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CHARACTERIZATION IN F1 GENERATION OF KABULI, DESI AND WILD *CICER* GENOTYPES FOR PLANT TRAITS

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It is important to understand the magnitude of the changes in variation created by the crossbreeding of cultivated chickpea varieties with a narrow genetic base, desi and kabuli types, and *C. reticulatum* and *C. echinospermum*, which are closely related species to cultivated chickpeas. The study was conducted at Dicle University, Agriculture of Faculty, Diyarbakir, Turkiye, in 2023. The experiment laid out in randomized complete block design with three replications. Desi × kabuli, kabuli × kabuli and kabuli × wild *Cicer* F1 crosses and their parents were evaluated to estimate the heterosis, heterobeltiosis, potence ratios and heritability for the days to first flowering, leave traits, plant height, number of nodes per plant, flower and foliage color, anthocyanin pigmentation and plant growth habit. The differences among genotypes were significant for all these traits. The magnitude of heterosis was differed between traits and crosses. For days to first flowering, heterosis for early crosses ranged from -2.56% to -7.13%. Azkan (lately) × *C. reticulatum* (medium early) (-14.06%) had the highest negative heterobeltiosis for days to first flowering. The high heritability was estimated for days to first flowering, days from emergence to podded, and days from flowering to podded. The estimated values of potence ratios in most F1 crosses were negative for the number of days to first flowering. In crosses between the white-flowered parents Azkan, Gokce, ILC 533, ILC 1929 and ILC 482 and the pink-flowered parents JG 11, ICCV 96029, ICCV 03107, Black and wild *Cicer* species the F1s were pink. When the white-flowered the kabuli parents to the pink-flowered the desi parents were crossed, the F1s showed the anthocyanin pigmentation on various plant parts.

Keywords: Cicer, chickpea, desi, heterosis, heterobeltiosis, kabuli, potence ratio, PCA, wild species

INTRODUCTION

Chickpea (*Cicer arietinum* L.) is one of the earliest grain crops cultivated and has been found in Middle Eastern at 7500–6800 BC (ZOHARY and HOPF, 2000). Chickpea is grown in about 50 countries particularly in the countries of south Asia (about 71% of global area), and it is

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commonly about 95% of the cultivated area in the developing countries. However, chickpea cultivation is not always remunerative because it has usually low and highly variable grain yields due to rainfed and low management input conditions. Chickpea can substantially fix nitrogen and meet up to 80% of its nitrogen requirement from symbiotic nitrogen fixation (SARAF *et al.*, 1998). Also, nitrogen remains in the soil following the chickpea crop, which is useful to subsequent crops. Chickpea is an important source of protein for people in developing countries. Chickpea has the highest nutritional compositions such as protein content, fiber, minerals and unsaturated fatty acids among dry food legume, and it is almost never containing any anti-nutritional factors (IPEKESEN *et al.*, 2022).

The chickpea wild species are *Cicer reticulatum* L., *C. echinospermum C. bijugum*, *C. judaicum* and *C. pinnatifidum* and other *Cicer* species. *C. arietinum* L. are closely related to *C. reticulatum* L. and *C. echinospermum*, as compared to *Cicer* species (KUPICHA, 1977). Sufficient variability is present in genus *Cicer*, which contains 43 wild *Cicer* species for chickpea improvement. Chickpea cultivated is a predominantly self-pollinated crop. There are two distinct types of cultivated chickpea as Desi and Kabuli. The Desi types have pink flowers, anthocyanin pigmentation on stems, small leaves, short plant height, small seeds, a colored and thick seed coat. The Kabuli types have white flowers, lack anthocyanin pigmentation on stems, large leaves and have white or beige colored seeds with a ram's head shape, a thin seed coat and a smooth seed surface.

The purpose of hybridization, which is one of the plant breeding methods, is to collect the desired characteristics in two or more lines, varieties or species. The new combination of genetic factors as a result of crossbreeding studies can provide the emergence of new and desired characters that are not present in the parents.

Genetic variability can be increased by incorporating traits from related wild species. The related species of *Cicer reticulatum* and *C. echinospermum* are of special significance because they grow vigorously and possess acceptable plant traits. Chickpea cultivated is crossable with *C. reticulatum* and *C. echinospermum*. However, chickpea x *C. echinospermum* crossability is sometimes low, and F1 hybrids can be sterile. Also, the cross success rate can be low when the female parent *C. echinospermum* is used (PUNDIR and MENGESHA, 1995).

Heterosis is descripted the improvement of an existing organism as determined by genetic factors of parents. Heterosis in crops is agronomically important as it defines superiority in performance in terms of biomass, yield and its attributes, abiotic and biotic stress tolerance. Hybrid vigour and heterosis in chickpea was first reported by PAL (1945). He reported that the number of pods per plant was the only trait which showed marked hybrid vigour. In self-pollinated crop such as chickpea the heterosis couldn't be initial exploited directly (SHARIF *et al.*, 2001; SAGAR and CHANDRA, 1977) due to flower cleistogamy and artificial hybridization, but in recent times heterosis is used in chickpea crops (MALIK *et al.*, 1987), and through selecting superior breeds, the growth and yield attributes of the chickpea crop is be try to improved (KUMAR *et al.*, 2017). Several research workers were reported beneficial heterosis for grain filling period, seeds per plant and grain yield in chickpea (HEDGE *et al.*, 2002; GUPTA *et al.*, 2003). In this study, we tried to observe the changes in vegetative characters through intraspecific and interspecific hybridization in chickpea, which has a narrow genetic base. The study was aimed to determine the heterosis, heterobeltiosis, potence ratios and heritability for some plant traits in different number desi, kabuli and wild *Cicer* F1 crosses and their parents.

