Genetic Analysis of Diallel Crosses of Chickpea Genotypes (*Cicer arietinum L.*) for Combining Ability and Gene Action estimation

ABSTRACT

This study examined the combining ability (GCA and SCA) and genetic variability in chickpea across 56 treatments, including 10 parental lines, 45 F1 hybrids, and a check variety, developed using a diallel mating design. Conducted at the Research Farm of Baba Raghav Das P. G. College, Deoria during the 2019-2020 and 2021-2022 rabi seasons, the experiment employed a randomized block design (RBD) with three replications. Analysis of Variance (ANOVA) revealed significant GCA and SCA contributions for traits like Days to 50% Flowering, Days to Maturity, and Plant Height, indicating a blend of additive and non-additive genetic effects. GCA analysis identified ICC 1205 and GNG-1958 as promising parents for early flowering and plant architecture, while SCA results highlighted hybrids such as JG 24 × IPC 18-131 for high pod production and yield potential. These insights aid breeders in optimizing chickpea traits for improved productivity, balancing genetic components to meet diverse agricultural objectives.

Keywords: Chickpea, General Combining ability, Specific Combining ability, DiallelMating design

1. INTRODUCTION

Chickpeas is commonly known as "Bengal Grams or chickpeas", are one of the most important food grain legumes. Chickpea seeds are a major source of protein, carbohydrates, minerals and vitamins for vegetarians (Jukanti*et al.*, 2012; William and Singh 1987). Combining ability research aids in discovering usable parental lines and desired specific cross combinations, which may then be used to produce better varieties. Such research is critical in determining the best breeding and selection techniques for crop development. The diallel analysis has proved very effective method to screen the large number of germplasms. Diallel mating design was suggested by Jinks and Hayman (1954). In this mating design each parent has equal chances to mate with different parent. General and specific combining ability refers to the average and specific performance of a parent in crosses with another parents. This mating design gives information about the GCA, SCA variance and effect. In addition to this it also provides information about the Additive (D) and Dominance (H) genetic variance component. This method is generally used for selection of advantageous parents for hybridization in plant breeding.

2. MATERIALS AND METHODS

The experimental materials for this study consisted of 56 wheat treatments, including 45 F1 hybrids, 14 parental lines and one standard variety used as a check. The parental lines includedICC 1205, GOKCE, BGD-209, GNG-1958, HC-5, 1PC-71, IPC 18-131, JG-24, JG-14 and BGD-72. The experimental hybrids were developed using a diallel mating design during the 2019-2020 rabi season at the Research Farm of BRD PG College, Deoria (Affiliated with DDU Gorakhpur University, Uttar Pradesh These hybrids, along with their 10 parental lines and the standard check variety HD-3086, were evaluated using randomized block design (RBD) with three replications during rabi seasons in 2021-2022.

3. STATISTICAL ANALYSIS

The analysis of variance (ANOVA) was conducted following Hayman (1954), and combining ability for the diallel design was analyzed using Griffing numerical approach (1956). Data was processed in R using the Agricole package (Version 1.3-5). Combining ability for each trait was calculated based on Hayes *et al.* (1955).

4. RESULTS AND DISCUSSION

4.1 Analysis of Variance (ANOVA)

The analysis of variance for combining ability in chickpea, following Griffing's (1956b) Method-2 and Model-I, revealed significant contributions from both General Combining Ability (GCA, additive effects) and Specific Combining Ability (SCA, non-additive effects) for most traits. For Days to 50% Flowering (DFF) and Days to 50% Podding (DFP), both GCA and SCA were highly significant, indicating that both genetic components are crucial. Days to Maturity (DTM) also showed significant variance, with GCA (28.90**) stronger than SCA (12.82**), suggesting a dominant additive effect. Plant Height (PHT) had strong variances for both GCA (65.85**) and SCA (84.42**).

