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Determination of Combining Ability in Chickpea (*Cicer arietinum* L.)

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Authors' contributions

This work was carried out in collaboration among all authors. Author NS designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors SBH and AB managed the analyses of the study. Author MZ managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

A 5×5 direct-crosses of Chickpea geneotypes (CM-98, Noor-91, Brittle-98, Punjab-2000 and Karak-1) were undertaken at Research area of the Department of Plant Breeding and Genetics, FAS&T, Bahauddin Zakariya University, Multan, Pakistan. Then Model-I and Model-II of Griffing approach (1956) of half-diallel was used for combining ability analysis. The results pertaining to menas of all traits relative to general and specific combining ability were found highly significant ($P \leq 0.01$) which evidenced presence of ample differences among studied geneotypes. However, variance showed by specific combining ability for traits like fibre content, free extract (N.F.E.), protein content, fat, ash and nitrogen content, moisture content, plant height and biomass per plant as compared to general combining ability. These results are suggestive of predominantly under the control of non-additive gene action. On the other hand, the magnitude of variance resulted from GCA was higher than from SCA for pods per plant, 100-seed weight and grain yield that showed that additive genetic effects were important for them.

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1. INTRODUCTION

Chickpea (*Cicer arietinum* L.) remained a precious legume crop supplying cheaper protein especially for poor people and is the main crop growing well in irrigated and rainfed areas in Pakistan [1]. It is oldest and widely cultivated legume crop in more than 50 countries of the world. It was related with the beginning of agriculture in the Fertile Crescent [2]. From the Mediterranean basin to the Indian Subcontinent and Southward to Ethopia and the East African highlands, chickpea production area prevailed. In Mediterranean regions, wild form of *Cicer* was found which was distinct in habitation, topographical and atmospheric conditions [3]. Being leguminous crop, it fixes nitrogen from the atmosphere that is instrumental in increasing soil fertility thereby increasing farmers premiums.

India, Pakistan, Mexico, Turkey, Ethiopia and Burma are major countries which are producing chickpea, however, production remained lower in Pakistan that is unable to meet consumer demand as compared to other chickpea producing countries [4]. Chickpea is an important pulse crop of country which is produced in *rabi* season, its cultivation is prevailing in the temperate areas of Pakistan as well [5], however, 90% of its sowing is undertaken in the rainfed areas of Pakistan. The leading chickpea producing areas are *Thal* lands which includes Mianwali, Bakhar and some parts of Jhang. It is also cultivated in pothohar districts of Chakwal, Attock, Jehlum and Rawalpindi .The percentage of available nutrients in different parts of chickpea as proteins (19.5%), carbohydrates (57-60%), fats (1.4%), ash (4.8%) and moisture ranges between 4.9 to 15.59% [6].

Chickpea is called poor man meat [7] but also parts of rational nourishment and food for vegetarians. Due to low yield corresponding drought and susceptibility to diseases average yield of chickpea remained on the lower side [8]. That is because of its poor cultivars present at the time which has improper genetic makeup. This paved the way to produce improved chickpea varieties having desirable genetic variability for human consumption. For plant breeders genetic variability is required as a prior condition for the selection of genotypes with more production.

All traits are improved with positive or negative change in the other traits; relation of these changes will guide the breeders to genetically improve the yield [9]. As the yield and yield related parameters in chickpea are controlled quantitatively through multiple genetic characters and these are affected powerfully by the environment [10]. Estimates of variation due to GCA were partitioned for both male and female parents for various traits to search out the potential parents [11]. For the grain yield and its contributing traits general and specific combining abilities have been calculated in chickpea [12]. The present study was conducted for inheritance of quality, yield and yield related components in a 5×5 direct cross set relating in various chickpea parents, which would help in further breeding programmes and development of high yielding chickpea genotypes.

2. MATERIALS AND METHODS

2.1 Plant Material and Location

Present study was conducted at Department of Plant Breeding and Genetics, Bahauddin Zakariya University, Multan. The experimental material for study consists of of 5x5 half diallel (direct cross) analysis comprises five chickpea varieties (CM-98, Noor-91, Brittle-98, Punjab-2000, Karak-1) taken from Nuclear Institute of Agriculture and Biology, Faisalabad.

2.2 Data Collection and Procedure

When flowering started, crossing was done for attempting only direct crosses. At maturity, crossed pods were harvested individually and threshed manually. F0 seeds of each cross with their parents were sown in the next season by Randomized Complete Block Design with three replications. When F1 generation was established, the data of all traits (12) including quality traits [crude fibre contents, total protein contents, total fat contents, ash contents, moisture contents, nitrogen free extracts (N.F.E.)] and yield traits [plant height, number of pods per plant, biomass per plant, 100-seed weight and grain yield] were recorded when crop reached at physical maturity. Fibre, protein, fat, ash, moisture contents and N.F.E. were determined according to AACC standard method [13].