MATERIALS AND METHODS

Plant material

The genetic materials included in the present study were kabuli (Azkan, Gokce, ILC 482, ILC 1929, ILC 533), desi (black, ICC 16207, ICCV 03107, ICCV 96029, JG 11) chickpea varieties and wild annual *Cicer* species (*C. echinospermum* and C. *reticulatum*) which were chosen as parents for hybridization. Parents and cross combinations were selected according to their phenological traits (early/lately), plant height, flower color and growth habit. The hybridization was undertaken at Dicle University, Agriculture of Faculty, Department of Field Crops, Diyarbakir, Turkiye, during the spring season of 2022. Parental genotypes were sown at intervals in a field. Seeds per genotype were sown every 2 weeks, and crosses were hybridized in the morning. Cross-combinations of Azkan × ILC 482, Diyar 95 × ILC 482, Azkan × JG 11, Black × ILC 482, Black × ILC 533, Gokce × ICCV 96029, ICC16207 × Diyar 95, ICCV 03107 × ILC 482, ICCV 03107 × ICCV 96029, ICCV 96029 × Azkan, ICCV 96029 × Gokce, ILC 533 × black, Azkan × C. *echinospermum*, Azkan × C. *reticulatum*, Gokce × C. *echinospermum* and ILC 1929 × C. *reticulatum* were obtained as F1 hybrid seeds.

Practices

F1 hybrids and their parents were evaluated in the field experiment in 2023 spring growing season. The experiment was set out in Randomized Complete Block Design with three replications. Seeds of each combination were sown in 1 m or 1.5 m (based on the number of hybrid seeds obtained) long rows spaced at 20 cm (plant to plant) and 50 cm (row to row) apart. Seeds were sown in early February. The parents were grown in three rows. Only one irrigation was application to ensure seed germination at post-sowing with sprinkler, but plants were not irrigated in the remaining period due to enough rains. Rainfall was irregular, and February and March were dry, April and May were wet. The lowest temperature was in March, and the highest temperature was in June. Weeds were removed by hand two times before flowering. Plants were not fertilized any fertilizer, although organic matter (0.77%) of soil were low.

Traits

Number of days to first flowering and number of days to podded were taken on each plant. The leave traits, plant height, number of nodes per plant and internode length and thickness observations were recorded on five plants from each cross. Leave and leaflet traits such as length and width and number of leaflets per leave were taken on the mid-node of each plant on five completed development leaves. Flower color, foliage color, anthocyanin pigmentation, reddish stem and plant growth habit observations were recorded for each progeny and parent.

Analysis

The data were statistically analyzed (STEEL and TORRIE, 1980) to determine the significance of difference between genotypes for parameters under consideration.

Heterosis and heterobeltiosis

The percentages of heterosis in F1 over the mid-parent (*MPH*) and better parent heterosis (heterobeltiosis) were calculated using standard formula:

$$\text{Heterosis over mid} - \text{parent} = \frac{F1 - Mid\ parent\ value}{Mid\ parent\ value} \times 100$$

$$\text{Heterosis over better paret} = \frac{F1 - Better\ parent\ value}{Better\ parent\ value} \times 100$$

Where, *F1* = mean performance of *F1*; *P1* =mean performance of parent 1; *P2* = mean performance of parent 2; *BP* = mean performance of the better parent in the cross; *MP*= mean of two parents. Data analyses were performed with Excell.

Heritability

$$\text{Heritability } (h^2) = (\sigma^2 g/\sigma^2 p) \times 100$$

Where, h2 =Heritability in broad sense, σ^2p = Phenotypic variance, $\sigma^2 g$ =Genotypic variance (FALCONER, 1989).

Genotypic variance $MSg = \sigma^2 g + \sigma^2 e/r$, phenotypic variance $(\sigma^2 p) = (\sigma^2 g) + (\sigma^2 e)$ (JOHNSON *et al.*, 1955).

Potence ratio

Potence ratio was calculated according to SMITH (1952) to determine the degree of dominance as follows:

$$P = \frac{F1 - MP}{(P2 - P1)/2}$$

where *P*: relative potence of gene set, *F1*: first generation mean, *P1* and *P2*: the mean of parents, *M.P.*: mid-parents value = *(P1 + P2)/2*. Complete dominance was indicated when *P* = +1; while partial dominance is indicated when "*P*" is between (−1 and +1), except the value zero, which indicates absence of dominance. Overdominance was considered when potency ratio exceeds ±1. The positive and negative signs indicate the direction of dominance of either parent.

GGE Biplot Analysis

F1 and parents -by-trait biplots were generated to determine which F1 and parents were best suited for trait such as; days to first flowering, days to flowering to podded, number of days from emergence to podded, number node for the first flower, leave length, leave width, leaf length, leaf width, number of leaf per leave, plant height and number of nodes per plant. PC1 values were defined as the mean of F1 hybrids and their parents and are located in the X (horizontal) plane in the GGE Biplot graphic plane, PC2 values are the stability of the investigated features and are located in the Y (vertical) plane in the graph. The Comparison biplot; illustrates an important concept of “stability” and the term "High stability" only makes sense when associated with average performance. The ranking biplot; AEC39's ordinate is the line through the origin and perpendicular to the AEC apse, showing greater G×E interaction effect and low stability in both directions away from the two-point origin, and distinguishes genotypes with below-average means from the above. (BHARTIYA *et al.,* 2017). The average plant characteristics of an F1 hybrid and its parents are approximated by the projections of their markers on the AEC x-axis, while stability is determined by their projections on the AEC ordinate line (y-axis) (YAN and RAJCAN, 2002; YAN and TINKER 2006). The GGE Biplot were carried out with GenStat 12th Edition Program.

RESULTS AND DISCUSSION

The differences among genotypes for days to first flowering, days to flowering to podded, number of days from emergence to podded and number node for the first flower were significant (Table 1.).

The magnitude of heterosis was differed between traits and crosses. Negative heterosis usually is desirable for the traits such as number of days to first flowering, days to flowering to podded and number of days from emergence to podded. For days to first flowering, heterosis for early crosses ranged from -2.56% to -7.13%, and the only four crosses might be flowered in short period. Heterobeltiosis ranged from -0.47% to 13.9%. Six crosses expressed heterobeltiosis in desired direction (negative heterobeltiosis). Azkan (lately) × C. *reticulatum* (medium early) (-14.06%) had the highest negative heterobeltiosis for days to first flowering (Table 1).

