JOURNAL OF AGRICULTURE AND BASIC SCIENCES
ISSN Online: 2518-4210
http://www.jabsjournal.com/

Full Length Research Article

Combining Ability Analysis through Line × Tester Method for Agronomic and Yield Related Components in Sunflower (*Helianthus annuus* L.)

Muhammad Azhar Hussain*, Ameer Bibi, Iftikhar Ali, Tariq Mahmood
Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad.
*Corresponding author: azharhussain301@gmail.com

Abstract

Five into five line x tester analysis was progressed to check the combining ability of sunflower inbred line for the development of higher yielding hybrids. Statistical Analysis results revealed that parent vs crosses mean square values were highly significant for traits under study. Combining ability analysis also showed that the female line, A-7, C-2 and C-3 were good general combiner for plant height, number of leaves, days to 50% flowering, head diameter, 100 achene weight, number of achene per head, achene weight per head while excluding stem girth and days to maturity. Similarly, testers B-7, C-4 and L-8 were also good general combiner for plant height, stem girth, number of leaves, days to 50% flowering, head diameter, number of achene per head, achene weight per head while excluding days to maturity and 100 achene weight. Specific combining ability study of under study genetic material revealed that crosses, A-7×L-8, A-11×L-8, C-2×L-8 C-3×L-4 and C-3×L-8 were proved to be good specific combiner for majority of seed yield related components. So these cross combinations might be utilized for the improvement of genetic material for achene yield in sunflower.

Key words: Achene yield, GCA, SCA, Sunflower

Introduction

Pakistan is an agricultural country. It has made impressive improvements in agriculture sector. It is included in those countries where population is increasing rapidly. The demand of edible oil is increasing with the change in eating habit. Pakistan is producing only 26% of necessities edible oil and 74% requirement met through import (Economic survey of Pakistan, 2013-14). Major share in local edible oil production is from cotton seed oil about 72%, Brassica 9% and sunflower 4-5%. Sunflower is an important oilseed crop. It is a good source of edible oil. Its oil contents ranging from 25 to 48 % but up to 58% also has been reported in some hybrids (Aslam *et al.* 2010). There is a dire need to increase the share of sunflower oil due its health benefits, especially curing heart diseases and rich source of essential vitamins and antioxidant properties. The production of sunflower in Pakistan climatic conditions is lower than developed country per acre yield due to many factors like, unavailability of pure hybrid seed, exotic hybrids, cultivation of marginal land, competition with other crops and low input used. Production of crops can be increased through the increasing cultivated land area and indirectly by enhancement of genetic potential of available germplasm for higher yield potential through improvement of yield components of plants.

In hybrids development General combining abilities (GCA) and Specific combining abilities (SCA) have important role. Genetically different inbred lines show significant heterosis in hybrids for vegetable oil and achene yield. Plant breeders remains in search for good combiners to exploit heterosis. Study of combining ability helps the breeders to identify breeding methods for the development of high yielding hybrids. Combining ability analysis refers the role of dominant genes in SCA value and additive genes in GCA value and presence of epistasis genes effects when SCA and GCA values both are non-significant. Many researchers found the significance of SCA and GCA effects in high oil yield and achene yield. Some plant breeders give more importance to GCA as they play more important role than SCA in yield and others prefers SCA (Goksoy *et al*., 2002) than GCA and considered it has more significant role in edible oil and yield (Fehr, 1993., Ahmad *et al.*, 2012.). So combining ability analysis through line × tester method is an efficient approach to define the parents with marvelous yield traits. So appropriate breeding strategies can be used for the enhancement of genetic potential of source breeding material for seed yield in sunflower.