While Total Pods per Plant (PP) had higher SCA (119.06**) than GCA (60.39**), indicating stronger non-additive influence, traits like Total Seeds per Pod (SP) and Swelling Index (SI) showed minimal genetic control with non-significant variances. Biological Yield per Plant (BYPP) and Harvest Index (HI) exhibited meaningful contributions from both GCA and SCA, though non-additive effects were more prominent for BYPP. Similarly, Seed Germination (SG), Pollen Germination (PG), and Chlorophyll Concentration (CC) all showed significant variance from both components, underscoring their genetic complexity.

Seed traits varied, with Seed Hydration Capacity (SHC) displaying stronger non-additive effects (SCA 0.47**) despite non-significant GCA. Meanwhile, Seed Index (SI) and Seed Protein

Content (SP) showed significant contributions from both genetic components, suggesting their importance for selective breeding. These findings highlight the need for both parental selection (GCA) and hybrid combinations (SCA) to optimize key traits like yield, maturity, and physiological performance. The study provides essential insights for breeders aiming to enhance chickpea production through targeted breeding strategies that balance additive and non-additive effects.

4.4. Combining ability effects

The general and specific combining ability (GCA and SCA) effects play a crucial role in evaluating chickpea traits, helping breeders identify superior parental lines and hybrids. For Days to 50% Flowering, early flowering is desirable, and parents like ICC 1205 and GNG-1958 exhibited significant negative GCA effects, while hybrids such as ICC 1205 × GOKCE and JG 24 × IPC 18-131 showed significant negative SCA values, making them good combiners. Similarly, for Days to 50% Podding, parents like GNG-1958 and JG-24 demonstrated non-significant negative GCA effects, while hybrids such as IPC 18-131 × HC 5 and JG 24 × IPC 18-131 exhibited significant negative SCA values, suggesting their suitability for early podding.

In Days to Maturity, IPC-71 exhibited significant negative GCA values, while crosses like JG 14 × IPC 71 displayed favorable negative SCA values, indicating shorter maturity periods. Plant Height showed desirable traits in parents like BGD-72 with significant negative GCA values, while hybrids such as IPC 71 × BGD 209 and BGD 72 × HC 5 recorded significant negative SCA values, highlighting their potential for reduced plant height. For Primary Branches per Plant, only two parents, GOKCE and IPC 18-131, exhibited positive significant GCA effects. Hybrids such as JG 24 × GOKCE showed significant positive SCA values, indicating good combiners for primary branching.

In the case of Secondary Branches per Plant, parents like GOKCE and IPC 18-131 recorded significant positive GCA values, with crosses such as JG 14 × ICC 1205 showing significant positive SCA effects, suggesting promising combinations. Total Pods per Plant was positively influenced by parents GNG-1958 and JG-24, with crosses such as JG 14 × ICC 1205 and JG 24 × IPC 18-131 exhibiting high SCA values, indicating superior pod production. For Total Seeds per Pod, four parents, including DBW-14 and CSW-18, exhibited significant GCA effects, and hybrids like JG 24 × GOKCE and IPC 18-131 × BGD 209 showed positive SCA values, demonstrating their value for seed production.

Seed Index revealed significant GCA values in parents like GOKCE and JG-24, with promising hybrids such as GNG 1958 × ICC 1205 showing strong SCA effects. For Biological Yield per Plant, HC-5 exhibited significant GCA effects, and hybrids such as ICC 1205 × GOKCE recorded positive SCA values, indicating good combiners for yield improvement. Harvest Index was positively influenced by parents like IPC 18-131, with crosses like JG 14 × ICC 1205 showing excellent SCA effects.

Seed Germination and Pollen Germination traits showed strong positive GCA effects in parents IPC 18-131 and JG-24, with hybrids like HC 5 × GOKCE demonstrating high SCA values. Chlorophyll Concentration exhibited favorable GCA values in GOKCE and IPC 18-131, with hybrids like JG 24 × GOKCE showing superior SCA effects. Seed Volume and Seed Hydration Capacity had positive GCA effects in parents IPC 18-131 and JG-24, with crosses like JG 24 × ICC 1205 showing promising SCA values. Seed Hydration Index also revealed good combiners in hybrids such as HC 5 × GNG 1958. Lastly, Seed Protein Content and Seed Yield per Plant showed promising GCA values in ICC 1205 and JG-24, with hybrids like JG 14 × IPC

18-131 and IPC 71 × HC 5 demonstrating significant SCA effects, making them ideal for enhancing protein content and overall yield. This detailed evaluation of GCA and SCA effects provides essential insights for chickpea breeding programs, guiding the selection of optimal parental lines and hybrid combinations.