For days to flowering to podded, negative heterosis ranged from -10.00% to -51.20%. High positive heterosis of the crosses was high number of pseudo flower per plant. Eleven crosses expressed heterobeltiosis in desired direction (negative heterobeltiosis). Azkan (lately) × ILC 482 (medium early) (-60.00%) and ICC 16207 (lately) × Diyar 95 (lately) (-56.10%) had the highest negative heterobeltiosis. Number of days from flowering to podding was higher in some crosses (ICCV 03107 (medium early) × ICCV 96029 (super early) and ILC 533 (medium early) × Black (early)) obtained from early varieties compared to late varieties (Table 1).

Number of days from emergence to podded was showed equally positive and negative heterosis. Negative heterosis ranged from -1.30 to -10.60%, negative heterosis showed that early podding in crosses was dominate. Six crosses expressed heterobeltiosis in desired direction (negative heterobeltiosis). ICCV 96029 (super early) × Azkan (lately) (-15.90%) and Azkan × C. *reticulatum* (-14.10%) had the highest negative heterobeltiosis (Table 1,2).

Heterosis in negative direction related to number node for the first flower is highly desirable for early mature, and it ranged from -1.40 to -28.40%. Negative heterobeltiosis varied from -3.70 to -31.80%. Generally, this trait was negatively related to the number of days to first flowering, and in crosses of many early cultivars, the first flowering node was formed at the lower part of the main stem (Table 1).

Heritability is a measure of how the contribution of genes in heterosis is the capacity of F1 hybrid crosses to exhibit improved phenotypes compared to those observed in parents (WAFULA *et al*., 2021). The high heritability estimates of number of days to first flowering, number of days from emergence to podded and days to flowering to podded showed that once early lines were obtained, they were easy to maintained (Table 1.).

Table 1. Analysis of variance, heterosis, heterobeltoisis, potence ratios and heritability estimates for the various studied characters of chickpea.

	Days to first flowering						Days to flowering to podded					
Genotypes	P1	P2	F1	Ht (%)	Hb (%)	Pr	P1	P2	F1	Ht (%)	Hb (%)	Pr
Azkan × ILC 482	69.00	59.30	72.30	12.70	4.78	-1.68	6.30	10.00	4.00	-50.90	-60.00	-2.20
ICCV 96029 × Azkan	54.30	69.00	61.70	0.08	-10.60	0.01	6.00	6.30	3.00	-51.20	-50.00	-21.00
Azkan × C.reti.	69.00	58.70	59.30	-7.13	-14.06	0.88	6.30	7.70	4.00	-42.90	-48.10	-4.29
ICCV 96029 × Gokce	54.30	59.70	55.00	-3.51	-7.87	-0.74	6.00	6.30	5.30	-13.80	-15.90	-5.70
Gokce × ICCV 96029	59.70	54.30	68.00	19.30	13.90	-4.07	6.30	6.00	5.00	-18.70	-20.60	7.70
Gokce × C.echino	59.70	57.30	57.00	-2.56	-4.52	1.25	6.30	4.30	6.00	13.20	-4.80	-0.70
Black × ILC 482	55.70	55.70	67.00	16.50	12.98	-	8.00	10.00	8.00	-11.10	-20.00	-1.00
Black × ILC 533	55.70	58.30	65.30	14.60	12.01	6.38	8.00	8.00	5.30	-34.40	-33.80	-
ILC 533 × Black	58.30	55.70	60.70	6.49	4.12	-2.85	8.00	8.00	8.70	8.70	8.70	-
Diyar 95 × ILC 482	64.00	59.30	63.70	3.33	-0.47	-0.87	4.00	10.00	6.30	-10.00	-37.00	-0.20
ICC 16207 × Diyar 95	63.70	64.00	65.30	2.27	2.03	9.67	10.70	4.00	4.70	-36.00	-56.10	0.79
ICCV 03107 × ICCV 96029	57.30	54.30	58.30	4.48	1.75	-1.67	6.00	6.00	9.70	61.70	61.70	-
ILC 1929 × C.reti.	63.30	58.70	57.00	-6.56	-9.95	1.74	9.30	7.70	7.00	-17.60	-24.70	1.88
Source	Df	**MS**					**MS**					
Replications	2	26.41					2.29					
Genotypes	24	67.17**					13.19**					
Error	48	5.8994					2.6128					
CV%		3.96					24.69					
$\sigma^2 g$		20.42					3.52					
$\sigma^2 p$		26.32					6.14					
h^2 (%)		87.5					57.3					
	Number of days from emergence to podded						Number node for the first flower					
Genotypes	P1	P2	F1	Ht (%)	Hb (%)	Pr	P1	P2	F1	Ht (%)	Hb (%)	Pr
Azkan × ILC 482	75.30	69.30	76.30	5.50	1.30	-1.33	15.00	12.30	13.30	13.30	-2.60	0.26
ICCV 96029 × Azkan	60.30	75.30	64.70	-4.60	-14.10	-0.41	9.70	15.00	10.70	10.70	-13.40	-0.62
Azkan × C.reti.	75.30	66.30	63.30	-10.60	-15.90	1.67	15.00	8.70	14.00	14.00	18.10	-0.68
ICCV 96029 × Gokce	60.30	66.00	60.30	-4.50	-8.60	-1.00	9.70	10.70	7.30	7.30	-28.40	-5.80
Gokce × ICCV 96029	66.00	60.30	73.00	15.60	10.60	-3.46	10.70	9.70	9.30	9.30	-8.80	1.80
Gokce × C.echino	66.00	61.70	63.00	-1.30	-4.50	0.40	10.70	7.70	11.00	11.00	19.60	-1.20
Black × ILC 482	63.70	69.30	75.00	12.80	8.20	3.04	10.70	12.30	13.30	13.30	15.70	2.25
Black × ILC 533	63.70	66.30	70.70	2.00	6.60	4.38	10.70	10.70	12.00	12.00	-1.40	-