Material and Methods

A field experiment was carried out to determine the combining ability of inbred lines of sunflower in the research area of the Department of Plant Breeding and Genetics, University of Agriculture Faisalabad. The experiment comprised of five female lines, and five male testers that were crossed in line × tester mating design to produce 25 F_1 cross combinations. Cross combinations and their parents were sown in the field following the randomized complete block design replicated three times. Plant to plant and row to row distance was maintained 25cm and 70cm, respectively. Dibbler was used to maintain uniform sowing depth for seed. All the recommended Agronomical and entomological practices performed from sowing till harvest. During the vegetative phase data were collected for days to 50% flowering and number of leaves. When more than 90% plants of each entry and in each replication attained physiological maturity data were collected for stem girth, days to maturity and head diameter. After harvesting of head from randomly selected plants from each entry and each replication they were sundried. After threshing of each head separately data were collected for 100 achene weight, number of achene per head and achene weight per head. Obtained data were statistically analyzed through procedures developed by Kempthorne, (1957) for analysis of variance and to study combining ability of the parent material for achene yield related traits.

Results and Discussion

Sunflower is an important oilseed crop has novel and balanced fatty acid profile. Its oil is a rich source of polyunsaturated fatty acids and has lots of health benefits especially for heart patients. Statistical analysis of data revealed that mean square values of all the traits under study were highly significant (Table 1). Treatment mean square values were highly significant for all the under study attributes that showed significant variability was present in the studied genetic material which is a prerequisite for the improvement of genetic material through breeding. Significant genetic variability has been reported previously in different crop plants for different traits which could be exploited for hybridization (Aslam *et al*., 2013 a, b; Aslam *et al*., 2014; Aslam *et al*., 2015 a, b, c; Aslam *et al*., 2016; Aslam *et al*., 2017; Naveed *et al*., 2014; Maqbool *et al*., 2015 a, b; Maqbool *et al*., 2016).

All the parental genotypes significantly differed from each other for yield related characters. This showed the suitability of source material for improvement is possible through conventional breeding. The crosses also showed significant variability from each other indicated that improvement have been occurred in F_1 generation through using these parental lines as source genotypes. Parent vs crosses interactions were highly significant for all the yield contributing traits. This showed the possibility of heterosis breeding could be useful and rewarding when manipulated using these parental genotypes. Similar findings also been reported for understudy traits by Sujatha *et al.* (2002); Devi *et al.* (2005); Bakht *et al.* (2006); Habib *et al.* (2007); Khan *et al.* (2008); Binodh *et al.* (2008); Chandra *et al*. (2011); Andarkhor *et al*. (2012); Tyagi *et al.* (2013); Kang *et al.* (2013) and Khan *et al.* (2013).

General combining ability (GCA) is the average performance of inbred lines in a series of crosses for a specific trait (Table 2). GCA is the study of additive genetic variance. Mostly the good combiner lines also performed well in cross combinations. When the additive variance is preponderance in the genetic material then selection could be fruitful in the breeding material. General combining ability analysis showed that among studied lines, A-5 and C-3 had expressed significant negative GCA effects while A-7 and C-2 exhibited positive significant GCA responses and A-11 exhibited non-significant response for plant height. Similar results were also discussed by Ortis *et al.* (2005) and Khan *et al.* (2009). Among testers, L-4 and B-4 gave highly significant negative GCA responses while remaining all testers expressed positive and significant GCA effects for plant height. Dwarf plant height is required in plants due to lodging and stem breakage resistance properties in plants. Lodging and stem breakage due to heavy wind storm causes huge loss of yield because the proper filling of achene does not take place. Among female lines C-2 exhibited desired positive GCA response for stem girth while A-7 had significant negative GCA values for this trait. Among studied testers, B-7 and C-4 had expressed required positive and significant GCA values for stem girth while L-8 responded by giving negatively significant GCA effects. Thick and green stem is required in sunflower plants because it provided resistance against stem breakage and it also participates in photosynthetic activity in plants. These results are in pars of Hassan *et al*. (2013) and Khan *et al.* (2013).

