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Full Length Research Article

Designate the Inheritance Pattern of Yield Related Indices in Spring Wheat

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Abstract

Eighteen single cross hybrids were sown along with their nine parents using RCBD in the research area of the Department of Plant Breeding and Genetics in the season 2015-16. Analysis of variance for all the characters under study showed significant difference among genotypes. The line 9865 proved its worth as a good general combiner for traits like number of tillers, spike length, number of spikelets per spike and grain weight per spike, while positive general combining ability for other traits like days to maturity, days to heading, number of grains per spike, 1000-grain weight and grain yield per plant was observed for the other female parent 9870. Among testers (males) Galaxy-13 exhibited positive general combining ability for all the traits under study excluding grain weight per spike which have negative effects. The cross 9870×AAS-11 proved to be the best specific combiner for the traits grain weight per spike, number of grains per spike and grain yield per plant. The GCA to SCA ratio illustrated that there is action of non-additive genes that is involved in the inheritance of most of the traits like flag leaf area, plant height, number of tillers per plant, days to maturity, grain weight per spike, grain yield per plant and 1000-grain weight. It is concluded that hybrid breeding will be more useful for improvement of mentioned traits. Additive gene action was involved in the inheritance of traits like days to heading, spike length, number of grains and number of spikelets per spike, therefore, selection will be useful in early segregating generations for above mentioned traits.

Key Words: Gene, inheritance, yield, heritability, alleles, spring wheat

Introduction

Wheat is the most important staple, economic and strategic crop. It is a staple crop as almost two billion of world people feeds on it, which accounts for 36% of world population. Worldwide, wheat production has high records. According to Economic Research and Foreign Agricultural Service, worldwide wheat production was 734.9 million tons for the year of 2015-16. (Anonymous, 2014-15) Wheat provides carbohydrates (55%) and calories (20%) which are globally consumed (Breiman and Graur, 1995). In changing environment and increasing population, it has become necessary for breeders to develop such superior varieties to boost the wheat productivity.

To overcome reduction in yield potential, the genetic material of varieties and genotypes have to be reshuffled so that these varieties and genotypes may attain an ideal genetic makeup which would help to give better performance in a range of changing environment (Khayatnejad *et al.*, 2010). Main objective of any wheat breeder is development of high yielding varieties all over the world. In and effective breeding program, planning and the choice of genotypes with desirable traits is important. This can be accomplished through scrutinizing maximal genetic potential within the attainable germplasm. Line × tester analysis (Kempthorn, 1957) is most promising method in this respect which helps in the selection of parents and crosses for improvement in further wheat breeding program (Rashid *et al.*, 2007: Ahmed *et al.*, 2015a). For the development of potential hybrids in several crops, choice of suitable parents and understanding of SCA and GCA effects is of a great importance to plant breeders (Kruvadi, 1991). New promising combinations could be used to improve existing yield level. Thus information attained would be useful in selecting desired parents and their crosses to develop an effective breeding program for development of highly productive wheat varieties.

Materials and Methods

The present study was conducted to estimate combining ability effects by using line × tester analysis in the research area of Department of PBG, University of Agriculture, Faisalabad. The experimental material comprised of six lines as female viz. 9865, 9866, 9495, 9868, 9869 and 9870 and three commercial varieties as testers' viz., Galaxy-13, BARS-2009 and AAS-11. The above mentioned genotypes were crossed in previously mentioned mating design during the year 2014-15. In the second year, the single crossed seeds were planted in the field in RCBD along nine parents in three replications during November 2015. Each replication consisted of six lines, three testers and 18 crosses sown in one-meter single row. Plant-plant and row-row distances were maintained at 15 and 30 centimeters respectively. The experimental material was kept under standardized agronomic conditions right from sowing till maturity.

At maturity, five randomly selected plants were taken from treatment row of each replication and data were recorded for plant height (cm) and flag leaf area (cm^2), number of tillers per plant, days to heading, days to maturity, spike length (cm), number of spikelets per spike, number of grains per spike, grain weight per spike (g), 1000-grain weight (g) and grain yield per plant (g) (Muller, 1991). The data recorded for all the characters were analyzed using analysis of variance as given by (Steel *et al.* 1997) to assess genotypic differences among crosses and parents. The traits which showed significant differences among the studied genotypes, were further partitioned through line × tester analysis given by Kempthorne (1957). The estimates of GCA for lines, testers and SCA for crosses were obtained.

