.62 |
| 2 | PDW 233 | 3.56** | -1.48** | 2.34 | -1.19** | -0.16 | 0.80* | -3.65** | -0.39 | -0.11 | -0.98** | -0.33 | -2.33* |
| 3 | UAS 428 | 5.48** | 0.18 | -3.25* | 0.17 | -0.12 | 0.67 | -3.15** | 3.45** | -0.28** | -1.44** | -0.01 | -3.77** |
| 4 | GW 2010-275 | 0.73 | 1.60** | 1.43 | -0.68** | 0.55** | 0.87* | 0.68 | 0.65 | -0.15* | 0.06 | -0.56 | 1.15 |
| 5 | HD 4730 | 1.15* | -3.31** | -3.34* | -0.25* | -0.14 | 0.27 | -1.98* | -1.78* | 0.34** | -1.85** | -2.49** | -2.31* |
| 6 | MACS 4054 | -5.10** | -0.98 | -1.06 | 1.08** | 0.01 | -1.28** | 2.76** | -0.23 | 0.31** | 2.04** | 2.46** | 2.59** |
| 7 | DDW 23 | -1.10* | 0.35 | 2.14 | -0.05 | -0.54** | 0.44 | 2.35* | -1.36 | -0.01 | -0.80** | -1.40* | -0.45 |
| 8 | DBPY 2012-06 | -1.68** | -0.23 | 3.99* | 1.94** | 0.07 | -1.02** | 1.10 | -0.31 | -0.14 | 2.13** | 1.85** | 3.58** |
| 9 | GDW 1255 | -1.43** | 1.01 | -0.35 | 0.68** | 0.35* | -0.28 | 1.26 | 1.77* | -0.05 | 0.58* | 0.80 | 0.57 |
| 10 | HI 8498 | -2.10** | 1.60** | 1.03 | -1.30** | 0.17 | 0.35 | 1.43 | 1.72* | 0.32** | -0.36 | -0.35 | -0.64 |
| **SE(gi)** | | **0.53** | **0.53** | **1.55** | **0.10** | **0.16** | **0.35** | **0.97** | **0.86** | **0.07** | **0.25** | **0.61** | **0.89** |
| **Gi – Gj (Line)** | | **0.75** | **0.75** | **2.20** | **0.14** | **0.22** | **0.49** | **1.37** | **1.21** | **0.10** | **0.36** | **0.86** | **1.25** |
| **Testers** | | | | | | | | | | | | | |
| 1 | UPD 2949 | -0.05 | -1.18** | -1.83* | -0.23** | -0.43** | 0.15 | -0.60 | -1.22* | 0.05 | 0.22 | -0.18 | 0.75 |
| 2 | DDW 39 | -0.05 | 0.85** | -0.81 | 0.44** | -0.30** | 0.24 | -0.40 | -1.79** | 0.01 | 1.46** | 0.94** | 2.94** |
| 3 | WHD 960 | 1.15** | 1.91** | 2.15* | 0.36** | 0.19* | -0.20 | 0.50 | 1.43** | 0.01 | 0.07 | -0.53 | 0.80 |
| 4 | PBND 4826 | -1.05** | 0.11 | 0.48 | -0.57** | 0.55** | -0.19 | 0.50 | 1.58** | -0.06 | -1.76** | -0.22 | -4.50** |
| **SE(gi)** | | **0.33** | **0.33** | **0.98** | **0.06** | **0.10** | **0.22** | | **0.61** | **0.54** | **0.04** | **0.16** | **0.38** |
| **Gi-Gj (Tester)** | | **0.47** | **0.47** | **1.39** | **0.09** | **0.14** | **0.31** | | **0.87** | **0.76** | **0.06** | **0.23** | **0.54** |

