Critical study of gene action and combining ability for varietal development in wheat: An Overview

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Abstract: A review of research work done on *Triticum aestivum*, at individual as well as multiple environments, was taken to study general and specific combining ability (GCA and SCA) for grain yield and its related traits. High SCA variance than GCA variance was reported in many experiments which indicating the non-additive genetic inheritance of these agronomic traits. However, in various other research experiments GCA variances and SCA variances indicated equal importance of additive and non-additive gene action. The reviewed results indicated the significance of studying combining ability and gene action governing yield, to identify potential parental genotypes and crosses that can help the breeders to plan a strong crop improvement strategy.
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Introduction

Triticum aestivum (bread wheat) belongs to family *Poaceae* (formerly known as the *Gramineae*) and is considered as major staple food and energy source in many countries including Pakistan. Hexaploid bread wheat (2n = 6x = 42) is an example of naturally occurring polyploid resulted from intergeneric hybridization and polyploidization. It is 2nd most produced crop (Shoran *et al.*, 2003), lagging behind only corn, provides a large portion of the total food supply and dietary protein and grown in a wide variety of environments (Jahangir *et al*. 2014). Wheat is grown as a primary food product and for livestock uses as well. Wheat contributes 10.1% to the value added in agriculture and 2.2 % in GDP of Pakistan. According to economic survey of Pakistan (2012-13) its production was 24.2 million tons with cultivated area of 8.693 million hectares during 2012-13. Due to wider it's wider adaptation it is widely cultivated throughout the globe and is first ever plant grown by the humans (Khayatnejad *et al.,* 2010; Mustafa *et al.,* 2015). Sustainable increase in production is demand of present situation of increasing food and feed demands and requires breeders to explore germplasm to select stable high yielding cultivars (Farroq *et al*. 2011ab; Azam *et al*. 2014; Abbas *et al*. 2014; Dar *et al*. 2014; Sabir *et al*. 2014; Butt *et al*. 2015; Qamar *et al*. 2015; Zameer *et al*. 2015). High yielding varieties should be developed by crossing good general combiners for multiple traits and selection should be done for transgressive segregants from subsequent hybrid genotypes. To develop high yielding hybrids assessment of GCA effects for grain yield and its component traits offers an important mean in selecting potential parents (Ali et al. 2014; Azam et al. 2014).

Combining Ability study for various traits of wheat

Sanjeev *et al.* (2005) estimated non-additive genetic effect for seed yield with other traits like No. of seeds, 1000 seed weight, protein content, sedimentation value and â-carotene, suggesting possibility for improvement of these traits through transgressive segregates and heterosis breeding for developing genotypes with high yielded superior genotypes. Among lines HI 8596, HD 4692 and HI 8591 and among testers Bij Red and HG 110 were estimated as good general combiners. Cross combinations HI 8381 × MPO 215, HI 8591 × MPO 215, HD 4694 × Bij Red, HI 8596 × MPO 215, HI 8591 × HG 110, and HI 8653 × Bij Red were the most favorable as having great specific combining ability effect and per se performance for seed yield and its parameters. An effort of multiple crossing by using all good general combiners would be helpful to get transgressive segregates for seed yield in later generations.

Malik *et al.* (2005) found that number of tillers/plant and plant height GCA variances were highly significant, significant for flowering days, length of spike and No. of spikelets/spike whereas for 1000-grain weight, leaf area, maturity days and yield/plant these were non-significant. However, SCA variances were non-significant for all studied traits. All examined traits were governed by additive genetic effects. For most of the studied traits Margalla 99 proved as best general combiner, whereas Pak. 81 and Margalla 99 were best specific combiners. Nazir *et al.* (2005) reported that mean square of parameters attributable to GCA, SCA and reciprocals effects were highly significant for all characters under study. The GCA variances were greater than those of SCA for all traits excluding productive tillers, seeds/spike and 1000 seed weight. The magnitude of specific combining ability was higher than general combining ability for traits showed that non-additive genetic effect played role in the expression of traits. For 1000 seed weight, leaf area, productive tillers, seeds/spike 243- 1 showed better general combining ability. Most of the cross combinations presenting desired significant specific combining ability effects involved non-additive genetic effects.