GCA effects for a number of leaves had expressed that lines, C-2 and A-7 were highly and positively significant for this attribute while lines, A-5 and A-11 responded non-significantly. Among the investigated testers, B-7 and L-8 had given positive and highly significant GCA effects for a number of leaves. More number of leaves per plant is required because it is the primary part in the plant body that participated directly in light harvesting and photosynthetic activity. As the number of leaves increases the photosynthetic activity and ultimately more reserved food for reproductive phase in plants. Similar findings also been discussed by Tyagi *et al.* (2013). The GCA study of lines for, days to 50% flowering had showed that A-7 and C-3 expressed negative and highly significant effects while among testers, B-7 and C-4 revealed significant negative GCA effects for this trait. Minimum days to 50% flowering in plants are required because it provides maximum duration for achene filling and for the development early maturing hybrids in sunflower. Same results also been discussed by Khan *et al.* (2009) and Kang *et al.* (2013). Days to maturity analysis had expressed that lines, A-5 and tester, B-7 responded by significant negative GCA effects. Minimum days to maturity are required for the development of early hybrids that can best fit to present cropping pattern. These results are in the range of Kang *et al*. (2013).

GCA effects for head diameter had revealed that only line C-3 exhibited significant and positive value while among testers, B-4, C-4 and L-8 expressed significant positive GCA effects for this attribute. Large head size is required in sunflower because it directly related to the number of achene per head and ultimately affects the yield. These findings have similarity with Sujatha *et al*. (2002). Among investigated lines, A-7 and C-3 was found with desired significant positive GCA effects while among testers, B-4 and B-7 responded well for a 100 achene weight. Significant positive values for 100 achene weight are required because it's the most important trait of yield. Similar study also been made by Ramesh *et al.* (2013) and Arshad *et al.* (2013).

Lines, A-5 and C-3 had revealed positive and significant GCA values for number of achene per head while among male testers, C-4, L-4 and L-8 gave similar response for this trait. More numbers of filled achene per head are required because it is the most important component of yield. These findings have correspondence with Ramesh *et al.* (2013) and Kang *et al.* (2013). Investigation of lines for achene weight per head revealed that C-2 and C-3 lines were highly significant in GCA effects and among testers, under study B-4, C-4 and L-8 also gave highly significant GCA values. Attia *et al.* (2012) and Tyagi *et al.* (2013) reported similar findings for achene weight per head.

Specific combining ability (SCA) is related to dominance variance (Table 3). The higher the values for SCA more chances for the development of higher yielding hybrids. SCA of cross combination had revealed that cross combinations, C-2×B-7, A-11×B-4 and A-5×L-8 showed highest negative significant SCA effects for plant height. Among total cross combinations under study ten crosses revealed significant positive SCA values for plant height and only one combination was non-significant for this trait while the remaining were negatively significant. Tan (2010) and Ciric *et al*. (2013) reported similar findings. Among cross combinations, C-3×C-4, C-3×L-8 and C-3×L-4 had expressed highly positive desired SCA effects for stem girth while thirteen crosses were negatively significant which is not desired, so careful selection criteria should be undertaken for this trait. Habib *et al*. (2006) found similar results for stem girth. SCA study for a number of leaves had revealed that crosses, C-3×L-4, C-3×C-4 and C-3×L-8 exhibited highly positively significant desired effects while six combinations expressed negative significant SCA effects. Ahmad *et al.* (2005) discussed same results. Days to 50% flowering investigation of SCA effects had showed that F_1 hybrid combinations, A-7×C-4, A-7×L-4 and C-2×B-7 expressed desired highly significant negative effects while crosses, C-3×C-4, C-3×L-8 and C-3×L-4 were highly positively significant. Devi *et al.* (2005) and Ciric *et al.* (2013) reported similar findings.