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

**Table 3: Specific combining ability effects for different characters in durum wheat**

| Sr. No. | Hybrids | Days of heading | Days to maturity | Plant Height | Number of effective tillers per plant | Length of main spike | Number of spikelets per main spike |
|---|---|---|---|---|---|---|---|
| **1** | **MPO 1215 × UPD 2949** | -4.78** | -2.40 | -6.84* | 0.17 | 0.45 | -1.42* |
| **2** | **MPO 1215 × DDW 39** | 2.21* | 1.26 | 5.16 | -1.18** | 0.81* | 0.32 |
| **3** | **MPO 1215 × WHD 960** | 3.35** | -1.83 | 1.34 | 1.17** | -1.34** | 2.22** |
| **4** | **MPO 1215 × PBND 4826** | -0.78 | 2.96** | 0.33 | -0.16 | 0.07 | -1.12 |
| **5** | **PDW 233 × UPD 2949** | 2.80* | 0.68 | 1.48 | -0.61** | -0.30 | 0.31 |
| **6** | **PDW 233 × DDW 39** | 0.13 | 1.68 | 0.64 | -0.73** | 0.03 | -0.28 |
| **7** | **PDW 233 × WHD 960** | -3.067** | 1.91 | -3.43 | 0.37 | -0.004 | 0.39 |
| **8** | **PDW 233 × PBND 4826** | 0.13 | -4.28** | 1.30 | 0.97** | 0.27 | -0.42 |
| **9** | **UAS 428 × UPD 2949** | 2.55* | -2.31* | -1.70 | -0.39 | -0.14 | 0.001 |
| **10** | **UAS 428 × DDW 39** | 0.21 | 0.35 | 1.69 | -2.10** | -0.12 | -0.87 |
| **11** | **UAS 428 × WHD 960** | 1.35 | 2.25* | 3.09 | 1.40** | -0.61 | 0.11 |
| **12** | **UAS 428 × PBND 4826** | -4.11** | -0.28 | -3.08 | 1.09** | 0.87** | 0.75 |
| **13** | **GW 2010-275 × UPD 2949** | 1.30 | 0.26 | -4.78 | 0.12 | -0.67* | 0.55 |
| **14** | **GW 2010-275 × DDW 39** | -1.70 | -3.40** | 5.30 | 1.26** | 0.25 | 1.24 |
| **15** | **GW 2010-275 × WHD 960** | 1.43 | 0.16 | -2.03 | -0.82** | 0.12 | -0.50 |
| **16** | **GW 2010-275 × PBND 4826** | -1.03 | 2.96** | 1.51 | -0.56** | 0.53 | -1.29 |
| **17** | **HD 4730 × UPD 2949** | 0.88 | -3.48** | 6.64* | -0.19 | 0.21 | 0.77 |
| **18** | **HD 4730 × DDW 39** | 2.88** | 5.51** | -7.09* | 1.40** | -1.57** | 0.20 |
| **19** | **HD 4730 × WHD 960** | -1.31 | -0.91 | 2.29 | -1.59** | 0.80* | -0.15 |
| **20** | **HD 4730 × PBND 4826** | -2.45* | -1.11 | -1.83 | 0.37 | 0.55 | -0.82 |
| **21** | **MACS 4054 × UPD 2949** | -1.20 | 2.85** | 3.16 | -0.61** | -0.16 | 1.37 |
| **22** | **MACS 4054 × DDW 39** | 3.80** | 1.85 | -5.22 | 1.77** | 0.31 | 0.16 |
| **23** | **MACS 4054 × WHD 960** | -4.06** | -1.25 | 1.08 | 0.14 | -0.03 | -1.22 |
| **24** | **MACS 4054 × PBND 4826** | 1.46 | -3.45** | 0.97 | -1.30** | -0.11 | -0.31 |
| **25** | **DDW 23 × UPD 2949** | -1.86 | 0.85 | 0.83 | 1.43** | 0.46 | 0.39 |
| **26** | **DDW 23 × DDW 39** | 1.53 | -3.15** | -2.14 | -0.84** | 0.78* | -0.25 |
| **27** | **DDW 23 × WHD 960** | 5.26** | 4.41** | -1.14 | -0.76** | -0.38 | -1.11 |
| **28** | **DDW 23 × PBND 4826** | -1.86 | -2.11 | 2.44 | 0.18 | -0.86** | 0.97 |
| **29** | **DBPY 2012-06 × UPD 2949** | 2.05 | -2.23* | 2.33 | -1.47** | 0.001 | -0.88 |
| **30** | **DBPY 2012-06 × DDW 39** | -3.28** | 2.10 | -1.63 | -0.10 | -0.13 | 0.16 |
| **31** | **DBPY 2012-06 × WHD 960** | -4.81** | -2.33* | 0.44 | 3.05** | 0.24 | 1.40* |
| **32** | **DBPY 2012-06 × PBND 4826** | 6.05** | 2.46* | -1.14 | -1.47** | -0.11 | -0.69 |
| **33** | **GDW 1255 × UPD 2949** | 1.13 | 4.51** | 2.49 | 0.12 | -0.47 | 0.27 |
| **34** | **GDW 1255 × DDW 39** | -2.20* | -5.48** | 2.76 | -0.90** | 0.11 | -1.09 |
| **35** | **GDW 1255 × WHD 960** | 1.26 | 1.41 | -7.12* | -0.70** | 0.64 | 0.40 |
| **36** | **GDW 1255 × PBND 4826** | -0.20 | -0.45 | 1.86 | 1.49** | -0.28 | 0.40 |
| **37** | **HI 8498 × UPD 2949** | -2.86** | 1.26 | -3.62 | 1.43** | 0.61 | -1.37 |
| **38** | **HI 8498 × DDW 39** | -0.53 | -0.73 | 0.53 | 1.43** | -0.49 | 0.39 |
| **39** | **HI 8498 × WHD 960** | 0.60 | -3.83** | 5.46 | -2.25** | 0.82* | -1.54* |
| **40** | **HI 8498 × PBND 4826** | 2.80* | 3.30** | -2.37 | -0.61** | -0.93** | 2.52** |
| | **SE±** | **1.07** | **1.06** | **3.11** | **0.20** | **0.32** | **0.70** |