Hasnain *et al.* (2006) concluded that Variety Pasban-90 was best general combiner for grains/ear and best specific combining ability was observed in crosses 6039-1 × 6529-1 and TW-161 × 6039-1 for spike length and spikelets per ear.

Knezevic *et al.* (2006) observed results presented that this character was controlled by non-additive as well as additive genetic effects. Significantly high value of SCA in F_2 hybrids designated superiority of non-additive gene action. The maximum value of GCA expressed variety Ana Morava whereas cross combination Ana Morava × Beogradanka found as the best specific combiner for No. of seeds. Cheema *et al.* (2007) showed that variances of SCA were significantly greater than GCA and reciprocal effects. In all characters under study, main part of the total mean square was attributable to the specific combining ability effects representing that these traits were mainly controlled by non-additive gene action. Crosses GPW-272 × GPW-36, GPW-272 × GPW-37 and GPW-273 × GPW-37 found as good specific combiners to produce segregants with greater No. of tillers, No. of seeds and maximum grain weight summarizing in production of wheat genotypes with high yield for arid regions. Dhadhal *et al.* (2008) found that results revealed the significance of non-additive and additive gene actions for almost all yield related traits. Days to maturity, Grain yield/plant, spike length, days to heading, spikelets/ spike and 1000-grain weight were inherited through additive gene action. The lines HUW 234, GW 322, GW 273, 7C Nad 63 tab's, MP 3077 and tester PBW 373 were good general combiners for yield components. For No. of spikelets/spike, spike length, 1000-grain weight, and No. of grains/spike the cross Chilero × GW 173 was proved to be the best as having high specific combining ability effects.

Yucel *et al.* (2009) estimated that the extents of GCA for all components excluding seed weight and seed height were greater than those of specific combining ability. The general combining ability effect was more noticeable for eight out of ten characters in relation with GCA to SCA ratio. Path coefficient analysis presented that seed width, No. of seeds and seed height had the maximum significant direct and indirect effect on most of parameters. Results gained from this research would be useful for production of new wheat cultivars with good seed characters for improvement in milling and baking quality. Al-Hamdany (2010) investigated that the yield of durum wheat was governed by dominance genetic effects. The genotypes Um-Rabie3 and Leeds were measured as appropriate according to their yield measurements and GCA effects. Two cross combinations (Waha × Brashua) and (Leeds × Brashua) showed significantly greater yield 2.943 and 2.955 ton/hec respectively than others, and also had significant positive SCA effects, highly significant positive inbreeding depression and hence they were measured as favorable hybrids.

Akram *et al.* (2011) found that significant GCA effects were observed for characters under study except in days to maturity, while SCA effects were significant except for spikelets per spike, flag leaf area, grain yield, lysine contents and protein. The SCA mean square was greater than GCA representing the significance of non-additive gene action. Among parents, Kohistan 97 and Chakwal 97 were best general combiners for grain yield/ plant. Shahkar 95 was better combiner for tillers/m^2, plant height, and No. grains/spike. Cross combination Kohistan 97 × Pothowar 93 presented the highest specific combining ability effects for 1000 seed weight. For grain yield per plant maximum SCA values were observed for the cross Kohistan 97× Pak 81.

Tsenov and Tsenova (2011) observed that the regularities in the gene action and the combining ability of the varieties by days to heading were totally analogous for the character days to maturity, too. This shows that earliness could be simply assessed by days to heading. Varieties Vratsa, Obriy and Pliska, had maximum combining ability for earlier days to heading and maturity. Gowda *et al.* (2012) investigated the magnitude of mean squares of general combining ability and specific combining ability effects and their interaction with environments in wheat. They evaluated four data sets generated in commercial hybrid winter wheat breeding programs with a total of 940 hybrids. In three experiments, GCA mean square for females, SCA mean square, GCA of females, environment interaction mean squares, GCA of males, times environment interaction mean square were significantly larger than zero but GCA variance for males was significant only in fourth experiment. For third experiment differences were significant among best hybrid and the best commercial cultivar. In contrast, 1.8% hybrids in second experiment and more than 21% hybrids in first and fourth experiment significantly performed the superior commercial cultivar. Therefore, selection based on general combining ability effects is favorable in hybrid development in breeding wheat.