ILC 533 × Black	66.30	63.70	69.30	6.60	4.50	-3.31	10.70	10.70	10.30	10.30	-3.70	-
Diyar 95 × ILC 482	68.00	69.30	70.00	2.00	1.00	2.08	15.00	12.30	14.30	14.30	4.80	-0.48
ICC 16207 × Diyar 95	63.70	68.00	70.00	-1.60	-5.80	1.93	11.70	15.00	11.30	11.30	-15.40	-1.24
ICCV03107 × ICCV96029	63.30	60.30	68.00	10.00	7.40	-4.13	11.70	9.70	9.30	9.30	-13.10	1.40
ILC 1929 × C.reti.	72.70	66.30	64.00	-7.90	-12.00	1.72	14.30	8.70	11.30	11.30	-1.70	0.07
Source	**Df**	**MS**					**MS**					
Replications	2	24.76					2.65					
Genotypes	24	69.81**					13.96 **					
Error	48	6.982					3.542					
CV%		3.89					16.47					
σ^2g		20.94					3.47					
σ^2p		27.92					7.01					
h^2 (%)		75.0					49.5					

**:0.01. *:0.05 significant. ht:heterosis. hb:heterobeltoisis. Pr: Potence ratio (Pr)

The estimated values of potence ratios in most F1 crosses were negative for the days to first flowering, days to flowering to podded, number of days from emergence to podded, number node for the first flower. Negative values of potence ratio indicated the presence of various degrees of recessiveness, i.e., partial- to under-recessiveness. In some F1 crosses the estimated potence ratios had a positive nature for these characters. These results reflected, generally, various degrees of dominance; i.e., partial- to over-dominance which involved in the inheritance of these characters. Four F1 crosses out of the evaluated thirteen F1 crosses showed a clear over-dominance for the days to first flowering; since, the estimated potency ratios ranged from 1.25 to 9.67. Days to flowering to podded in most F1 crosses the estimated potency ratios was negative, and indicated the presence of various degrees of recessiveness, i.e., partial- to under-recessiveness in the inheritance of this character. Also, seven F1 crosses exhibited partial-dominance for days to flowering to podded. For number node for the first flower, only three F1 crosses out of the evaluated thirteen F1 crosses showed a clear over-dominance; since, the estimated potency ratios ranged from 1.40 to 2.25 (Table 1). In some crosses for days to flowering to podded and number node for the first flower were absent dominance (P=zero). LAKMES *et al.,* (2022) reported flowering time differed between families, with the frequency distributions indicating quantitative inheritance controlled by both genes of major and minor effects.

The differences among genotypes for plant height, number of nodes per plant, number of leaflets per leave and leave length were significant (Table 2).

Short plant height is desirable in heavy soils where excessive growth affect the yield negatively. However, tall plant height is important for photosynthetic area due to large plant canopy, and tall and large plants having be generally large seeded. Heterosis for tall plant height ranged from 3,7 to 28,8%. Heterobeltiosis for tall plants varied from 1.60 to 18.80% over better parent. Also, nine crosses had short plant height with negative heterosis, and the maximum negative heterosis and heterobeltiosis were in Gokce × C. *echinospermum* (-28.80% and -33.00%) (Table 2.).

Number of nodes per plant was an important plant trait for lodging. Positive heterosis ranged from 0.70% to 44.60%. Thirteen crosses expressed heterobeltiosis in negative direction. Azkan (tall) × C. *reticulatum* (tall) (-26.70%) had the highest negative heterobeltiosis (Table 2.).

Table 2. Analysis of variance. heterosis. heterobeltoisis. potence ratios and heritability estimates for the various studied characters of chickpea.

	Plant height (cm)						Number of nodes per plant					
Genotypes	P1	P2	F1	Ht (%)	Hb (%)	Pr	P1	P2	F1	Ht (%)	Hb (%)	Pr
Azkan × ILC 482	46.30	43.00	42.00	-5.90	-9.30	1.61	22.00	23.70	23.00	0.70	-3.00	0.18
Azkan × JG 11	46.30	36.30	33.30	-19.40	-28.10	1.60	22.00	18.70	19.00	-6.60	-13.60	0.82
Azkan × C. echino	46.30	50.00	45.30	-5.90	-9.40	-1.54	22.00	20.70	24.00	0.00	-7.70	-4.08
Azkan × C.reti.	46.30	53.30	45.70	-8.20	-14.30	-1.17	22.00	23.00	20.30	-18.30	-26.70	-4.40
ICCV 96029 × Azkan	34.70	46.30	42.00	3.70	-9.30	0.26	19.00	22.00	25.30	23.40	15.00	3.20
Gokce × ICCV 96029	56.70	34.70	44.70	-2.20	-21.20	0.09	26.00	19.00	24.00	6.70	-7.70	-0.43
ICCV 96029 × Gokce	34.70	56.70	45.70	0.00	-19.40	0.00	19.00	26.00	25.00	11.10	-3.90	0.71
Gokce × C.echino	56.70	50.00	38.00	-28.80	-33.00	4.58	26.00	20.70	20.70	-20.40	-20.40	1.00
Diyar 95 × ILC 482	38.70	43.00	50.00	22.40	16.30	4.26	15.70	23.70	22.00	11.70	-7.20	0.58
ICC 16207 × Diyar 95	32.00	38.70	42.00	18.80	8.50	1.99	19.30	15.70	25.30	44.60	31.10	-4.33
Black × ILC 482	36.80	43.00	31.70	-20.60	-8.70	-2.65	24.30	23.70	23.70	-1.30	-2.50	1.00
Black × ILC 533	36.80	34.70	38.70	8.30	5.20	-2.81	24.30	20.00	21.00	-5.20	-13.60	0.53
ILC 533 × Black	34.70	36.80	43.70	-2.60	1.60	7.57	20.00	24.30	21.00	-6.10	-17.00	-0.53
ICCV 03107 × ILC 482	32.00	43.00	33.00	-12.00	-23.30	-0.82	16.00	23.70	20.00	0.80	-15.60	0.04
ICCV03107 × ICCV96029	32.00	34.70	41.00	22.90	18.20	5.67	16.00	19.00	20.00	14.30	5.30	1.67
ILC 1929 × C.reti.	37.70	53.30	44.30	22.20	18.80	-0.15	21.30	23.00	23.00	-5.20	-13.60	1.00
Sources	Df	MS					MS					
Replications	2	7.606					8.310					
Genotypes	24	129.71**					26.53*					
Error	48	21.23					14.48					
CV%		11.2					17.3					
σ^2g		36.15					4.014					
σ^2p		57.39					18.50					
h^2 (%)		63.0					21.7					
	Number of leaflets per leave						Leave length (cm)					
Genotypes	P1	P2	F1	Ht (%)	Hb (%)	Pr (%)	P1	P2	F1	Ht (%)	Hb (%)	Pr (%)
Azkan × ILC 482	18.70	15.70	17.30	0.60	-7.50	-0.07	8.72	5.96	7.91	7.80	-9.30	-0.41
Azkan × JG 11	18.70	16.30	14.70	-16.00	-21.40	2.33	8.72	5.84	6.68	-8.20	-23.40	0.42
Azkan × C. echino	18.70	16.70	14.00	-20.90	-25.10	3.70	8.72	4.16	7.20	11.80	-17.40	-0.33
Azkan × C.reti.	18.70	15.70	12.70	-26.20	-32.10	3.00	8.72	5.80	5.92	-18.50	-32.10	0.92
ICCV 96029 × Azkan	13.00	18.70	18.00	13.60	-3.70	0.75	6.28	8.72	8.44	12.50	-3.20	0.77
Gokce × ICCV 96029	15.30	13.00	12.70	-10.20	-17.00	1.26	8.72	6.28	7.80	4.00	-10.60	-0.25
ICCV 96029 × Gokce	13.00	15.30	12.70	-10.20	-17.00	-1.26	6.28	8.72	8.44	12.50	-3.20	0.77
Gokce × C.echino	15.30	16.70	13.70	-14.40	-18.00	-3.28	8.72	4.16	6.44	0.01	-26.20	0.00
Diyar 95 × ILC 482	15.70	15.70	16.00	1.90	1.90	-	8.32	5.96	8.04	12.60	-3.40	-0.76
ICC 16207 × Diyar 95	16.70	15.70	16.30	0.60	-2.40	-0.20	5.00	8.32	6.80	2.10	-18.30	0.08