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

(Conti…)

| Sr. No. | Hybrids | Grain filling period | Number of grains per main spike | 100-grain weight | Grain yield per plant | Biological yield per plant | Harvest index |
|---|---|---|---|---|---|---|---|
| 1 | **MPO 1215 × UPD 2949** | 2.18 | -2.21 | -0.48** | -1.63** | -0.96 | -3.11 |
| 2 | **MPO 1215 × DDW 39** | -0.35 | 3.33 | -0.32* | 2.27** | 3.94** | 1.24 |
| 3 | **MPO 1215 × WHD 960** | -4.58* | -2.19 | 0.22 | 0.44 | -0.41 | 2.12 |
| 4 | **MPO 1215 × PBND 4826** | 2.75 | 1.06 | 0.51** | -1.07* | -2.55* | -0.25 |
| 5 | **PDW 233 × UPD 2949** | 0.01 | -0.83 | 0.15 | -1.95** | -0.55 | -4.67* |
| 6 | **PDW 233 × DDW 39** | 0.81 | -1.78 | 0.19 | 1.19* | -0.90 | 4.39* |
| 7 | **PDW 233 × WHD 960** | 1.25 | 0.003 | 0.54** | -2.61** | -1.36 | -5.92** |
| 8 | **PDW 233 × PBND 4826** | -2.08 | 2.61 | 0.18 | 3.38** | 2.82* | 6.20** |
| 9 | **UAS 428 × UPD 2949** | -3.48 | 4.00** | 0.21 | 0.94 | 0.99 | 1.72 |
| 10 | **UAS 428 × DDW 39** | -0.35 | -5.81** | 0.08 | 0.61 | -0.69 | 2.48 |
| 11 | **UAS 428 × WHD 960** | 0.75 | 0.53 | -0.15 | -3.27** | -0.18 | -8.93** |
| 12 | **UAS 428 × PBND 4826** | 3.08 | 1.28 | -0.14 | 1.71** | -0.12 | 4.72** |
| 13 | **GW 2010-275 × UPD 2949** | -1.98 | 1.66 | -0.10 | 0.95 | 2.34 | -0.23 |
| 14 | **GW 2010-275 × DDW 39** | -1.51 | 1.54 | -0.29 | -1.35* | -2.30 | -0.95 |
| 15 | **GW 2010-275 × WHD 960** | -0.08 | 1.54 | 0.47** | 0.30 | -1.93 | 3.17 |
| 16 | **GW 2010-275 × PBND 4826** | 3.58 | -4.75** | -0.07 | 0.09 | 1.89 | -1.99 |
| 17 | **HD 4730 × UPD 2949** | -0.65 | 2.14 | 0.55** | -1.08* | -0.51 | -2.57 |
| 18 | **HD 4730 × DDW 39** | 0.81 | -2.29 | -0.40** | -1.41** | 0.72 | -4.75** |
| 19 | **HD 4730 × WHD 960** | -0.41 | -1.28 | 0.27 | 1.30* | -0.69 | 4.82** |
| 20 | **HD 4730 × PBND 4826** | 0.25 | 1.43 | -0.42** | 1.20* | 0.49 | 2.51 |
| 21 | **MACS 4054 × UPD 2949** | 3.93* | -5.14** | 0.63** | 1.01 | -1.08 | 4.13* |
| 22 | **MACS 4054 × DDW 39** | -0.93 | -1.70 | 0.30* | 2.14** | 4.35** | 0.18 |
| 23 | **MACS 4054 × WHD 960** | 0.83 | 5.52** | -0.15 | -1.78** | -1.83 | -2.52 |
| 24 | **MACS 4054 × PBND 4826** | -3.83 | 1.32 | -0.78** | -1.37** | -1.44 | -1.79 |
| 25 | **DDW 23 × UPD 2949** | -0.31 | -2.73 | -0.53** | -1.52** | -0.81 | -3.41 |