CONCLUSION

In conclusion, this study highlights the importance of both general and specific combining ability in chickpea breeding, as both additive and non-additive genetic effects significantly impact key agronomic traits. Traits like Days to Flowering, Maturity, and Plant Height displayed valuable GCA and SCA variances, underscoring the relevance of parent selection and hybridization for early maturation and plant structure optimization. High SCA values for yield-related traits, such as Total Pods and Seed Protein Content, reveal potential hybrids that can enhance productivity. This comprehensive analysis provides a framework for breeders to strategically combine parental lines and hybrids, optimizing both genetic components to improve chickpea yield, adaptability, and quality in targeted breeding programs.

Ethical issues: None.

REFERENCES

Agricolae: Statistical Procedures for Agricultural Research. [https:// cran.r-project.org/web/packages/agricolae/index.html] [Accessed November 03, 2023]

Begna, T. (2021). Combining ability and heterosis in plant improvement. *Open Journal of Plant Science*, *6*(1), 108-117.

de Mendiburu, F. (2021). agricolae tutorial (Version 1.3-5). Universidad Nacional Agraria: La Molina, Peru.

Edae, E. A., Byrne, P. F., Haley, S. D., Lopes, M. S. and Reynolds, M. P. (2014). Genome-wide association mapping of yield and yield components of spring wheat under contrasting moisture regimes. *Theoretical and applied genetics*, *127*, 791-807.

Fasahat, P., Rajabi, A., Rad, J. M. and Derera, J. J. B. B. I. J. (2016). Principles and utilization of combining ability in plant breeding. *Biometrics & Biostatistics International Journal*, 4(1), 1-24.

Hayman, B.I. (1954). The analysis of variance of diallel tables. *Biometrics*, *10*(2), 235-244.

Hays, H.K., Immer, F.R. and Smith D.C. (1955). Methods of plant Breeding. *Mc Graw Hill Book Co. Inc*., New York, 432.

Iannucci, A. and Codianni, P. (2019). Phenotypic parent selection within a khorasan wheat collection and genetic variation in advanced breeding lines derived by hybridization with durum wheat. *Frontiers in plant science*, *10*, 1460.

Kempthorne, O. (1957). An Introduction to Genetic Statistics, New York, *John Wiley and Sons*, 1st Edn; c. p. 456-471.

Khan, K., Rahman, M. S.; Alam, M. R. and Paul, N. R. (2019). Genetic variability, heritability, and genetic advance in wheat (*Triticum aestivum* L.). *Bangladesh Journal of Agricultural Research*, 33(3), 373-379.

Kumar, S.; Singh, S.K.; Mishra, M.N. and Jaiswal, H.K. (2017). Combining ability analysis for grain yield and its component traits in bread wheat (*Triticum aestivum* L.). *Journal of Wheat Research*, 9(2), 144-151.

Liu, Z., Jiang, J., Ren, A., Xu, X., Zhang, H., Zhao, T. and Yang, H. (2021). Heterosis and combining ability analysis of fruit yield, early maturity, and quality in tomato. *Agronomy*, *11*(4), 807.

Maan, D.S. and Yadav, S. (2022). Combining ability analysis in bread wheat (*Triticum aestivum* L.). *Crop Improvement*, 37(1), 41-45.

Singh, R. K., Prasad, A., Muthamilarasan, M., Parida, S. K. and Prasad, M. (2020). Breeding and biotechnological interventions for trait improvement: status and prospects. *Planta*, *252*, 1-18.