Results and Discussion

The selection of genetically superior parents and selection within segregating population is very important and difficult task (Aslam *et al.*, 2015 a, b, c; Aslam *et al.*, 2016; Maqbool *et al.*, 2015a, b; Maqbool *et al.*, 2016). Therefore, it is needed that the breeders should have perfect knowledge of the nature of inheritance.

The analysis of variance for all characters studied is given in Table 1. Genotypes showed significant differences for the studied parameters. Among lines in Table 1, highly significant differences were found for GPS, DH, DM, TPP, GWPS, SL and SPS. Significant differences were observed in tester (male parent) for FLA, TPP, PL, SL, GYPP, PH, GPS, SPS and 1000-GW. Significant differences for all traits under study except FLA and GWPS were observed among the parents. Interaction of line × tester was also significant for PH. Significant differences were also observed for traits like TPP, DM, 1000-GW and GYPP. While remaining traits showed non-significant effects. Line × tester analysis revealed that genetic variability was present among the genotypes for yield and its related traits. So, these genotypes could be exploited for hybrid breeding program in wheat. Similar results were given by other scientists like Khayatnejad *et al.* (2010) and Lohithaswa *et al.* (2013).

General and specific combining ability effects

Plant height (cm)

In case of PH, -ve GCA effects (Table 2) were more important because stricter selection pressure was done selection for short-statured progeny in the segregating gerneration. Hence, genotype 9495 from the female parents, and BARAS-09 among male parents were proved to be the potential. The SCA effects (Table 3) of crosses showed a wide variation from positive to negative values for PH. The maximum negative SCA effects were observed for 9866 × Galaxy-13 cross combinations. So, the best specific combiner for PH was 9868 × Galaxy-13 all crosses. These results were further confirmed by the findings of Fellahi *et al.* (2013) and Hammad *et al.* (2013).

Flag leaf area (cm^2)

Among the three male parents (Table 2) only Galaxy-13 showed the positive value of 2.79 for GCA effects of female parents 9868 (3.19). The best combiners (Table 3) for FLA was 9868 × Galaxy-13 among other crosses. Similarly, same results were also confirmed by reported by Aslam *et al.* (2015c), Raj and Kandalkar (2013) and Ahmed *et al.*, (2015b) for FLA.

Number of tillers per plant

TPP is thought to be positively linked with the yield of crop (Hammad *et al.*, 2013). Among female parents, 9865 (1.75) exhibited higher and positive GCA effects (Table 2) followed by male parent Galaxy-13 (0.71). The 50% crosses had positive SCA effects (Table 3) and 50% had negative SCA effects. Masood and Kronstad (2000), Jain and Sastry (2012), and Hammad *et al.* (2013) also reported similar results in their experiments for TPP.

Days to Heading

In this study female parent 9870 showed high GCA effects (Table 2) followed by 9865. The cross (Table 3) 9870 × Galaxy-13 showed the higher value of SCA effects (1.12) for DH. The negative SCA effects were estimated in 7 crosses out of total 18. Rashid *et al.* (2007) and Kruvadi (1991) confirmed the above mentioned results from their findings.

Days to Maturity

In this study two female parents viz., 9870 and 9865 showed the high GCA effects (Table 2) as 3.33 and 0.56 respectively. Highest SCA effects (Table 3) were observed in crosses 9865 × Galaxy-13 (2.28) followed by 9868 × AAS-11 (1.72) while 50% cross combination showed negative SCA effects. Breiman and Graur (1995), and Khayatnejad *et al.* (2010) also came up with the similar results.

Spike length (cm)

SL is also positively correlated with yield of the crop as more number of spikelets and hence more grains will be there increasing the yield. Table 2 shows that 9865 among lines had high GCA with the value of (1.09). Among crosses, 9495 × AAS-11 had highest (Table 3) and positive SCA effects (0.71). Similarly, Istipliler *et al.* (2015) and Ashraf *et al.* (2015) also came up with the almost same results for SL.