| 26 | **DDW 23 × DDW 39** | 2.15 | -2.87 | 0.63** | 0.99 | 0.56 | 2.00 |
| 27 | **DDW 23 × WHD 960** | -1.08 | 3.23 | -0.22 | -0.22 | -1.62 | 1.53 |
| 28 | **DDW 23 × PBND 4826** | -0.75 | 2.37 | 0.12 | 0.75 | 1.86 | -0.15 |
| 29 | **DBPY 2012-06 × UPD 2949** | -4.73* | -3.47* | -0.12 | 0.06 | -2.66* | 3.66* |
| 30 | **DBPY 2012-06 × DDW 39** | 2.067 | 2.41 | -0.26 | -1.82** | -2.09 | -2.55 |
| 31 | **DBPY 2012-06 × WHD 960** | 5.83** | -0.92 | 0.30* | 3.52** | 4.95** | 3.06 |
| 32 | **DBPY 2012-06 × PBND 4826** | -3.16 | 1.98 | 0.08 | -1.76** | -0.19 | -4.17* |
| 33 | **GDW 1255 × UPD 2949** | 2.43 | 4.27* | -0.35* | 4.50** | 4.81** | 6.11** |
| 34 | **GDW 1255 × DDW 39** | -2.76 | 1.55 | 0.03 | -1.63** | -3.04* | -0.54 |
| 35 | **GDW 1255 × WHD 960** | 0.33 | -4.53* | -0.51** | -2.04 | -0.63 | -4.69* |
| 36 | **GDW 1255 × PBND 4826** | 0.59 | -1.30 | 0.82** | -0.82 | -1.14 | -0.88 |
| 37 | **HI 8498 × UPD 2949** | 2.600 | 2.31 | -0.03 | -1.29* | -1.56 | -1.63 |
| 38 | **HI 8498 × DDW 39** | 0.06 | 5.62** | 0.03 | -0.97 | -0.55 | -1.51 |
| 39 | **HI 8498 × WHD 960** | -2.83 | -1.90 | 0.31* | 4.38** | 3.72** | 7.35** |
| 40 | **HI 8498 × PBND 4826** | 0.16 | -6.03** | -0.31* | -2.11** | -1.61 | -4.21* |
| | **SE±** | **1.94** | **1.72** | **0.14** | **0.51** | **1.22** | **1.78** |

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

## CONCLUSION

The good general combiners for more traits having more practical utility and genotype MACS 4054 manifested high GCA for grain yield and also showed high desirable GCA of relative traits *viz.*, number of effective tillers per plant, length of main spike, number of grains per main spike, 100-grain weight, grain yield per plant and biological yield per plant, in similar fashion genotype UAS 428 also showed high GCA for days to heading, days to maturity plant height, grain filling period and number of grains per main spike, these genotypes can be exploited for different plant breeding methods and in similar fashion the best cross combinations for grain yield and its other attributing traits are also having more practical value. The Best cross combinations *viz.*, GDW 1255 × UPD 2949, HI 8498 × WHD 960 and DBPY 2012-06 × WHD 960 were found to be best specific combiners for grain yield per plant.