2.3 Data Analysis

Before subjecting the data to diallel cross set, simple analysis of variance was performed for determining the significance of genotypic differences of traits under study. Then Model-I and Model-II of half-diallel was used for combining ability analysis [14].

3. RESULTS AND DISCUSSION

The analyses of variance of chickpea for general and specific combining ability are given in Table 1. The mean squares for general and specific combining ability for all the characters were highly significant (P≤ 0.01). The variances for general combining ability for fibre content, protein content, N.F.E., fat, moisture, ash content, plant height and biomass per plant were lesser than that due to specific combining ability which revealed that variations in the inheritance of these characters were affected by the activity of non-additive gene effects. [15] reported the similar results for plant height and biomass per plant. [16] revealed that both additive and dominance gene effects were significant for protein content. These results are corroborated by [17] wherein both additive and non-additive gene action has been reported in Chickpea under heat stress. But in case of pods per plant, 100-seed weight and grain yield, the amount of general combining ability variance was higher due to specific combining ability variance. [18] described that for plant height, pods per plant, biomass per plant and 100-seed weight, additive gene effects were found significant. [19] stated that for plant height, pods per plant and grain yield both additive and non additive genetic components were significant. [20] proposed that variances due to general and specific combining ability were significant for plant height, pods per plant, 100-seed weight and grain yield.

Estimates of general combining ability effects for different traits of chickpea (*Cicer arietinum* L.) are presented in Table 2. All the parents were compared for general combining ability and its effects showed highly significant results for all the characters (Table 1). [21] presented effect of combining ability in chickpean for yield traits. Analyses of these comparison showed that three parents, Noor-91, Punjab-2000 and Karak-1 was good combiner for fibre and fat content while other two showed bad general combining ability for these traits. Noor-91, Brittle-98 and Punjab-2000 exhibited best general combining ability for ash and moisture content of chickpea. For protein content the parents, CM-98, Noor-91, Brittle-98 and Karak-1attained positive values and displayed good general combining ability for this character as shown in Table 2. CM-98, Brittle-98 and Punjab-2000 were good general combiner for nitrogen free extract while only CM-98 and Punjab-2000 parents showed good GCA for plant height. Three parents, namely, Brittle-98, Punjab-2000 and Karak-1 were good general combiner for number of pods per plant but for biomass per plant three parents i.e. CM-98, Brittle-98 and Punjab-2000 showed best general combining ability. General combining ability effects for 100-seed weight indicated that only two parents, CM-98 and Punjab-2000 gave positive values while for grain yield Brittle-98, Punjab-2000 and Karak-1 gained positive values and examined to be best general combiner for this character.

Estimates of specific combining ability effects of different traits of chickpea are presented in Table 3. Performance of all parents was compared in their specific combinations and ranking order of these comparisons showed that out of 10 crosses, four crosses CM-98×Noor-91, CM-98×Brittle-98, CM-98×Punjab-2000 and Punjab-2000×Karak-1 showed best SCA for fibre content. For protein content, 7 crosses namely, CM-98×Brittle-98, CM-98×Punjab-2000, Noor-91×Brittle-98, Noor-91×Punjab-2000, Noor-91×Karak-1, Brittle-98×Punjab-2000 and Brittle-98×Karak-1 were best for specific combining ability effects. Half combinations, CM-98×Noor-91, CM-98×Karak-1, Noor-91×Brittle-98, Brittle-98×Karak-1 and Punjab-2000×Karak-1 showed best specific combining ability for nitrogen free extract while for fat content only four combinations i.e. CM-98×Karak-1, Noor-91×Brittle-98, Noor-91×Karak-1 and Brittle-98×Punjab-2000 exhibited best SCA effects. CM-98×Brittle-98, CM-98×Karak-1, Noor-91×Punjab-2000 and Punjab-2000×Karak-1 cross combinations were considered excellent for moisture content and also four comparisons i.e. CM-98×Noor-91, CM-98×Punjab-2000, CM-98×Karak-1, Noor-91×Karak-1, Brittle-98×Punjab-2000 and Punjab-2000×Karak-1 had good specific combining ability effects for ash content. For plant height only three crosses, namely, CM-98×Karak-1, Noor-91×Karak-1 and Brittle-98×Punjab-2000 attained negative values and revealed that these were not best for controlling inheritance of specific combining ability. For pods per plant and biomass per plant five combinations were good specific combiner and five were not good. CM-98×Brittle-98, CM-98×Karak-1 and Punjab-2000 showed good specific combining ability for 100-seed Weight and grain yield. Similar results for good combining ability for yield in Chickpea has been reported by [22]

Table 1. Analysis of variance (mean squares) for general and specific combining ability for different traits of chickpea (*Cicer arietinum* L.)