Number of spikelets per spike

Highest positive effects (Table 2) were recorded for 9865 (1.70) followed by genotype Glaxy-13, 9870 and 9495. Among crosses, the cross 9869 × Baras-09 had highest and positive SCA effects (0.91) for SPS followed by 9866 × AAS-11 (0.86). Table 3 shows that the negative SCA effects were found in 8 out of 18 crosses. Similar results were given by Khayatnejad *et al.,* (2010) and Lohithaswa *et al.* (2013) for SPS.

Number of grains per spike

Two male parents out of three showed the positive GCA (Table 2) value. The highest positive SCA effects were observed for 9869 × AAS-11 (2.38) followed by 9866 × BARAS-09 (2.29). The negative SCA effects were observed in 10 by 18 crosses (Table 3). The maximum negative SCA effects were observed 9869 × Galaxy-13 (-2.17) cross combinations. The above results were in accordance with Kashif and Khan (2008), and Srivastava *et al.* (2012).

Grain weight per spike (g)

Among female parents 9865 having higher GCA value (0.34) followed by genotype 9870 with 0.16 GCA value, only two line having negative GCA effects (Table 2). Among male parents only one parent having negative GCA effects out of three male parents. It is worth mentioning that value of GCA effects of lines was higher than testers. Positive SCA effects (Table 3) ranged from 0.21 (9869 × AAS-11) to 0.13 (9870 × Galaxy-13). While negative SCA effects were observed in crosses 9866 × BARAS-09 (-0.16). Almost same results were given by Khayatnejad *et al.* (2010) and Khan *et al.*, (2015) and were in line with our results.

1000-grain weight (g)

Line 9870 showed the highest GCA effects (Table 2) with a value of 4.24 followed by 9865 with 3.05. Four female parents out of six and two male parent out of three revealed negative GCA effects for 1000-grain weight. Among crosses, the cross 9495 × AAS-11 had maximum SCA effects (4.75) followed by cross 9866 × Galaxy-13 (3.97). The negative SCA effects were found in 8 crosses out of total 18 (Table 3). Collinearity of our results was found with those of Masood and Kronstad (2000), and Dhadhal *et al.* (2008).

Grain yield per plant (g)

GYPP is the ultimate objective which we want to improve. So, positive GCA (Table 2) effects contribute towards achieving our goal. The negative SCA effects were observed for 9868 × AAS-11 (-1.57). The negative SCA effects as shown in Table 3 were observed in 10 out of 18 crosses. cross 9869 × AAS-11 proved to be the best for GYPP among other crosses. The above mentioned results were in accordance with the findings of Khayatnejad *et al.*, (2010) and Lohithaswa *et al.* (2013) for GYPP.

Gene action

If GCA variances are higher than that of SCA then additive genes are involved and selection will be useful in the earlier generations. If SCA variances are higher than that of GCA then non-additive genes are controlling the character and hybrid breeding may be suggested. The GCA to SCA ratio (Table 4) suggested that there was an involvement of non-additive type gene action in the inheritance of most of the traits like PH, FLA, TPP, DM, GWPS, 1000-GW and GYPP. In this case hybrid production program may be suggested and it will be more useful. The traits like DH, SL, GPS and SPS were governed by additive-type gene action, therefore, selection will be useful in early segregating generation. These traits have also been observed by Istipliler *et al.* (2015), Ashraf *et al.* (2015). Additive gene action according to the results for the traits i.e. DH, SL, GPS and SPS have been reported earlier in literature by Khayatnejad *et al.*, (2010) and Lohithaswa *et al.* (2013). While, equal contribution of additive as well as non-additive type gene action was also reported by Kashif and Khan (2008), and Srivastava *et al.* (2012) in the inheritance of these characters under study.

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References

Anonymous. (2015). Economic Survey of Pakistan. Finance Division, Government of Pakistan, Islamabad.

Ahmed, H.G.M.D., A.S. Khan, M.S. Sadam, M.H. Yasir, S. Zahid, M. Benish and A. Khan. (2015a). Designate the gene dose for yield related indices in spring wheat. *Int. J. of Bio*. 6(2):396-401.