Black × ILC 482	11.70	15.70	21.70	58.40	27.70	4.00	5.80	5.96	6.10	3.70	2.40	2.75
Black × ILC 533	11.70	17.00	15.70	9.40	-7.70	0.51	5.80	5.92	7.28	24.20	23.00	23.67
ILC 533 × Black	17.00	11.70	14.00	-2.40	-17.70	0.13	5.92	5.80	7.52	28.30	27.00	-27.67
ICCV 03107 × ILC 482	20.00	15.70	15.30	-14.30	-23.50	1.19	7.00	5.96	5.20	-19.80	-25.70	2.46
ICCV03107 × ICCV96029	20.00	13.00	14.70	-10.90	-26.50	0.51	7.00	6.28	6.12	-7.80	-12.60	1.44
ILC 1929 × C.reti.	17.30	15.70	11.00	-33.30	-36.40	6.87	7.72	5.80	4.20	-37.90	-45.60	2.67
Sources	Df	MS					MS					
Replications	2	1.690					0.114					
Genotypes	24	17.419 **					4.99**					
Error	48	2.5468					0.73					
CV%		10.3					12.8					
$\sigma^2 g$		4.96					1.14					
$\sigma^2 p$		7.51					1.87					
h^2 (%)		66.0					60.9					

**:0.01. *:0.05 significant. ht:heterosis. hb:heterobeltoisis

Heritability estimates for number of leaflets per leave, plant height was medium (66.10 to 63.00%, respectively). Number of nodes per plant had low heritability with 21.70% (Table 2.).

Number of leaflets per leave was an important plant trait for photosynthetic area. Chickpea is usually cultivated rainfed and low management input conditions, so it has low and highly variable grain yields. In arid and low-input growing conditions, high leaf area and photosynthetic activity can guarantee grain yield. However, high leaf area is a desirable feature as long as it does not adversely affect light intensity transmittance.

At the same time, it is known that lately matured genotypes also form a high rate of leaves. Heterosis in positive direction ranged from 0.60 to 58.40%, and the maximum positive heterobeltiosis were in Black (low) × ILC 482 (medium) (27.70%). However, heterobeltiosis in negative direction in crosses was dominant for number of leaflets per leave (Table 2).

The estimated values of potence ratios in eleven F1 crosses were positive for the plant height and number of leaflets per leave. These results indicated the presence of partial- to over-dominance. Seven F1 crosses showed a clear over-dominance ranged from 1.26 to 6.87 for the number of leaflets per leave. Over-dominance for plant height ranged from 1.60 to 5.67. The estimated values of potence ratios in some F1 crosses were positive for number of nodes per plant, and Gokce × C. *echinospermum*, Black × ILC 482 and ILC 1929 × C. *reticulatum* were showed complete dominance due to P = +1.00. Leave length in most F1 crosses the estimated potence ratios was positive and negative. Five F1 crosses showed over-dominance, and six F1 crosses exhibited partial-dominance (Table 2.).

The differences among genotypes for leave length and width, leaflet length and width were significant (Table 2,3). The heterosis for leave length ranged from -37.90 to 28.30%. Usually, positive heterosis was considered for this trait. ILC 533 × Black cross had the highest positive heterosis (28,3%). Total thirteen crosses showed heterobeltiosis in negative direction which ranged from -3.20 to -45.60%. ILC 1929 (large) × C. *reticulatum* (medium) (-45.60%) had the highest negative heterobeltiosis.

Table 3. Analysis of variance. heterosis. heterobeltoisis. potence ratios and heritability estimates for the various studied characters of chickpea.