Singh, S. K., Kumar, S., Kashyap, P. L., Sendhil, R. and Gupta, O. P. (2023). Wheat. In Trajectory of 75 years of Indian agriculture after independence. *Springer Nature Singapore*., 11 137-162

Table: 1 Analysis of variance for yield and its contributing characters

Characters	Replications	Treatments	Parents	Hybrids	Parents vs Hybrids	Error
d.f.	*2*	*55*	*10*	*44*	*1*	*108*
Days to 50% flowering (DFF)	206.891	94.83**	155.885	83.51*	43.394	20.477
Days to 50% poding (DFP)	76.097	41.22**	47.037	40.71**	11.399	35.893
Days to maturity (DTM)	17.188	46.50**	15.407	53.84**	3.234	24.842
Plant height (PHT)	230.699	243.98**	116.531	242.87**	1440.080	33.866
Primary branches per plant (PBP)	3.256	2.31**	1.904	2.36**	3.755	0.464
Secondary branches per plant (SBP)	40.652	21.28**	10.413	11.18**	563.278	1.956
Total pods per plant (PP)	693.847	327.85**	15.917	229.04**	7482.912	53.432
Total seeds per pods (SP)	1.052	0.041**	0.043	0.03**	0.238	0.034
Seed Index (SI)	10.324	27.59**	19.607	29.11**	32.461	3.110
Biological yield /Plant (BYPP)	1020.736	73.85**	21.707	68.86**	763.040	50.854
Harvest Index (HI)	193.004	171.56**	61.643	176.60**	939.136	35.181
Seed germination (SG)	27.626	60.90**	285.052	7.95**	373.620	60.545
Pollen Germination (PG)	187.596	64.57**	13.041	74.96**	71.060	9.448
Chlorophyl concentration (CC)	256.703	70.66**	23.417	76.95**	219.058	19.898
Seed Volume (SV)	1.539	5.51**	1.706	5.88**	23.663	1.565
Seed Hydration capacity per seed (SHC)	1.330	1.35**	0.000	1.65**	0.337	1.336
Seed Hydration index (SHI)	21.201	20.44**	0.030	24.98**	4.689	20.547
Swelling index (SI)	0.000	0.06**	0.003	0.06**	0.014	0.001
Seed protein content (SP)	0.450	13.87**	7.463	14.83**	29.399	2.048
Seed yield /Plant (SYP)	23.451	37.29**	12.007	29.79**	594.792	2.930

Table 2. Estimates of general combining ability (gca) effects of parents for twenty characters in chickpea

Parents	DFF	DFP	DTM	PHT	PBP	SBP	PP	SP	SI	BYPP
ICC 1205	-1.689*	-0.094	1.856*	-4.617	-0.103	-0.838*	-2.06	-0.061*	-0.146	0.147
GOKCE	1.450*	1.85	2.078*	-0.425	0.511*	0.773*	2.064	0.017	1.640*	-1.106
BGD-209	1.617*	2.128*	-0.2	-1.067	-0.145	-0.375	-0.742	0.012	-0.927*	1.052
GNG-1958	-3.356*	-1.289	0.272	0.864	-0.026	-0.036	2.294*	0.042	0.121	0.255
HC-5	1.839*	0.572	-1.033	1.908*	0.124	-0.786*	-1.787	-0.002	-1.299*	2.405*
1PC-71	-0.467	-1.233	-2.700*	0.294	-0.220*	-0.810*	-2.820*	0.006	-1.207*	-0.156
IPC 18-131	0.283	0.211	1.522	-0.319	0.369*	1.395*	1.922	0.02	-0.088	-1.084
JG-24	0.839	-1.261	0.494	2.161*	-0.042	0.912*	3.432*	0.012	1.534*	-0.487
JG-14	0.561	-0.872	-0.783	3.497*	-0.142	-0.063	-0.23	-0.005	0.459	-1.312
BGD-72	-1.078	-0.011	-1.506	-2.297*	-0.326	-0.172	-2.072	-0.041	-0.088	0.286
SE (gi)	0.716	0.947	0.788	0.920	0.108	0.221	1.156	0.029	0.279	1.128
SE(gi – gj)	1.067	1.412	1.175	1.372	0.161	0.330	1.723	0.044	0.416	1.681