Ahmed, H.G.M.D., M.S. Saddam, A. Khan, A. Fatima, S. Saleem, M. Hassan, S. Zahid and M. Benish. (2015b). Genetic mechanisms of yield related morphological markers response to increase grain yield in different environment of hexaploid wheat. *J. Bio. Env. Sci*. 6(3):158-166

Ashraf, S., I. Khaliq, S. Malook, S.A. Qasrani, S. Jabeen, R. Faridi, H.M. Ahamed, M.N. Yousaf and A. Raza. (2015). Genetics of yield components for drought tolerant wheat (*Triticum aestivum* L.) genotypes. *Int. J. Biosci*. 6(12):21-34.

Aslam, M., M.A. Maqbool and R. Cengiz. (2015a). 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., Q. Sohail, M.A. Maqbool, Q.U. Zaman and Z. Ahmed. (2015c). 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.

Breiman, A. and D. Graur. (1995). Wheat evaluation. *Israel J. Plant Sci*. 43: 58-95.

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.

Fellahi, Z.E.A., A. Hannachi, H. Bouzerzour, and A. Boutekrabt. (2013). Line × Tester Mating Design Analysis for Grain Yield and Yield Related Traits in Bread Wheat (Triticum aestivum L.). *Int. J. Agron*. 1:1-9

Hammad, G., M. Kashif, M. Munawar, U. Ijaz, M.M. Raza, M. Saleem and Abdullah. (2013). Genetic analysis of quantitative yield related traits in spring wheat (*Triticum aestivum* L.). *Am. Euras. J. Agri. Environ. Sci*. 13(9): 1239-1245.

Istipliler, D., E. Elker, F. Aykuttonk, G. Civi and M. Tosun. (2015). Line × tester analysis and estimating combining abilities for yield and some yield components in bread wheat. *Turk. J. Field Crops* 20: 72-77.

Kashif, M. and A.S. Khan. (2008). Combining ability studies for some yield contributing traits of bread wheat under normal and late sowing conditions. *Pakistan J. Agri. Sci*. 45(1):44-49.

Kempthorne, O. (1957). An introduction to genetic statistics. John Willey and Sons, New York, USA: 458-471.

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.

Khan, A., I. Khaliq, M.S. Saddam, H.G.M.D. Ahmed, S.A. Zafar, W. Aslam and D. Muhammad. (2015). Estimation of genetic mechanism of stomatal traits influencing grain yield in hexaploid wheat (*Triticum aestivum* L.). *Int. J. Biosci*. 6(6): 72-77.

Kruvadi, S. (1991). Diallel analysis and heterosis for yield and associated characters in durum wheat under upland condition. *Turialba Pibl.* 41(3):335-338.

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*.

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. (2015a). 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. (2015b). Drought tolerance indices based evaluation of chickpea advanced lines under different water treatments. *Res. Crops*. 16 (2): 336-344.

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.

Muller, J. (1991). Determining of leaf surface area by means of linear measurements in wheat and triticale (brief report). *Archivefuchtungsforshung*. 21(2):121-123.

Raj, P. and V.S. Kandalkar. (2013). Combining ability and heterosis analysis for grain yield and its components in wheat. *J. Wheat Res*. 5(1):45-49.

Rashid, M., A.A. Cheema and M. Ashraf. (2007). Line × tester analysis in basmati rice. *Pakistan J. Bot*. 39(6):2035-2042.

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.

Steel, R.G.D., J.H. Torrie and D.A. Dickey. (1997). Principles and Procedures of Statistics: A biometrical approach (3rd Ed.). McGraw Hill, New York.

Table 1. Mean square values for various yield related traits in line × tester analysis