Highly significant negative SCA effects for days to maturity were expressed by the crosses, C-2×B-7, A-7×C-4 and A-7×L-4. Investigation of head diameter for SCA values revealed that cross combinations, C-3×L-8, C-3×C-4 and C-3×L-4 were found highly and positively significant for this character. Tan (2010) and Ciric *et al.* (2013) presented similar results for head diameter. A study of 100 achene weight showed that crosses C-3×C-4, C-3×L-4 and C-3×L-8 expressed positive and significant SCA effects with desired direction. Tyagi *et al.* (2013) and Kang *et al.* (2013) discussed same findings. Statistical investigation for a number of achene per head exhibited that C-3×L-8, C-3×L-4 and C-3×C-**4** were positively significant with desired direction of SCA effects. SCA effects for studied character achene weight per head exhibited that, C-3×C-4, C-3×L-8 and C-3×L-4 crosses were highly significant with positive direction. Hassan *et al.* (2012), Ramesh *et al*. (2013) and Kang *et al.* (2013) reported similar results for a number of achene per head and achene weight per head.

Conclusion

The studied results from combining ability analysis for achene yield and yield related traits in sunflower had showed that highly significant genetic variability was present among the genotypes under study. Analysis of variance results exhibited highly significant parent vs crosses mean square values of all the traits under study suggested that these parental lines can be successfully exploited for the development of higher yielding hybrids. General combining ability (GCA) investigation revealed that inbred line A-5 and tester L-4, for short stature hybrids, line A-11 and tester L-8 for thick stem, line C-2 and tester B-7 for number of leaves, line C-3 and tester C-4 for days to 50% flowering, line A-5 and tester B-7 for days to maturity, line C-3 and tester L-8 for head diameter, line A-7 and tester B-7 for 100 achene weight, line C-3 and tester C-4 for number of achene per head and line C-2 and tester L-8 could be successfully exploited for higher achene yield in sunflower. Among studied cross combination SCA study had showed that, C-2×L-4, C-3×C-4, C-3×L-4, C-2×L-8, C-3×L-8 crosses could be exploited for the genetic improvement of breeding material in sunflower for number of leaves, head diameter, 100 achene weight, number of achene per head and achene weight per head while cross combinations, A-7×L-4, A-5×L-8, A-7×C-4, A-11×L-8 and A-7×L-8 will be useful for the development of early maturing hybrid genotypes in sunflower.

References

Ahmad, M.W., M.S. Ahmed and H.N. Tahir. (2012). Combinig ability analysis for achene yield and related traits in sunflower (*Helianthus annuus* L.). *Chilean J. Agri. Res*., 72: 21-26.

Ahmad, S., M.S. Khan, M.S. Swati, G.S. Shah, and I.H. Khalil. (2005). A study on heterosis and inbreeding depression in sunflower (*Helianthus annuus* L.). *Songklanakarin J. Sci. Tech*., 27:1-8.

Andarkhor, S.A., N. Mastibege, and V. Rameeh. (2012). Combining ability of agronomic traits in sunflower (*Helianthus annuus* L.) using line × tester analysis. *Internat. J. Biol.,* 4:89-95.

Arshad, M., M.A. Khan, I. Ullah, and M. Amjad. (2013). Development of short duration and high yielding indigenous (*Helianthus annuus* L.). *Sci. Tech. Davison.,* 32:205-214.

Aslam S., S.M. Khan M. Saleem, A.S. Qureshi, A. Khan, M. Islam and S.M. Khan. (2010). Heterosis for the improvement of oil quality in Sunflower (*Helianthus annuus* L.). *Pak. J. Bot.,* 42(2):1003-1008.

Aslam, M., B. Farid, K. Khakwani, M.A. Maqbool and H. Zou. (2017). In-vivo maternal haploid seed production and chromosome doubling with different anti-microtubular agents in maize. *Int. J. Agric. Biol*., 114-120.

Aslam, M., M.A. Maqbool and R. Cengiz. (2015c). Drought Stress in Maize (*Zea mays* L.): Effects, Resistance Mechanisms, Global Achievements and Biological Strategies for Improvement. *Springer Briefs in Agric*., 1-74.

Aslam, M., M.A. Maqbool, M. Yaseen and Q.U. Zaman. (2015b). AMMI Biplot analysis for comparative evaluation of maize genotypes under different saline environments. *Pak. J. Agric. Sci.,* 52(2): 339-347.