Continue…

Parents	HI	SG	PG	CC	SV	SHC	HYI	SI	SP	SYP
ICC 1205	-0.941	0.091	0.866	-0.513	-0.354	-0.086	-0.335	-0.006	0.583*	-0.535
GOKCE	0.064	0.932	1.418*	1.726*	0.171	0.331	1.248	0.001	0.637*	-0.516
BGD-209	-3.443*	0.029	-3.240*	-1.874*	-0.215	-0.087	-0.329	-0.008	-1.570*	-1.613*
GNG-1958	1.805	0.993	1.285*	1.553*	0.046	-0.081	-0.316	0.016*	0.419	1.095*
HC-5	-2.191*	-4.971*	-0.573	-0.658	-0.548*	-0.087	-0.308	-0.012*	-0.939*	-0.389
1PC-71	-3.347*	0.335	0.843	-0.499	-0.718*	-0.086	-0.306	-0.015*	0.332	-1.602*
IPC 18-131	2.111*	1.029	0.779	1.834*	0.543*	-0.076	-0.274	0.023*	0.707*	0.781*
JG-24	3.089*	0.599	0.518	-0.763	0.707*	0.338	1.292	0.023*	0.203	1.574*
JG-14	2.373*	0.682	-0.796	-0.149	0.543*	-0.085	-0.354	-0.021*	0.423	0.873*
BGD-72	0.48	0.279	-1.101*	-0.655	-0.176	-0.082	-0.318	0	-0.795*	0.333
SE (gi)	0.938	1.230	0.486	0.705	0.198	0.183	0.717	0.004	0.226	0.271
SE(gi – gj)	1.398	1.834	0.724	1.051	0.295	0.272	1.068	0.006	0.337	0.403

Table 3. Estimates of specific combining ability (sca) effects of crosses for twenty characters in chickpea