	Leave width (cm)						Leaflet length (cm)					
Genotypes	P1	P2	F1	Ht(%)	Hb(%)	Pr	P1	P2	F1	Ht(%)	Hb(%)	Pr
Azkan × ILC 482	3.96	2.40	3.37	6.00	-14.9	-0.24	2.00	1.04	2.05	34.9	2.5	-1.10
Azkan × JG 11	3.96	2.24	2.68	-13.6	-32.3	0.49	2.00	1.32	1.56	-6.0	-22.0	0.29
Azkan × C. echino	3.96	1.28	2.36	-9.9	-40.4	0.19	2.00	0.68	1.16	-13.4	-42.0	0.27
Azkan × C.reti.	3.96	1.84	2.68	-7.6	-32.3	0.21	2.00	1.04	1.08	-29.0	-46.0	0.92
ICCV 96029 × Azkan	2.52	3.96	3.44	6.2	-13.1	0.28	1.80	2.00	1.92	0.01	-4.0	0.00
Gokce × ICCV 96029	3.52	2.52	3.20	6.0	-9.1	-0.36	2.40	1.84	1.44	-32.7	-41.0	2.33
ICCV 96029 × Gokce	2.52	3.52	2.40	-20.5	-31.8	-1.24	1.80	2.44	1.72	-19.6	-29.5	-1.40
Gokce × C.echino	3.52	1.28	2.32	-3.3	-34.1	0.07	2.40	0.68	1.04	-33.3	-57.4	0.59
Diyar 95 × ILC 482	3.60	2.40	3.56	18.7	-1.1	-0.93	2.20	1.04	2.20	34.2	-1.8	-0.93
ICC 16207 × Diyar 95	1.88	3.60	2.60	-5.1	-27.8	-0.16	1.10	2.24	1.36	-19.1	-39.3	-0.57
Black × ILC 482	2.04	2.40	2.52	13.5	5.0	1.67	1.20	1.04	1.27	15.5	9.5	-2.83
Black × ILC 533	2.04	2.24	2.83	32.2	26.3	6.90	1.20	1.28	1.67	36.9	30.5	7.50
ILC 533 × Black	2.24	2.04	2.88	34.6	28.6	-7.40	1.30	1.16	1.56	27.9	21.9	-5.67
ICCV 03107 × ILC 482	2.68	2.40	2.44	-3.9	-9.0	0.71	1.60	1.04	1.32	0.0	-17.5	0.00
ICCV 03107 × ICCV 96029	2.68	2.52	3.20	23.1	19.4	-7.50	1.60	1.84	1.52	-11.6	-17.4	-1.67
ILC 1929 × C.reti.	3.08	1.84	2.04	-17.1	-33.8	0.68	1.70	1.04	1.16	-14.7	-31.0	0.63
Sources	Df	MS					MS					
Replications	2	0.631					0.115					
Genotypes	24	1.16**					0.54**					
Error	48	0.172					0.04					
CV%		15.4					13.3					
σ^2g		0.328					0.167					
σ^2p		0.5					0.207					
h^2 %		65.6					80.7					
	Leaflet width (cm)											
Genotypes	P1	P2	F1	Ht (%)	H (%)	Pr						
Azkan × ILC 482	1.24	0.60	0.98	6.50	-21.00	-0.19						
Azkan × JG 11	1.24	0.64	0.96	2.10	-22.60	-0.07						
Azkan × C. echino	1.24	0.36	0.68	-15.00	-45.20	0.27						
Azkan × C.reti.	1.24	0.52	0.68	-22.70	-45.20	0.56						
ICCV 96029× Azkan	0.92	1.24	0.92	-14.80	-25.80	-1.00						
Gokce × ICCV 96029	1.40	0.92	0.76	-34.50	-45.70	1.67						
ICCV 96029 × Gokce	0.92	1.40	0.80	-31.00	-42.90	-1.50						
Gokce × C.echino	1.40	0.36	0.68	-22.70	-51.40	0.38						
Diyar 95 × ILC 482	1.36	0.60	0.84	-14.30	-38.20	0.37						
ICC 16207×Diyar 95	0.76	1.36	0.76	-28.30	-44.10	-1.00						
Black × ILC 482	0.44	0.60	0.57	9.60	-5.00	0.62						
Black × ILC 533	0.44	0.60	0.78	50.00	30.00	3.25						
ILC 533 × Black	0.60	0.44	0.80	53.90	33.30	-3.50						
ICCV 03107 × ILC 482	0.92	0.60	0.72	-5.30	-21.70	0.25						
ICCV 03107 × ICCV 96029	0.92	0.92	0.88	-4.40	-4.40	-						
ILC 1929 × C.reti.	0.96	0.52	0.76	2.70	-20.80	-0.09						
Sources	Df	MS										
Replications	2	0.031										
Genotypes	24	0.173**										
Error	48	0.015										
CV%		15.2										
σ^2g		0.053										
σ^2p		0.068										
h^2 %		77.9										

**:0.01. *:0.05 significant. ht:heterosis. hb:heterobeltoisis

However, Azkan (large) × C. *echinospermum* (small) (-17.40%), Azkan × C. *reticulatum* (-32.10%), Gokce (large) × *C. echinospermum* (-26.20%) crosses were exhibited highly negative heterobeltiosis compared to crosses for leave length (Table 2).

Positive heterosis for leave width ranged from 6.00 to 34.60%. Heterobeltiosis varied from -40.40 to 28.60% over better parent. Also, four crosses had positive heterobeltiosis. Black (medium) × ILC 533 (medium) and its reciprocal had positive heterobeltiosis (28.60% and 26.30%). The maximum negative heterobeltiosis were in Azkan × C. *echinospermum* for leave width (Table 3).

For leaflet length heterosis in positive direction was observed from six crosses. Heterobeltiosis varied from -57.40 to 30.50% over better parent. Twelve crosses had negative heterobeltiosis. The highest heterosis and heterobeltiosis in negative direction were in Gokce × *C. echinospermum*. For leaflet width, heterosis in positive direction ranged from 2.10 to 53.90%. Black × ILC 533 and its reciprocal had the maximum positive heterosis (50.00% and 53.90%). Fourteen crosses had negative heterobeltiosis, and ranged from -4.40 to -51.40%. Azkan × C. *echinospermum* (-45.20%), Azkan × C. *reticulatum* (-45.20%), Gokce × ICCV 96029 and reciprocal (45.70% and 42.90%), Gokce × *C. echinospermum* (-51.40%) and ICC 16207 × Diyar 95 (-44.10%) crosses were exhibited highly negative heterobeltiosis compared to crosses. Increasing leaf size in chickpea was important in terms of photosynthesis activity. The performances of the large-leaved parents were hindered by the small-leaved ones. Wild *Cicer* species as parents had small leaf size, and their crosses never had large leaf size in the F1 generation in all combinations (Table 3.).