Aslam, M., M.A. Maqbool, Q.U. Zaman and M.A. Akhtar. (2016). Phenotypic Indicators Based Grouping of Mungbean *(Vigna Radiata* L. Wilczek) Genotypes Under Saline Conditions Using K-Mean Cluster Analysis. *J. Agric. Basic Sci*., 1(1): 37-44.

Aslam, M., M.A. Maqbool, S. Akhtar and W. Faisal. (2013b). Estimation of genetic variability and association among different physiological traits related to biotic stress (*Fusarium oxysporum* L.) in chickpea. *J. Anim. Plant Sci*., 23(6): 1679-1685.

Aslam, M., Q. Sohail, M.A. Maqbool, Q.U. Zaman and Z. Ahmed. (2015a). Combining Ability Analysis and Genetic Inheritance of Salt Tolerance Indicators in Maize (Zea mays L.) Following Diallel Mating Design. *Int. J. Agric. Biol*., 17: 523–530.

Aslam, M., S.M.A. Basra, M.A. Maqbool, H. Bilal, Q.U. Zaman and S. Bano. (2013a). Physio-chemical distinctiveness and metroglyph analysis of cotton genotypes at early growth stage under saline hydroponic. *Int. J. Agric. Biol*., 15: 1133–1139.

Attia, S.A.M., E.H.E. Seidy, A.A.E. Gammaal, and R.M.M. Awad. (2012). Heritability, genetic advance and association among characters of sunflower hybrids study. *J. Agric. Res. Kafer El-Sheikh Uni.*, 38:254-265.

Bakht, J., S. Ahmad, M. Tariq, H. Akber, and M. Shafi. (2006). Performance of various hybrids of sunflower in Peshawer valley. *J. Agric. and Biol. Sci*., 1:25-29.

Binodh, A.K., N. Manivannan, and P.V. Verman. (2008). Combining ability analysis for achene yield and its contributing characters in sunflower (*Helianthus annuus* L.). *Madras Agric. J*., 95: 295-300.

Chandra, B.S., S.S. Kumar, A.R.G. Ranganadha, and M.Y. Dudhe. (2011). Combining ability studies for the development of new hybrids over environments in sunflower (*Helianthus annuus* L.). *J. Agric. Sci*., 3:230-237.

Ciric, M., S. Jocic, S. Cvejic, P. Canak, M, Jockovic, R. Marinkovic, and M. Mirosavljevic. (2013). Evaluation of combining abilities of new sunflower inbred lines. Ratar povrt., 50(1): 8-15.

Devi, K.R., A.R.G. Ranganatha, and M. Ganesh. (2005). Combining ability and heterosis for seed yield and its attributes in sunflower. *Agric. Sci. Digest,* 25:11-14.

Fehr, W.R. (1993). Principles of Cultivar Development. Vol. 1. MacMillan Publ. Co. New York, USA.

Goksoy, A.T., A. Turkec and Z.M. Turan. (2002). Quantitative inheritance in sunflower (Helianthus annuus L.). *Helia,* 25(37):131-140.

Habib, H., S.S. Mehdi, A. Rashid, M. Zafar, and M.S. Anjum. (2007). Heterosis and heterobeltiosis studies for flowering traits, plant height and seed yield in sunflower (*Helianthus annuus* L.). *Int. J. of Agric. Biol.,* 9:355-358.

Habib, H., S.S. Mehdi, A. Rashid, S. lqbal, and M.A. Anjum. (2006). Heterosis studies in sunflower (*Helianthus annuus* L.) crosses for agronomic traits and oil yield under Faisalabad conditions. *Pak. J. of Agric. Sci.*, 43:131-135.

Hassan, S.M.F., M.S. Iqbal, G. Rabbani, N. Din, G. Shabbir, M. Riaz, and I.R. Noorka. (2013). Correlation and path analysis for yield and yield components in sunflower (*Helianthus annus*. L). *Afric. J. of Biotech.*, 12:1968-1971.