Crosses	DFF	DFP	DTM	PHT	PBP	SBP	PP	SPP	SI	BYPP
ICC 1205 X GOKCE	-7.14*	-3.31	-4.30	-14.22*	-0.31	-0.36	0.81*	0.51*	0.89*	4.23*
BGD 209 X GOKCE	-4.31*	-1.59	-3.69	12.19	0.88	-1.58	-9.24*	0.10	1.09*	1.35
GNG 1958 X GOKCE	0.32	2.49	-0.50	4.06	-0.41	0.48	8.38**	-0.04	3.25	1.21
HC 5 X GOKCE	4.13	3.97	-3.53	-2.02*	0.21	-0.30	-4.01	-0.19	-1.23	8.79*
IPC 71 X GOKCE	-2.23	-0.90	2.81	-3.97*	1.65**	0.56	1.39	0.00	1.98	4.52
IPC 18-131 X GOKCE	9.35	1.99	4.59	11.61	-0.34	-1.35	-1.07	-0.01	1.06	2.95
JG 24 X GOKCE	7.12*	5.47	0.95	2.69	1.37**	4.43	18.21**	0.19*	3.00	-7.82
JG 14 X GOKCE	-6.26	-0.59	3.23	0.86	0.27	0.11	-3.19	0.05	-0.79	2.58
BGD 72 X GOKCE	5.04*	2.55	8.61	1.75	0.02	0.98	6.08**	0.01	-2.08	-0.85
BGD 209 X ICC 1205	-1.79	0.80	-0.25	14.26*	-0.17	1.20*	1.23	-0.05	0.48	1.53
GNG 1958 X ICC 1205	4.52	0.55	1.28	4.53	0.78	0.70	15.70	0.08*	2.56*	-7.67
HC 5 X ICC 1205	2.99	3.69	2.92	-1.98	-0.81	1.99	2.81	0.03	-1.15	-3.99
IPC 71 X ICC 1205	1.96	1.16	-1.75	2.63	0.34	0.18	-3.66	0.06	-5.31	-0.79
IPC 18-131 X ICC 1205	7.88	2.72	2.36	2.05	-0.12	-2.29	-8.57	-0.09	1.37	13.20
JG 24 X ICC 1205	0.32	0.85	4.73	1.23	0.39	3.02*	18.12**	0.28	2.84*	-3.66
JG 14 X ICC 1205	11.26*	6.13	3.00	5.76	1.65**	3.06*	20.42**	0.10	2.46	-6.60
BGD 72 X ICC 1205	1.91	-2.06	3.73	4.63	0.44	-1.56	-9.34	0.14	-2.16	8.36*
GNG 1958 X BGD 209	14.68*	7.27	4.56	-4.76	-0.20	0.48	-2.70	0.45*	-0.27	-2.16
HC 5 X BGD 209	-3.17*	-1.26	-1.80	12.36	0.11	1.70	1.38	-0.10	0.62	3.95
IPC 71 X BGD 209	-2.21	-1.12	-2.14	-15.02*	0.46	1.92	4.58	0.13	0.32	-0.75
IPC 18-131 X BGD 209	-1.96	-4.90	-1.36	-7.47*	-0.50	0.42	3.04	0.08*	-2.06	4.24
JG 24 X BGD 209	-0.18	-0.42	-3.33	-5.19*	0.11	1.07	2.73	0.06	1.52	0.41
JG 14 X BGD 209	0.43	0.19	0.28	-8.42*	-0.42	1.68	8.79	0.01	0.82	-0.86
BGD 72 X BGD 209	5.74	1.33	3.67	18.20	0.43	2.05	10.63*	0.14	-2.26	-3.33
HC 5 X GNG 1958	1.13	-0.84	-5.28	-0.80	0.16	1.83	9.65	0.04	-1.40	-0.38
IPC 71 X GNG 1958	2.43	2.63	0.06	6.35	0.67	3.12	3.01	0.06	0.18	6.31
IPC 18-131 X GNG 1958	0.68	-3.48	-0.83	10.65**	0.82	3.58	15.30*	0.22	4.96	-1.56
JG 24 X GNG 1958	-7.21	-6.34*	-0.80	5.25	-0.14	-0.47	-8.67	0.03	-4.93	10.77*
JG 14 X GNG 1958	-0.93	-2.73	-1.86	-0.49	-0.21	0.67	-2.38	-0.09	-4.12	4.00
BGD 72 X GNG 1958	0.38	-2.92	-0.80	-12.13*	0.51	-0.09	1.63	-0.09	-3.71	2.60
IPC 71 X HC 5	-3.76	-1.90	-4.97	9.57	0.29	0.80	0.66	-0.06	2.80	2.13
IPC 18-131 X HC 5	-10.84	-6.67*	4.14	1.51	-0.27	0.26	7.02*	-0.07	4.77*	3.32*
JG 24 X HC 5	2.93	3.13	1.17	-11.90*	-0.22	-1.72	-1.39	-0.03	-4.05	3.92*
JG 14 X HC 5	0.88	4.08	0.11	14.33	0.98	0.69	3.11	-0.05	-4.71	1.05
BGD 72 X HC 5	-0.82	-2.11*	-2.16	-11.90*	0.46	1.66	-4.55	0.06	2.84	-4.35

IPC 18-131 X IPC 71	0.80	1.47	-1.53	-13.83*	-1.42	-1.68	-0.78	-0.01	-2.28	-1.05
JG 24 X IPC 71	-2.09	1.27	1.17	3.08	-0.61	0.91	-1.86	-0.21	-0.61	-0.88
JG 14 X IPC 71	0.52	2.55	-4.22*	-2.32**	-0.61	1.48	3.14	0.05	2.87*	-0.02
BGD 72 X IPC 71	-5.17*	-2.31*	-0.83	15.91	-1.09	0.59	9.38	-0.02	2.58*	1.28
JG 24 X IPC 18-131	-5.84*	-3.50*	-3.72*	11.86	1.57	4.27	15.76*	0.08	2.84*	-1.52
JG 14 X IPC 18-131	0.77	4.44	1.56	5.32*	1.00	3.34	10.22*	0.06	2.28	-1.83
BGD 72 X IPC 18-131	0.41	1.24	-3.72	-2.91	-1.52	-0.18	-1.43	-0.13	-4.80	-5.79
JG 14 X JG 24	-6.12	-2.75*	0.59	-1.86	-1.66	-0.38	-7.48	0.07	0.70	2.94
BGD 72 X JG 24	-3.48	-3.61*	1.31	-4.06	-0.37	1.18*	5.59*	0.01	2.24	3.78
BGD 72 X JG 14	-2.21	-1.01	-6.41	5.34	-0.97	0.81	4.32	0.03	4.02	2.00
SE (Sij)	2.41	3.19	2.65	3.09	0.36	0.74	3.89	0.10	0.94	3.79
SE (Sij – Skl)	3.37	4.47	3.72	4.34	0.51	1.04	5.45	0.14	1.31	5.32
SE (Sij – Sik)	3.54	4.68	3.90	4.55	0.53	1.09	5.71	0.15	1.38	5.57