Zare-kohan and Heidari (2012) found the significant genotype × site interaction was observed for grain filling and plant height duration but interaction was absent for seed yield, days to heading and days to maturity. For all the characters the mean square due to GCA and SCA were significant. Therefore, non-additive and additive gene actions were not equally involved in genetic control of researched traits. The Bakers ratio for days to heading 0.90 and 0.91 at Zarghan and Shiraz respectively, days to maturity 0.81 and 0.82 and seed yield 0.89 and 0.87 in both sites and for plant height 0.88 at Shiraz revealed the great significance of additive mean squares in the genetic control of these characters. The general combining ability estimates showed that Chamran for early heading, dwarfness, and maturity and grain filling duration, Darab2 for early heading, dwarfness and maturity, Marvdasht for grain filling duration and grain yield showed best combining abilities. Graphical representation and the average degree of dominance indicated that all characters were controlled through partial dominance. Pimentel *et al.* (2013) estimated maximum correlation (0.83) of the effects of GCA was observed among generations, but expressionless impact of generation's effects and years was obtained on the grouping of crosses. The progenies resulting from the crossing between the genotype BRS 264, IAC 364 (Tucurui III) and BRS 254 the genotypes VI 98053, UFVT1, Pioneiro and MGS 1 Alianca exhibited the highest potential for attaining superior genotypes for seed yield. The utilization of the partial diallel analysis in progressive generations is encouraging for wheat breeding programs. GCA and SCA provided an estimate to access the performance of inbred lines and hybrids (Ali *et al.* 2014a; Ali *et al.* (2013)).

Masood *et al.* (2015a) The higher value of general combining ability suggested that the inbred lines may be used for the development of synthetic varieties through pure line selection, pedigree selection or recurrent back cross selection while higher specific combining ability suggested that the inbred lines may be used to develop hybrids to improve grain yield of wheat through heterosis breeding program. Masood *et al.* (2015b) concluded that the selection of suitable parents on the basis of higher 1000-grain weight and grain yield/plant be used for the development of synthetic and hybrids. Masood *et al.* (2015c) illustrated from these results that cross combinations *viz*., 9705 × AARI-11, 9703 × Millat-11 and 9705 × Millat-11 will be the best suited F_1 hybrid combinations, having best specific combining ability for two traits each, to fit into future hybrid breeding programs. So these parents and F_1 genotypes having superior performance can be further incorporated into the hybrid breeding programs or selection of the most appropriate parents based upon their performance.

References

1. Abbas, SQ, MUl Hassan, B Hussain, T Rasool and Q Ali. 2014. Optimization of zinc seed priming treatments for improving the germination and early seedling growth of *Oryza sativa*. Adv. life sci., 2(1) pp: 31-37.
2. Akram, Z., S. Ajmal, K.S. Khan, R. Qureshi and M. Zubair. 2011. Combining ability estimates of some yield and quality related traits in spring wheat (*Triticum aestivum* L.). Pakistan J. Bot. 43(1): 221-231.
3. Al-Hamdany, Gh. A.T.A. 2010. Genetic analysis of F_2 diallel crosses in durum wheat. Mesopotamia J. Agri. 38(4):1-7.
4. Ali, Q., M. Ahsan, M.H.N. Tahir and S.M.A. Basra, 2012. Genetic evaluation of maize (*Zea mays* L.) accessions for growth related seedling traits. *IJAVMS,* 6: 164-172.
5. Ali Q, Ali A, Ahsan M, Ali S, Khan NH, Muhammad S, Abbas HG, Nasir IA, Husnain T. 2014c. Line × Tester analysis for morpho-physiological traits of Zea mays L. seedlings. Adv. life sci., 1(4): 242-253.
6. Ali Q, Ahsan M, Ali F, Aslam M, Khan NH, Munzoor M, Mustafa HSB, Muhammad S. 2013. Heritability, heterosis and heterobeltiosis studies for morphological traits of maize (Zea mays L.) seedlings. Adv. life sci., 1(1): 52-63.
7. Ali, Q., A. Ali, M. Tariq, M.A. abbas, B. Sarwar, M. Ahmad, M.F. Awaan, S. Ahmad, Z.A. Nazar, F. Akram, A. Shahzad, T.R. Samiullah, I.A. Nasir, and T. Husnain 2014a. Gene Action for Various Grain and Fodder Quality Traits in *Zea Mays*. *Journal of Food and Nutrition Research*, 2(10): 704-717.
8. Azam S, Samiullah TR, Yasmeen A, Din S, Iqbal A, Rao AQ, Nasir IA, Rashid B, Shahid AA, Ahmad M, Husnain T. 2013. Dissemination of Bt cotton in cotton growing belt of Pakistan. Adv. life sci., 1(1): 18-26.
9. Butt SJ, Varis S, Nasir IA, Sheraz S, Shahid A, Ali Q. Micro Propagation in Advanced Vegetable Production: A Review. (2015). Adv. Life Sci. 2(2). pp: 48-57.
10. Cheema, N.M., M. Ihsan, M.A. Mian, G. Rabbani, M.A. Tariq and A. Mahmood. 2007. Gene action studies for some economic traits in spring wheat. Pakistan J. Agri. Res. 20(3/4):99-104.