## REFERENCES

Ahmad, E., Akhtar, M., Badoni, S., & Jaiswal, J. P. (2017). Combining ability studies for seed yield related attributes and quality parameters in bread wheat

(*Triticum aestivum* L.). *J. Genet. Genomics & Pl. Br.*, *1*(1), 21-27.

Baker, R.J.H. (1978). Issues in diallel analysis. *Crop. Sci*., *18*, 553-536.

Barot, H. G., Patel, M. S., Sheikh, W. A., Patel, L. P., & Allam C. R. (2014). Heterosis and combining ability analysis for yield and its component traits in wheat (*Triticum aestivum* L.). *Elec. J. Pl. Br.*, *5*(3), 350-359.

Chowdhary, M. A., Muhammad, S., & Ashraf, M. I. (2007). Analysis on combining ability of metric traits in bread wheat (*Triticum aestivum* L.). *J. Agric. Res.*, *45*(1), 11-17.

Dhadhal, B. A., & Dobariya, K. L. (2006). Combining ability analysis over environments for grain yield and its components in bread wheat (*Triticum aestivum* L.). *Natnl. J. Pl. Improv*., *8*, 172-173.

Gami, R. A., Tank, C. J., Chauhan, R. M., Patel, S. S., & Thakor, D. M. (2011). Heterosis for grain yield and quality components in durum wheat (*Triticum durum* Desf.). *Res on Crops 12*(2), 496-498.

Griffing, B. (1956). Concept of general and specific combining ability in relation to diallel crossing system. *Aus. J. Bio. Sci., 9*, 463-493.

Jatav, S. K., Baraiya, B. R., & Kandalkar, V. S. (2017). Combining ability for grain yield and its components under different environments in wheat. *Int. J. Curr. Microbiol. App. Sci., 6*(8), 2827-2834.

Kerkhi, S. A., & Kumar, D. (2015). Combining ability analysis for yield and some quality traits in spring wheat (*Triticum aestivum* L.). *Electronic Journal of Plant Breeding*, *6*(1), 26-36.

Lohithaswa, H. C., Desai, S. A., Hanchinal, R. R., Patil, B. N., Math, K. K., Kalappanavar, I. K., Bandivadder, T. T., & Chandrashekhara, C. P. (2013). Combining ability in tetraploid wheat for yield, yield attributing traits, quality and rust resistance over environments. *Karnataka Journal of Agricultural Science*, *26*(2), 190-193.

Pansuriya, A. G., Dhaluk, L. K., Vanpariya, L. G., Savaliya, J. J., Patel, M. B., & Mehta, D. R. (2014). Combining ability over environments for grain yield and its components in bread wheat (*Triticum aestivum* L.). *Int. e. J.*, *3*(1), 36-46.

Patel, N. A., Joshi, V. I., Patidar D. R., & Patel, J. A. (2018). Combining ability analysis of some yield and quality traits in durum wheat (*Triticum durum* Desf.). *Electronic Journal of Plant Breeding*, *9*(4), 1443-1449.

Romero, G.E., & Frey, K.J. (1973). Inheritance of semi-dwarfness in several wheat crosses. *Crop Sci.*, *13,* 333-337.

Sami, U. A., Abdus, S. K., Ali, R., & Sajiad, S. (2010). Gene action analysis of yield and yield related traits in spring wheat (*Triticum aestivum* L.). *International J. Agric. Biology.*, *12*(1), 125-128.

Sharma, A. K., & Garg, D. K. (2005). Combining ability over environments in bread wheat (*Triticum aestivum* L.). *J. Maharashtra Agric. Univ., 30*, 153-156.

Singh, K., Singh, U. B., & Sharma, S. N. (2013). Combining ability analysis for yield and its components in bread wheat (*Triticum aestivum* L.). *J. Wheat Res.*, *5*(1), 63-67.

Vanpariya, L. G., Chovatia, V. P., & Mehta, D. R. (2006). Combining ability studies in bread wheat (*Triticum aestivum* L.). *National J. Pl. Improv*., *8*(2), 132-137.