Kang, S.A., F.A. Khan, M.Z. Ahsan, W.S. Chatha, and F. Saeed. (2013). Estimation of combining ability for the development of hybrid genotypes in (*Helianthus annuus* L.). *J. Biol. Agric. Healthcare*, 39:68-74.

Kempthorne, O. (1957). Introduction to genetic Statistics. John Wiley and Sons, New York, USA.

Khan, H., H. Rahman, H. Ahmad, H. Ali, Inamullah, and M. Alam. (2008). Magnitude of combining ability of sunflower genotypes in different environments. *Pak. J. Bot*., 40: 151-160.

Khan, H., H.U. Rehman, J. Bakht, S.A. Khan, I. Hussain, A. Khan, and S. Ali. (2013). Genotype × environment interaction and heritability estimates for some agronomic characters in sunflower. *J. of Animal and Plant Sci*., 23:1187-1184.

Khan, S.A., H. Ahmad, A. Khan, M. Saeed, S.M. Khan, and B. Ahmad. (2009). Using line x tester analysis for earliness and plant height traits in sunflower (*Helianthus annuus* L.). Recent Res. Sci. and Tech., 1:202-206.

Maqbool, M.A., M. Aslam, H. Ali and T.M. Shah. (2016). Evaluation of advanced chickpea (*Cicer arietinum* L.) accessions based on drought tolerance indices and SSR markers against different water treatments. *Pak. J. Bot*., 48(4): 1421-1429.

Maqbool, M.A., M. Aslam, H. Ali, T.M. Shah and B.M. Atta. (2015b). GGE biplot analysis based selection of superior chickpea (*Cicer arietinum* L.) inbred lines under variable water environments. *Pak. J. Bot*., 47(5):1901-1908.

Maqbool, M.A., M. Aslam, H. Ali, T.M. Shah, B. Farid and Q.U. Zaman. (2015a). Drought tolerance indices based evaluation of chickpea advanced lines under different water treatments. Res. Crops., 16 (2): 336-344.

Naveed, S., M. Aslam, M.A. Maqbool, S. Bano, Q.U. Zaman and R.M. Ahmad. (2014). Physiology of high temperature stress tolerance at reproductive stages in maize. *J. Anim. Plant Sci*., 24(4): 1141-1145.

Ortis, H., G. Nestares, E. Frutos, and N. Machado. (2005). Combining ability analysis for agronomic traits in sunflower (*Helianthus annuus* L.). *Helia*, 28:125-134.

Pakistan Economic Survey. (2013-14). Govt. of Pakistan, Ministry of Finance, Economic Advisor's Wing, Islamabad.

Ramesh, M., J. Arunkumar, Y. Prashanth, A.R.G. Ranganatha and Y. Dudhe. (2013). Population improvement for seed yield and oil content by using working germplasm in sunflower (*Helianthus annuus* L.). *Sabrao J. Breed. and Genet*., 45:291-295.

Sujatha, H.L., Chikkadevaiah and Nandini. (2002). Genetic variability study in sunflower inbreds. *Helia*, 25:93-100.

Tan, A.S. (2010). Study on the determination of combining abilities of inbred lines for hybrid breeding using line× tester analysis in sunflower (*Helianthus annuus* L.). *Helia*, 33:131-148.

Tyagi, V., S.K. Dhillon, R.K. Bajaj, and J. Kaur. (2013). Divergence and association studies in sunflower (Helianthus annuus L.). *Helia*, 36:77-94.