11. Dar AI, Saleem F, Ahmad M, Tariq M, Khan A, Ali A, Tabassum B, Ali Q, Khan GA, Rashid B, Nasir IA, Husnain T. Characterization and efficiency assessment of PGPR for enhancement of rice (*Oryza sativa* L.) yield. (2014). Adv. Life Sci. 2(1). pp: 38-45.
12. Dhadhal, B., K. Dobariya, H. Ponkia, and L. Jivani. 2008. Gene action and combining ability over environments for grain yield and its attributes in bread wheat (*Triticum aestivum* L.). Int. J. Agri. Sci. 4(1):66-72.
13. Farooq, J., K. Ihsan, A.M. Amjad, K. Muhammad, U.R. Aziz, N. Muhammad A. Qurban, N., Wajad and F.Amjad. 2011a. Inheritance pattern of yield attributes in spring wheat at grain filling stage under different temperature regimes. Australian Journal of Crop Science, 5(13): 1745-1753.
14. Farooq, J., Khaliq, I., Kashif, M., Ali, Q., & Mahpara, S. 2011b. Genetic analysis of relative cell injury percentage and some yield contributing traits in wheat under normal and heat stress conditions. *Chilean Journal of Agricultural Research*, *71*(4), 511-520.
15. Gowda, M., C.F.H. Longin, V. Lein and J.C. Reif. 2012. Relevance of Specific versus General Combining Ability in Winter Wheat. Crop Sci. 52:2494-2500.
16. Hasnain, Z., G. Abbas, A. Saeed, A. Shakeel, A. Muhammad and M.A. Rahim. 2006. Combining ability for plant height and yield related traits in wheat, *Triticum aestivum* L. J. Agri. Res. 44(3):167-173.
17. Hassani, M., G. Saeidi and A. Rezai. 2005. Estimation of genetic parameters and combining ability for yield and yield components in bread wheat. J. Water Soil Sci. Isfahan Uni. Tech. 9(1):157-171.
18. Iqbal, M., A.A. Khan. 2006. Analysis of combining ability for spike characteristics in wheat (*Triticum aestivum* L.). Int. J. Agri. Biol. 8(5):684-687.
19. Jahangir GZ, Nasir IA, Iqbal M. Disease free and rapid mass production of sugarcane cultivars. 2014. Adv. life sci., 1(3): 171-180.
20. Jain, S.K. and E. Sastry. 2012. Heterosis and combining ability for grain yield and its contributing traits in bread wheat (*Triticum aestivum* L.). Res. Rev.: J. Agri. Allied Sci. 1(1):17-22.
21. Khayatnejad, M., M. Zaefizadeh and R. Gholamin. 2010. Study of genetic diversity and path analysis for yield of durum wheat under drought stress condition. Plant Ecophysiol. 2: 133-136.