Source of variation	Df	Plant height (cm)	Flag leaf area (cm^2)	No. of tillers per plant	Days to heading	Days to maturity	Spike length (cm)	No. of spikelets per spike	No. of grains per spike	Grain weight per spike (g)	1000-grain weight (g)	Grain yield per plant (g)
Replications	2	11.13^{ns}	7.66^{ns}	0.32^{ns}	2.26^{ns}	5.86^{ns}	0.94^{ns}	0.13^{ns}	2.23^{ns}	0.03^{ns}	4.08^{ns}	4.49*
Treatments	26	48.89*	55.31*	8.37*	26.55*	27.38*	7.02*	9.97*	61.29*	0.35*	41.44*	25.37*
Parents	8	99.32*	37.09^{ns}	6.12*	16.54*	12.95*	7.55*	5.28*	27.08*	0.19^{ns}	25.29*	21.72*
P vs C	17	24.85*	60.78*	5.19*	24.65*	14.16*	2.56*	9.67*	40.22*	0.21*	50.43*	10.00*
Crosses	1	54.12*	107.98*	80.50*	138.89*	367.51*	78.72**	52.36*	693.16*	4.09**	17.74*	315.73*
Lines	5	14.79^{ns}	84.60^{ns}	11.09*	73.27*	28.22*	5.64*	19.37*	101.21**	0.54*	91.34*	23.22*
Testers	2	107.57*	105.43*	6.97*	1.24^{ns}	10.06^{ns}	4.71*	25.69*	32.03*	0.02^{ns}	11.55^{ns}	3.76*
Lines × Testers	10	13.33**	39.94^{ns}	1.88*	5.02^{ns}	7.94*	0.59^{ns}	1.62^{ns}	11.37^{ns}	0.08^{ns}	37.75*	4.64^{ns}
Error	52	4.73	24.51	0.69	4.22	3.54	0.55	1.40	9.21	0.09	4.13	3.94

* = Significant at 0.05 probability level ** = Highly significant at 0.01 probability level ns= Non-Significant

Table 2. Estimation of general combining Ability (GCA) effects for yield related traits in wheat

Parents	Plant height (cm)	Flag leaf area (cm^2)	Days to heading	Days to maturity	No. of tillers per plant	Spike length (cm)	No. of spikelets per spike	No. of grains per spike	Grain weight per spike (g)	1000-grain weight (g)	Grain yield per plant (g)
Lines (females)											
9865	0.28	2.54	1.81481	0.56	1.755	1.09	1.86	3.44	0.34	3.0592	1.785852
9866	-0.19	-3.52	-1.6296	-1.22	-0.83333	-0.83	-1.00	-3.24	0.02	-4.144	-2.10713
9495	-1.50	-1.37805	-1.2963	-0.89	-0.1222	-0.42	0.33	-0.34	0.00	-0.58197	-0.84594
9868	-0.91	3.193124	-1.9629	-0.44	-0.27778	-0.15	-1.74	-1.34	-0.14	-0.17645	-0.74894
9869	2.24	-3.21428	-1.9629	-1.33	-1.3	-0.56	-0.96	-3.20	-0.37	-2.40446	-0.08081
9870	0.08	2.376	5.03703	3.33	0.7777	0.87	1.50	4.66	0.16	4.248657	1.996963
S.E (GCA for lines)	0.73	1.6502	0.6848	0.63	0.2765	0.25	0.39	1.01	0.10	0.677	0.661
Testers (males)											
Galaxy-13	0.83	2.793868	0.09259	0.61	0.716667	0.11	1.38	0.15	-0.03	0.826602	0.072028
BARS-2009	-2.75	-1.45231	-0.2963	0.22	-0.31667	0.45	-0.60	1.25	0.03	-0.05399	0.416737
AAS-11	1.92	-1.34156	0.20370	-0.83	-0.4	-0.56	-0.77	-1.40	0.00	-0.77262	-0.48876
S.E (GCA for testers)	0.51	1.166882	0.48424	0.44	0.19554	0.17	0.28	0.72	0.07	0.479101	0.467878

Table 3. Estimation of specific combining Ability (SCA) effects for yield related traits in wheat