Heritability estimates for leave length and width was medium (60.90 to 65.60%, respectively), and leaflet length and width had high heritability (80.70 to 77.90%, respectively).

Potency ratios had positive and negative nature for evaluated F1 crosses for leave width, leaflet length and leaflet width. Two F1 crosses out of the evaluated sixteen F1 crosses showed a clear over-dominance for these characters. The F1 crosses Black × ILC 482 and Black × ILC 533 exhibited over dominance, with degrees 1.67 to 6.90 for leave width. Gokce × ICCV 96029 and Black × ILC 533 showed over dominance, with degrees 2.33 to 7.50, and ICCV 96029 × Azkan and ICCV 03107 × ILC 482 had p=0.00 for leaflet length (Table 3.).

The thickness and length of eight nodes of the main stem were measured in plants of all genotypes. The differences among genotypes for internode length and thickness were significant in this study. The internode thickness is high in the lower parts of the stem, while the internode length is high in the middle and upper parts of the stem (Fig 1). Internode length from first to eighth was 1.03 cm to 2.07 cm, and internode thickness ranged from 2.48 cm to 5.46 cm (Table 4, Fig 1). Azkan, Diyar 95 and Gokce varieties were tall plant height and erect growth habit. ICCV 96029 showed in short plant height and weak stem. Internode thickness of the Gokce × ICCV 96029 cross was higher than its parents and other genotypes. ICCV 96029 × Azkan cross was not show performance like Gokce till seventh and eighth internodes (Table 4.).

Chickpea is performed the best with a long, warm growing season. The chickpea growing season is exposed to drought stress due to high temperatures and evapotranspiration, and a lack of rainfall in our arid and semiarid regions. Tall and late maturing chickpea genotypes form weak stems due to low evaporation and high temperature during long and dry periods. In tall genotypes with weak stem, the plant stem is broken towards the end of the growing season, and the machine harvesting be difficult. In addition, vigor plant stem may be important in preventing stem breakage, especially in genotypes with erect and semi-erect growth habits. Likewise, in rainy climate and fertile soils tall plants is caused weak stem.

Table 4. Internode length and thickness of chickpea

Internode length and thickness	First		Second		Third		Fourth	
Genotypes	L	T	L	T	L	T	L	T
Azkan	0.83	7.06 ab	0.97 cd	6.26 a	1.17 c-f	5.34 b	1.27 bcd	4.90 b
Gokce	1.03	5.99 d	1.07 cd	5.25 bc	1.10 def	4.53 cd	1.20 cd	4.41 bc
Gokce × ICCV 96029	1.00	7.10 a	1.03 cd	6.36 a	1.30 cd	6.09 a	1.50 a-d	5.62 a
ICCV 96029 × Azkan	1.17	5.49 de	0.90 d	4.76 cd	1.67 ab	4.19 de	1.83 a	3.96 cd
ICCV 96029	1.00	3.74 gh	1.00 cd	3.67 f	1.20 cde	3.15 g	1.37 bcd	3.01 ef
Azkan × C. reti.	0.67	4.49 fg	1.17 c	4.30 de	1.07 ef	4.33	1.43 bcd	3.54 de
Gokce × C.echino.	1.00	6.84 abc	1.43 ab	5.51 b	1.60 b	4.30 d	1.60 ab	3.57 de
Diyar 95	1.33	4.25 fgh	1.53 a	3.57 fg	1.87 a	3.60 efg	1.57 abc	3.25 ef
ILC 1929	1.17	6.17 cd	0.97 cd	4.91 c	0.97 f	4.50 cd	1.17 d	4.22 c
ICC 16207	1.00	4.73 ef	1.20 bc	3.61 g	1.33 c	3.29 g	1.43 bcd	3.14 ef
ICC 4958	1.20	6.28 bcd	1.00 cd	3.99 ef	1.07 ef	3.23 g	1.33 bcd	2.79 f
ICCV 03107	1.00	4.82 ef	1.00 cd	4.95 bc	1.17 c-f	3.94 def	1.60 ab	3.45 de
JG11	1.00	5.8 d	1.00 cd	5.22 bc	1.00 ef	4.94 bc	1.43 bcd	4.51 bc
ILC5 33 × Black	1.07	3.61 h	1.47 a	3.69 f	1.67 ab	3.53 fg	1.87 a	3.26 ef
	Fifth		Sixth		Seventh		Eighth	
Genotypes	L	T	L	T	L	T	L	T
Azkan	1.73 ab	4.37 b	1.80 cde	4.43 ab	1.97 bcd	4.28 a	1.97	3.97 a
Gokce	1.70 abc	4.28 bc	1.57 ef	4.20 b	1.60 d	4.12 a	1.90	4.00 a
Gokce × ICCV 96029	1.97 a	5.25 a	2.00 bc	4.73 a	2.37 ab	4.29 a	2.10	4.09 a
ICCV 96029 × Azkan	1.70 abc	4.01 cd	1.53 ef	3.47 c	2.17 bc	3.37 bc	2.10	3.00 bcd
ICCV 96029	1.60 bc	2.79 g	1.93 bcd	2.60 fg	1.73 cd	2.47 efg	1.67	2.14 fgh
Azkan × C. reti.	1.47 bcd	3.36 e	1.50 ef	3.33 cd	1.97 bcd	2.92 cde	2.33	2.76 cde
Gokce × C.echino.	1.70 abc	3.35 e	1.60 ef	3.20 cde	1.97 bcd	2.92 cd	2.20	2.60 def
Diyar 95	2.00 a	3.12 ef	2.03 abc	2.90 efg	2.40 ab	2.35 gh	2.33	1.89 h
ILC 1929	1.23 d	4.18 bc	1.17 g	4.04 c	1.57 d	3.48 ab	1.83	3.22 bc
ICC 16207	1.67 abc	3.10 ef	1.63 def	3.02 def	1.90 bcd	2.94 cd	1.97	2.67 de
ICC 4958	1.60 bc	2.99 fg	1.43 fg	2.59 g	1.97 bcd	2.60 d-g	1.93	2.41 efg
ICCV 03107	1.77 ab	3.13 ef	2.33 a	2.77 fg	2.17 bc	2.00 h	1.70	1.96 gh
JG11	1.37 cd	4.39 b	1.37 fg	4.43 ab	1.83 cd	3.96 a	2.30	3.45 b
ILC 533 × Black	1.67 abc	3.16 ef	2.17 ab	2.81 efg	2.73 a	2.44 fgh	2.70	2.61 def
Anova	MS							
Genotypes (length)	0.077 ns	4.474**	0.129**	3.08**	0.248**	2.2015**	0.132**	1.953**
Error	0.063	0.239	0.024	0.125	0.018	0.138	0.0488	0.134
Genotypes (thickness)	0.1254**	1.473**	0.334**	1.629**	0.3094**	1.6711**	0.238ns	1.536**
Error	0.0419	0.0286	0.0345	0.0637	0.099	0.0719	0.1238	0.082