22. Knezevic, D., V. Zecevic, D. Micanovic, M. Madic, A. Paunovic, N. Dukic, D. Urosevic, B. Dimitrijevic and S. Jordacijevic. 2006. Genetic analysis of number of kernels per spike in wheat (*Triticum aestivum* L.). Kragujevac J. Sci. 28:153-157.
23. Lohithaswa, H., S. Desai, R. Hanchinal, B. Patil, K. Math, I. Kalappanavar, T. Bandivadder and C. Chandrashekhara. 2013. Combining ability in tetraploid wheat for yield, yield attributing traits, quality and rust resistance over environments. Karnataka J. Agri. Sci. 26(2):190-193.
24. Mahpara, S., Z. Ali and M. Ahsan. 2008. Combining ability analysis for yield and yield related traits among wheat varieties and their F_1 hybrids. Int. J. Agri. Biol. 10(6):599-604.
25. Majeed, S., M. Sajjad and S.H. Khan. 2011. Exploitation of non-additive gene actions of yield traits for hybrid breeding in spring wheat. J. Agri. and Soc. Sci. 7(4):131-135.
26. Malano, I.A. 2008. Line × tester analysis for estimating combining ability in bread wheat (*Triticum aestivum* L.). SAUT, Tandojam (Pakistan). Plant genetics breed. pagination 100.
27. Malik, M.F.A., S.I. Awan and S. Ali. 2005. Genetic behavior and analysis of quantitative traits in five wheat genotypes. J. Agri. Soc. Sci. 1(4):313-315.
28. Masood, M.S. and W.E. Kronstad. 2000. Combining ability analysis over various generations in a diallel cross of bread wheat. Pakistan J. Agri. Res. 16(1):1-4.
29. Masood SA, S Ahmad, M Kashif and Q. Ali. Role of combining ability to develop higher yielding wheat (*Triticum aestivum* L.) genotypes: An overview. *Nat Sci* 2014a;12(11): 155-161.
30. Masood SA, S Ahmad, M Kashif and Q. Ali. Correlation analysis for grain and its contributing traits in wheat (*Triticum aestivum* L.). *Nat Sci* 2014b;12(11):168-176.
31. Masood SA, Q. Ali and HG Abbas. Estimation of general and specific combining ability for grain yield traits in *Triticum aestivum*. *Nat Sci* 2014c;12(11):191-198.
32. Meena, B.S. and E.VD. Sastry. 2003. Combining ability in bread wheat (*Triticum aestivum* L.). Ann. Biol. 19(2): 205-208.
33. Mustafa, H. S. B., Batool, N., Ali, Q., Farooq, J., Ali, G. M., & Shehzad, A. 2015. Comprehensive Overview for Developing Drought Tolerant Transgenic Wheat (Triticum aestivum L.). J Agrobiol 30(2): 55–69.
34. Nazir, S., A.S. Khan and Z. Ali. 2005. Combining ability analysis for yield and yield contributing traits in bread wheat. J. Agri. Soc. Sci. 1(2):129-132.