Table 1: ANOVA table for studied traits

SOV	DF	PH	SG	NL	D50%F	DM	HD	100AW	NA/H	AW/H
Replication	2	15.78**	1.30**	0.58^{ns}	27.27**	40.71**	15.51**	1.85**	18.08**	44.44**
Treatments	34	2463.94**	1.63**	33.20**	17.38**	16.46**	19.59**	1.39**	25.56**	8747.58**
Parents	9	3879.20**	2.62**	14.09**	16.28**	6.74**	9.63**	1.23**	15.38**	4608.46**
Crosses	24	1451.95**	1.22**	40.86**	14.56**	15.44**	14.81**	1.21**	16.20**	10317.37**
P vs C	1	14014.19**	2.56**	21.14**	95.10**	128.28**	224.02**	7.24**	341.66**	8324.63**
Females	4	1891.05**	0.28**	49.85**	15.29**	10.45**	11.43**	1.51**	5.09**	18063.02**
Males	4	1737.65**	2.65**	98.82**	18.35**	5.41**	37.70**	2.12**	45.69**	12469.44**
F Vs M	1	5713.20**	0.59**	0.30^{ns}	4.80**	0.83^{ns}	2.70^{ns}	1.28**	0.06**	9896.85**
Line X Tester	16	1270.75**	1.10**	24.13**	13.43**	19.20**	9.93**	0.90**	11.61**	7842.93**
Error	68	0.60	0.05	2.02	0.82	0.67	1.01	0.06	0.01	0.33

******= Significant at 0.01 level *****= Significant at 0.05 level NS= Non significant

PH=Plant Height, **SG**= Stem girth, **NL**= Number of leaves, **D50%F**= Days to 50% flowering, **DM**= Days to maturity, **HD**= Head diameter, **100AW**= 100 achene weight, **NA/H**= Numbers of achene per head and **AW/H**= Achene Weight per head

Table 2: General combining ability (GCA) effects of studied genotypes

Traits	Lines							Testers		
	A-5	**A-7**	**A-11**	**C-2**	**C-3**	**B-4**	**B-7**	**C-4**	**L-4**	**L-8**
PH	-16.71**	8.43**	0.23^{NS}	11.83**	-3.77**	-2.37**	6.49**	10.23**	-17.37**	3.03**
SG	0.01^{NS}	-0.17**	0.11^{NS}	0.15**	-0.11^{NS}	0.11^{NS}	0.40**	0.15**	0.05^{NS}	-0.71**
NL	0.57^{NS}	0.84*	-0.69^{NS}	2.04**	-2.76**	-0.36^{NS}	2.51**	-3.76**	-0.69^{NS}	2.31**
D50%F	1.31**	-0.89**	-0.23^{NS}	0.77**	-0.96**	0.11^{NS}	-0.83**	-1.03**	-0.03^{NS}	1.77**
DM	-1.19**	0.08^{NS}	1.15**	0.15^{NS}	-0.19^{NS}	-0.05^{NS}	-0.59**	-0.19^{NS}	1.01**	-0.19^{NS}
HD	0.27^{NS}	-1.07**	-0.67^{NS}	0.33^{NS}	1.13**	0.40**	-1.67**	1.33**	-1.67**	1.60**
100AW	-0.23**	0.35**	0.12^{NS}	0.19**	-0.42**	0.25**	0.31**	0.02^{NS}	-0.63**	0.06^{NS}
NA/H	17.25**	-37.08**	-20.89**	-10.30**	51.01**	-11.88**	-44.39**	27.13**	9.41**	19.73**
AW/H	-0.03^{NS}	-0.61**	-0.54**	0.59**	0.58**	0.72**	-1.13**	1.28**	-2.48**	1.61**

******= Significant at 0.01 level *****= Significant at 0.05 level NS= Non significant

PH=Plant Height, **SG**= Stem girth, **NL**= Number of leaves, **D50%F**= Days to 50% flowering, **DM**= Days to maturity, **HD**= Head diameter, **100AW**= 100 achene weight, **NA/H**= Numbers of achene per head and **AW/H**= Achene Weight per head