Source	d.f.	Fibre content	Protein Content	N.F.E.	Fat Content	Moisture Content	Ash Content	Plant height	Pods plant $^{-1}$	Biomass plant $^{-1}$	100- seed Wt	Grain yield
GCA	4	1.89**	10.87**	10.34**	1.98**	1.38**	0.01**	16.86**	188.21**	176.54**	6.74**	7.53**
SCA	10	7.70**	20.29**	30.64**	6.29**	2.67**	0.01**	32.03**	137.82**	227.71**	4.68**	5.81**
Error	28	0.02	0.04	0.07	0.01	0.02	0.00	0.68	3.38	1.45	0.47	0.60
V gca		-0.83	-1.34	-2.89	-0.61	-0.19	-0.00	-2.17	7.19	-7.31	0.29	0.25
V sca		7.68	20.25	30.56	6.28	2.65	0.01	31.34	134.45	226.26	4.21	5.21

**and ** = Significant at 5% and 1% respectively. GCA = general combining ability, SCA = specific combining ability, N.F.E. = nitrogen free extract, V gca = variance of general combining ability, V sca = variance of specific combining ability*

Table 2. Estimates of general combining ability effects for different traits of chickpea (parents)

Sr. No.	Parent	Fibre content	Protein content	N.F.E.	Fat Content	Moisture Content	Ash Content	Plant height	Pods plant $^{-1}$	Biomass plant $^{-1}$	100- seed Wt	Grain yield
1	CM-98	-0.02	0.44	0.39	-0.70	-0.13	-0.02	1.43	-2.00	6.77	1.35	-0.63
2	NOOR-91	0.43	1.04	-1.83	0.33	0.04	0.01	-1.99	-7.54	-7.06	-0.09	-1.49
3	BRITTLE-98	-0.87	0.36	0.83	-0.42	0.02	0.05	-1.01	1.98	1.01	-1.13	0.34
4	PUNJAB- 2000	0.09	-2.17	1.18	0.26	0.65	0.00	1.61	1.13	1.04	0.54	0.86
5	KARAK- 1	0.36	0.32	-0.57	0.53	-0.58	-0.04	-0.04	6.44	-1.76	-0.67	0.92
S.E. (gi-gj)		0.07	0.10	0.14	0.05	0.08	0.03	0.44	0.98	0.64	0.37	0.41

S.E. (gi-gj) = standard error for general combining ability

Table 3. Estimates of specific combining ability effects for different traits of chickpea (direct crosses)

Sr. No	Cross	Fibre content	Protein Content	N.F.E.	Fat Content	Moisture Content	Ash content	Plant height	Pods plant $^{-1}$	Biomass plant $^{-1}$	100- seed Wt	Grain yield
1	CM-98 × NOOR-91	1.81	-9.72	10.71	-1.20	-1.64	0.06	6.47	-3.16	1.56	3.25	-0.78
2	CM-98×BRITTLE-98	3.12	0.54	-3.51	-1.01	0.70	-0.09	7.10	9.06	31.25	0.29	0.31
3	CM-98× PUNJAB-2000	1.66	7.06	-6.79	-1.66	-0.23	0.01	2.12	-8.76	-1.39	-2.99	-1.86
4	CM-98 × KARAK-1	-2.17	-2.52	1.04	3.25	0.28	0.15	-6.57	-0.47	-5.04	1.88	1.28
5	NOOR-91× BRITTLE-98	5.27	1.12	5.06	0.05	-0.83	-0.09	2.49	2.60	-2.67	-0.02	2.22
6	NOOR-91× PUNJAB-2000	-0.26	1.27	-1.52	-2.96	3.60	-0.14	2.21	10.38	6.88	-0.00	2.00
7	NOOR-91× KARAK-1	-0.57	0.66	-2.57	3.53	-1.18	0.11	-3.48	-1.90	-1.92	0.95	-2.50
8	BRITTLE-98×PUNJAB-2000	-1.57	1.94	-1.99	3.03	-1.40	0.02	-4.66	-2.40	-11.37	1.86	-0.43
9	BRITTLE-98×KARAK-1	-1.93	0.59	5.05	-2.71	-0.87	-0.10	5.73	24.02	19.02	-1.26	3.04
10	PUNJAB-2000×KARAK-1	1.09	-1.93	1.68	-2.14	1.21	0.07	5.59	5.25	9.69	2.62	3.38
S.E. (sij-sik)		0.18	0.25	0.35	0.12	0.19	0.08	1.08	2.41	1.57	0.90	1.02

S.E. (sij-sik) = standard error for specific combining ability

4. CONCLUSION

The results of Combining Ability analysis concluded that both additive and non additive gene action remained responsible and thus genetically diverse varieties should be used for different crossing combinations for yield and quality traits in Chickpea and such parents should be utilized in furture crossing and improvement programs.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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