35. Pakistan Economic Survey. 2012-13. Govt. of Pakistan, Ministry of Finance, Economic Advisor's Wing, Islamabad.
36. Pimentel, A.J.B., M.A.d. Souza, P.C.S. Carneiro, J.R.d.A.S. Rocha, J.C. Machado and G. Ribeiro. 2013. Partial diallel analysis in advanced generations for selection of wheat segregating populations. Pesq. Agropec. Brasileira. 48(12):1555-1561.
37. Sabbir MZ, Arshad M, Hussain B, Naveed I, Ali S, Abbasi A and Ali Q, (2014). Genotypic response of chickpea (*Cicer arietinum* L.) for resistance against gram pod borer (*Helicoverpa armigera* (Hubner))**.** Adv. life sci., 2(1): 23-30.
38. Sanjeev, R., S. Prasad and M.A. Billore. 2005. Combining ability studies for yield and its attributes in *Triticum durum*. Madras Agric. J. 92(1-3):7-11.
39. Senapati, N., S. Swain and M. Patnaik. 2000. Combining ability and nature of gene action in bread wheat. Environ. Ecol. 18(1):258-260.
40. Shabbir, G., T. Kiran, Z. Akram, M. Ijaz Tabassum and K. Nawaz Shah. 2012. genetics of some biometric traits in bread wheat (*Triticum aestivum* L.). J. Agri. Res. 50(4):457-468.
41. Sharma, S., R. Sain and R. Sharma. 2003. Genetics of spike length in durum wheat. Euphytica. 130(2):155-161.
42. Sharma, S.N., U. Menon and R.S. Sain. 2004. Combining ability for physiological traits in spring wheat over environments. Acta Agronomica Hungarica. 52(1):63-68.
43. Sheikh, S. and I. Singh. 2000. Combining ability analysis in wheat plant characters and harvest index. Int. J. Trop. Agri. 18(1):29-37.
44. Shoran, J., L. Kant and R. Singh. 2003. Winter and spring wheat: an analysis of combining ability. Cereal Res. Commun. 31(4):347-354.
45. Singh, K., U.B. Singh and S.N. Sharma. 2013. Combining ability analysis for yield and its components in bread wheat (*Triticum aestivum* L. em. Thell.). J. Wheat Res. 5(1):63-67.
46. Sleper, D.A. and J.M. Poehlman. 2006. Breeding field crops. 5th ed. Iowa State University Pres. USA.
47. Srivastava, M.K., D. Singh and S. Sharma. 2012. Combining ability and Gene action for seed yield and its components in Bread Wheat (*Triticum aestivum* L.). Electronic J. Plant Breeding, 3(1):606-611.
48. Sudesh, R.K. Yadava and O.P.S. Rana. 2002. Combining ability effects in bread wheat involving ''gigas" spike genotypes as tester. Res. Crops 3(2): 426-431.
49. Tahmasebi G., J. Heydarnezhadian and A.P. Aboughadareh. 2013. Evaluation of yield and yield components in some promising wheat lines. Int. J. Agri. Crop Sci. 5(20):2379-2384.
50. Tripathi, S., S. Marker, P. Pandey, K. Jaiswal and D. Tiwari. 2011. Relationship between some morphological and physiological traits with grain yield in bread wheat (*Triticum aestivum* L. em. Thell.). Trends in Appl. Sci. Res. 6(9):1037-1045.
51. Tsenov, N. and E. Tsenova. 2011. Combining ability of common winter wheat cultivars (*Triticum aestivum* L.) by date to heading and date to physiological maturity. Bulgarian J. Agri. Sci. 17(3):277-287.
52. Tariq M, Ali Q, Khan A, Khan GA, Rashid B, Rahi MS, Ali, A, Nasir IA, Husnain T. (2014). Yield potential study of Capsicum annuum L. under the application of PGPR. Adv. life sci., 1(4): 202-207.
53. Qamar, Z, Aaliya K, Nasir IA, Farooq AM, Tabassum B, Qurban A, Ali A, Awan MF, Tariq M and Husnain T. An overview of genetic transformation of glyphosate resistant gene in *Zea mays*. *Nat Sci*. 2015;13(3): 80-90.
54. Shan MA, Tahira F, Shafique M, Hussnain M, Perveen R, *et al* (2015). Estimation of Different Biochemical Intensities in Drinking Water from Eastern Region of Lahore City. Adv. life sci., 2(3): 131-134.
55. Yucel, C., F.S. Baloch and H. Ozkan. 2009. Genetic analysis of some physical properties of bread wheat grain (*Triticum aestivum* L. em Thell). Turkish J. Agri. For. 33:525-535.
56. Zameer M, Mahmood S, Mushtaq Z, Tabasum B, Ali Q, et al. (2015). Detection of bacterial load in drinking water samples by 16s rRNA ribotyping and RAPD analysis. Adv. Life Sci. 2(3). pp: 135-141.
57. Zare-kohan, M. and B. Heidari. 2012. Estimation of genetic parameters for maturity and grain yield in diallel crosses of five wheat cultivars using two different models. J. Agri. Sci. 4(8):74-85.

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