Table 3: Specific combining ability (SCA) effects of studied genotypes

Genotypes	PH	SG	NL	D50%F	DM	HD	100AW	NA/H	AW/H
A-5×B-4	34.71**	-0.13 NS	1.29 NS	0.43 NS	0.12 NS	-0.13 NS	0.31*	-21.69**	0.16*
A-7×B-4	0.57NS	-0.08 NS	0.03 NS	-2.37**	0.19 NS	1.87**	0.06 NS	27.26**	2.02**
A-11×B-4	-20.23**	0.08 NS	-1.44 NS	2.29**	-2.55**	0.13 NS	-0.78**	51.43**	-0.91**
C-2×B-4	-3.83**	0.30*	-4.51**	0.29 NS	1.45**	-0.53 NS	0.11 NS	-8.33**	-0.27**
C-3×B-4	-11.23**	-0.17 NS	4.63**	-0.64 NS	0.79 NS	-1.33*	0.29*	-48.67**	-1.00**
A-5×B-7	10.17**	0.38**	-0.57 NS	1.69**	-2.01**	0.27 NS	0.07 NS	-2.36**	0.43**
A-7×B-7	-12.29**	-0.07 NS	-0.84 NS	-0.77 NS	-2.95**	-0.40 NS	0.36*	-20.23**	-0.05 NS
A-11×B-7	6.91**	-0.65**	0.36 NS	0.56 NS	0.32 NS	-0.80 NS	0.29*	-22.06**	-0.34**
C-2×B-7	-17.57**	-0.64**	-2.88**	-4.95**	-8.39**	-2.06**	-0.63**	-38.79**	-2.93**
C-3×B-7	-3.69**	-0.11 NS	-0.77 NS	-1.35*	-2.19**	-0.48 NS	-0.16 NS	-9.57**	-0.70**
A-5×C-4	-11.89**	0.49**	1.03 NS	-3.11**	-2.08**	-2.40**	0.03 NS	-51.68**	-2.42**
A-7×C-4	-15.01**	-0.55**	-2.94**	-4.72**	-8.50**	-2.28**	-0.56**	-46.89**	-3.07**
A-11×C-4	-4.28**	-0.14 NS	-0.66 NS	-1.25*	-2.20**	-0.48 NS	-0.11 NS	-12.33**	-0.64**
C-2×C-4	20.56**	0.71**	3.22**	5.91**	9.67**	2.60**	0.67**	50.48**	3.54**
C-3×C-4	38.35**	1.20**	5.08**	12.48**	23.98**	5.97**	0.92**	168.71**	7.30**
A-5×L-4	1.71**	-0.03 NS	-0.37 NS	-0.77 NS	0.05 NS	-0.40 NS	0.02 NS	-3.19**	-0.32**
A-7×L-4	-15.38**	-0.56**	-2.60**	-4.92**	-8.69**	-2.11**	-0.63**	-39.77**	-3.00**
A-11×L-4	-2.82**	-0.11 NS	-0.75 NS	-1.33*	-2.20**	-0.53 NS	-0.12 NS	-12.23**	-0.70**
C-2×L-4	15.03**	0.60**	3.73**	5.61**	10.21**	1.93**	0.56**	45.84**	2.72**
C-3×L-4	24.64**	1.27**	5.04**	14.36**	23.06**	6.01**	1.29**	133.71**	7.86**
A-5×L-8	-34.69**	-0.71**	-1.37 NS	1.76**	3.92**	2.67**	-0.44**	78.92**	2.15**
A-7×L-8	-17.47**	-0.51**	-2.80**	-4.79**	-8.59**	-2.14**	-0.60**	-41.96**	-2.96**
A-11×L-8	-3.51**	-0.12 NS	-0.63 NS	-1.39**	-2.16**	-0.59 NS	-0.14 NS	-12.31**	-0.79**
C-2×L-8	18.88**	0.58**	3.27**	5.98**	9.67**	2.40**	0.65**	48.07**	3.30**
C-3×L-8	47.45**	1.20**	6.89**	13.54**	21.98**	5.77**	1.48**	115.48**	7.80**

******= Significant at 0.01 level *****= Significant at 0.05 level NS= Non significant

PH=Plant Height, **SG**= Stem girth, **NL**= Number of leaves, **D50%F**= Days to 50% flowering, **DM**= Days to maturity, **HD**= Head diameter, **100AW**= 100 achene weight, **NA/H**= Numbers of achene per head and **AW/H**= Achene Weight per head