Continue….

Crosses	HI	SG	PG	CC	SV	SHC	HYI	SI	SP	SYP
ICC 1205 X GOKCE	2.72*	0.748*	-0.58	0.97*	0.01	-0.36*	-1.45*	-0.03*	0.33*	0.19*
BGD 209 X GOKCE	3.54**	-1.51	7.08*	7.56*	1.56	0.08	0.25	-0.02*	2.01*	0.54*
GNG 1958 X GOKCE	6.46**	-0.81	1.56	-3.36	0.06	0.08	0.19	0.02	-0.31	3.58*
HC 5 X GOKCE	-5.58	5.48*	1.08	-0.81	-0.94	0.10	0.44	0.09	-0.02	-0.55
IPC 71 X GOKCE	1.12	0.85	3.66*	-3.67	0.26	0.08	0.24	0.00	0.02	2.35
IPC 18-131 X GOKCE	-7.25	-1.51	-1.60	1.26	0.03	0.06	0.18	-0.02	-0.61	-2.63
JG 24 X GOKCE	8.99	3.31*	5.59*	13.32*	1.83*	-0.31	-1.23	0.04	1.51*	1.65*
JG 14 X GOKCE	-7.52	-1.17	-0.36	0.65	-1.00	0.07	0.26	0.01	-0.80	-2.85
BGD 72 X GOKCE	-2.14	-1.43	-6.39	4.25*	-0.78	0.07	0.32	-0.02	2.42	-1.36
BGD 209 X ICC 1205	1.14	-2.02	-2.47	1.83	-0.90	-0.34	-1.33	-0.01	1.77	1.83
GNG 1958 X ICC 1205	13.72	2.24*	1.07	7.60	1.30*	-0.33	-1.36	0.03	4.01*	4.01*
HC 5 X ICC 1205	5.54	5.31	-1.14	-0.82	0.73	-0.33	-1.25	0.00	-0.58	1.68*
IPC 71 X ICC 1205	-8.92*	0.67	2.78	1.39	0.87	-0.33	-1.07	-0.04	-3.53	-4.77
IPC 18-131 X ICC 1205	-13.52*	-2.68*	1.84	-5.21	-2.53	-0.35	-1.42*	0.04	-0.37	-3.33
JG 24 X ICC 1205	11.06**	2.18	4.60*	2.72	0.48	4.21*	16.45*	0.03	2.36	4.57
JG 14 X ICC 1205	13.19**	-0.17	6.75*	11.17*	2.17	-0.32	-1.32	-0.01	3.08	3.97
BGD 72 X ICC 1205	13.68*	-0.27	0.06	-4.92	0.86	-0.33	-1.24	0.08	0.10	-4.87