Crosses	Plant height (cm)	Flag leaf area (cm^2)	Days to heading	Days to maturity	Number of tillers per plant	Spike length (cm)	Number of spikelets per spike	No. of grains per spike	Grain weight per spike (g)	1000-grain weight (g)	Grain yield per plant (g)
9865 × Galaxy-13	-1.66	-0.18734	1.018519	2.28	-0.32778	0.44	-0.15	2.19	0.01	-0.36271	0.439083
9865 × BARS-09	0.74	1.24122	-1.92593	-0.33	0.538889	-0.45	0.49	-1.92	-0.02	1.517882	-0.17229
9865 × AAS-11	0.91	-1.05388	0.907407	-1.94	-0.21111	0.01	-0.34	-0.26	0.00	-1.15518	-0.26679
9866 × Galaxy-13	-2.89	-4.75475	-1.53704	-0.28	-0.00556	-0.14	-0.89	-0.50	0.13	3.972817	0.065394
9866 × BARS-09	0.67	2.083048	0.851852	0.78	-0.57222	0.52	0.02	2.29	-0.16	0.120539	-1.13466
9866 × AAS-11	2.23	2.671699	0.685185	-0.50	0.577778	-0.38	0.86	-1.79	0.03	-4.09336	1.069267
9495 × Galaxy-13	1.51	-0.92785	-1.2037	-0.28	-1.25	-0.55	0.05	-1.50	-0.07	0.290873	-1.11207
9495 × BARS-09	1.14	-0.3062	1.185185	0.11	0.783333	-0.15	-0.58	0.86	0.13	-5.04355	1.459497
9495 × AAS-11	-2.65	1.234051	0.018519	0.17	0.466667	0.71	0.53	0.65	-0.06	4.75268	-0.34742
9868 × Galaxy-13	2.66	7.167643	0.12963	-0.72	1.038889	0.11	0.45	0.03	0.09	-0.49612	1.373874
9868 × BARS-09	-1.69	-3.47071	0.518519	-1.00	-0.19444	-0.26	-0.11	-0.54	0.03	1.115897	0.203152
9868 × AAS-11	-0.97	-3.69693	-0.64815	1.72	-0.84444	0.15	-0.34	0.51	-0.13	-0.61977	-1.57703
9869 × Galaxy-13	1.34	-2.61495	0.462963	-2.17	0.327778	-0.01	0.00	-2.17	-0.30	-4.8527	-1.29425
9869 × BARS-09	-1.37	0.222562	0.518519	0.22	0.094444	0.15	0.91	-0.21	0.09	2.294138	-0.30563
9869 × AAS-11	0.03	2.392388	-0.98148	1.94	-0.42222	-0.14	-0.91	2.38	0.21	2.558565	1.599876
9870 × Galaxy-13	-0.96	1.317243	1.12963	1.17	0.216667	0.16	0.55	1.96	0.13	1.447842	0.527972
9870 × BARS-09	0.51	0.230085	-1.14815	0.22	-0.65	0.19	-0.74	-0.48	-0.07	-0.0049	-0.05007
9870 × AAS-11	0.45	-1.54733	0.018519	-1.39	0.433333	-0.34	0.20	-1.49	-0.06	-1.44294	-0.4779
S.E (SCA effects)	1.26	2.858265	1.186142	1.09	0.478972	0.43	0.68	1.75	0.17	1.173552	1.146062

Table 4. Estimation of GCA, SCA, additive and dominance variance

	Plant height (cm)	Flag leaf area (cm^2)	Days to heading	Days to maturity	No. of tillers per plant	Spike length (cm)	No. of spikelets per spike	No. of grains per spike	Grain weight per spike (g)	1000-grain weight (g)	Grain yield per plant (g)
Cov. H. S (lines)	0.16	4.96	7.58	2.25	1.02	0.56	1.97	9.98	0.051461	5.95	2.06
Cov. H. S (testers)	5.24	3.64	-0.21	0.12	0.28	0.23	1.34	1.15	-0.00344	-1.46	-0.05
Cov. H. S (average)	0.35	0.62	0.59	0.19	0.10	0.06	0.24	0.87	0.003866	0.38	0.16
Cov. F. S	18.68	26.76	16.26	6.75	3.47	1.92	8.34	25.97	0.0978	19.95	4.61
Variance of GCA	0.35	0.62	0.59	0.19	0.10	0.06	0.24	0.87	0.003866	0.38	0.16
Variance of SCA	2.87	5.14	0.27	1.47	0.40	0.01	0.07	0.72	-0.00478	11.21	0.23
Additive variance	0.70	1.24	1.18	0.38	0.2	0.12	0.48	1.74	0.007732	0.76	0.32
Dominance variance	2.87	5.14	0.27	1.47	0.40	0.01	0.07	0.72	-0.00478	11.21	0.23
σ^2 GCA/ σ^2 SCA	0.121951	0.120623	2.185185	0.129252	0.25	6	3.428571	1.208333	-0.80879	0.033898	0.695652