GNG 1958 X BGD 209	-1.26	-0.08	-3.34	3.60	-0.98	0.09	0.37	0.06	-2.62*	-1.79
HC 5 X BGD 209	-7.16	5.21*	-4.15	5.55	0.48	0.07	0.23	0.00	0.69	-2.86
IPC 71 X BGD 209	-3.52	-0.09	-11.56**	0.99	0.22	0.10	0.41	0.01	2.64	-2.32
IPC 18-131 X BGD 209	-0.18	2.22	-9.50	-5.24	-1.04	0.07	0.31	-0.01	*-1.97*	1.78
JG 24 X BGD 209	5.24*	-0.69	0.10	-2.25	1.06	-0.34	-1.40	0.04	-1.15	2.96
JG 14 X BGD 209	4.90	-2.10	8.41	-1.16	-1.04	0.07	0.23	-0.01	-0.89	1.76
BGD 72 X BGD 209	5.29*	-0.70	7.04*	-2.82	1.68	0.07	0.34	-0.03	0.85	1.54
HC 5 X GNG 1958	-4.86	4.59	4.00	0.15	-0.14	0.07	0.30*	-0.03	-1.92	-2.75
IPC 71 X GNG 1958	-1.82	-0.72	0.25	-1.07	0.23	0.08	0.33	-0.01	-1.03	1.38*
IPC 18-131 X GNG 1958	7.98	1.59	3.88	12.02*	1.70	0.07	0.12	0.04	3.36	3.95*
JG 24 X GNG 1958	-8.34	-3.65	-2.43	-2.74	-0.83	-0.37	-1.33	-0.07	0.69	-0.69
JG 14 X GNG 1958	-3.90	-0.40	-3.78	-3.02	-0.64	0.08	0.47	0.07	-1.14	-0.38
BGD 72 X GNG 1958	1.74	-1.33	0.52	-3.35	0.78	0.10	0.54	-0.04	-1.58	2.39*
IPC 71 X HC 5	7.79*	3.57*	3.43*	0.37	-0.85	0.06	0.13	0.01	0.82	5.18*
IPC 18-131 X HC 5	2.48	1.22	4.16*	-0.09	1.15*	0.07	0.11	-0.07	0.07	1.83
JG 24 X HC 5	0.78	4.31*	-3.57	-3.56	-0.04	-0.33	-1.14	-0.02	2.74*	1.68
JG 14 X HC 5	4.03	5.89*	-5.59	-1.41	0.16	0.06	0.41	-0.01	-1.15	2.74*
BGD 72 X HC 5	6.55*	5.96*	0.72	0.50	-1.39	0.08	0.23	-0.01	0.30	2.26*
IPC 18-131 X IPC 71	8.78	-3.09	-0.58	-0.12	-2.11	0.07	0.38	0.04	0.10	3.77*
JG 24 X IPC 71	1.58	1.01	2.68	-3.49	0.93	-0.34	-1.34	-0.04	0.36	0.62
JG 14 X IPC 71	1.77	-1.08	-1.67	-1.44	2.03	0.08	0.25	0.00	2.08*	0.65
BGD 72 X IPC 71	5.96*	-0.34	1.63	2.20	-0.29	0.07	0.16	0.06	-0.98	3.25*
JG 24 X IPC 18-131	7.29*	0.98	4.74*	8.51	2.07	-0.30*	-1.21	0.07	1.42*	3.46*
JG 14 X IPC 18-131	5.84*	0.23	3.39*	0.23	2.03*	0.10	0.30	-0.02	4.10*	2.50
BGD 72 X IPC 18-131	6.71*	1.29*	-5.30*	-0.13	-0.51	0.06	0.42	0.08*	1.07	1.44
JG 14 X JG 24	-0.48	-0.34	-5.68*	1.03	0.27	-0.35*	-1.45	-0.01	-1.96	0.88
BGD 72 X JG 24	-7.71*	-0.60	0.62	0.50	-0.18	-0.33	-1.39	-0.06	-0.35	-2.61*
BGD 72 X JG 14	5.23	1.31	1.94	1.85	-0.71	0.07	0.16	-0.01	-1.54	3.59
SE (Sij)	3.15	4.14	1.63	2.37	0.67	0.61	2.41	0.01	0.76	0.91
SE (Sij – Skl)	4.42	5.80	2.29	3.32	0.93	0.86	3.38	0.02	1.07	1.28
SE (Sij – Sik)	4.64	6.08	2.40	3.49	0.98	0.90	3.54	0.02	1.12	1.34