**:0.01. *:0.05 significant, L: length, T: thickness

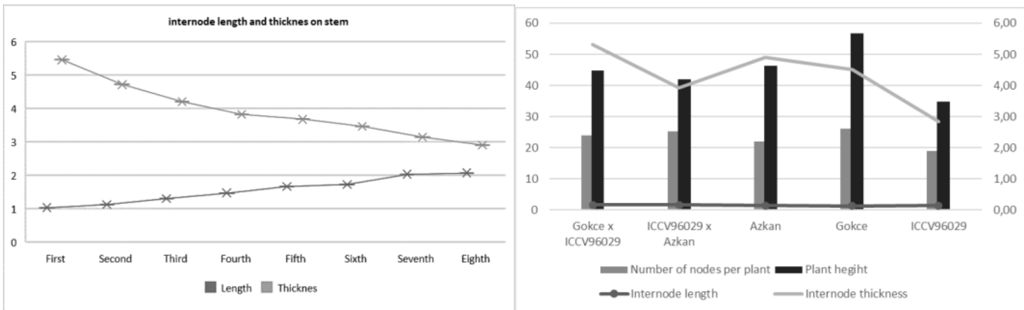

Fig. 1 Internode length and thickness from first to eighth internodes. Azkan, Gokce and ICCV 96029 and F1 crosses

Table 5. Flower color, leaf color and plant habit in F1 crosses

	Flower color			Foliage color			Anthocyanin pigmentation	Reddish stem	Plant growth habit		
Genotypes	P1	P2	F1	P1	P2	F1	-	-	P1	P2	F1
Azkan × ILC 482	W	W	W	G	G	G. LG	-	-	E	SE	SE
Azkan × JG 11	W	P	P	G	DG	DG	+	+	E	SP	SE
Azkan × C. reti	W	Pr	Pr	G	DG	G. DG	+	+	E	P	SP
ICCV 96029 × Azkan	P	W	P	LG	G	G	+	+	SE	E	SE
Gokce × ICCV 96029	W	P	P	G	LG	G	+	+	E	SE	SE
ICCV 96029 x Gokce	P	W	P	G	G	G. LG	+	-	SE	E	SE
Gokce × C. echino.	W	Pr	Pr	G	DG	DG	+	-	E	P	P
Diyar 95 × ILC 482	W	W	W	G	DG	G	-	-	E	SE	E
ICCV 16207 × Diyar 95	P	W	P	DG	G	LG	+	+	SP	E	SE
Black × ILC 482	P	W	P	DG	G	LG	+	+	SP	SE	SE
Black x ILC 533	P	W	P	DG	LG	LG. G.DG	+	+	SP	E	SP
ILC 533 × Black	W	P	P	LG	DG	LG	+	+	E	SP	SP
ICCV 03107 × ILC 482	P	W	P	DG	G	LG	+	-	E	SE	SE
ICCV 03107 × ICCV 96029	P	P	P	G	LG	LG. G	+	+	E	SE	SE
ILC 1929 × C. reti	W	Pr	Pr	LG	DG	LG	+	+	SE	P	P

W:White. P:Pink. Pr:Purple. G:Green. LG:Light Green. DG:Dark Green. E: Erect. SE:Semi-Erect. SP: SE: Semiprostrate. P:Prostrate. +: Present. -:Absent

Flower color, foliage color and plant habit in F1 crosses were given in Table 5. In this study no statistical analysis for flower color, foliage color, anthocyanin pigmentation, reddish on stem and plant growth habit traits. Evaluations were made according to F1 observations.

In crosses between the white-flowered parents Azkan, Gokce, ILC 533, ILC 1929 and ILC 482 and the pink-flowered parents JG 11, ICCV 96029, ICCV 03107, Black and wild *Cicer* species the F1s were pink. In both crosses between the white-flowered female parents Azkan, Gokce and the white -flowered male parent ILC 482 the F1s were white. KUMAR *et al.*, (2000) also reported such result. Flower color is a useful morphological marker in chickpea (*Cicer arietinum* L.). In chickpea, three major and distinct flower colors are identified, namely pink, blue, and white. About two-thirds of the world germplasm accessions at ICRISAT are pink flowered and nearly one-third have white flowers. Those with blue flowers are rare (PUNDIR *et at*., 1988). The trait is governed by single gene and the violet color is dominant over the white flower color (ATANASOVA and MIHOV, 2006). However, KUMAR (1997) reported a pink-flowered F1 between the two white flowered parents. This indicated that these parents had different genetic structure for their white flower colors. For this reason, he reported that the tri-genic model of inheritance suit to explain this flower color segregation.

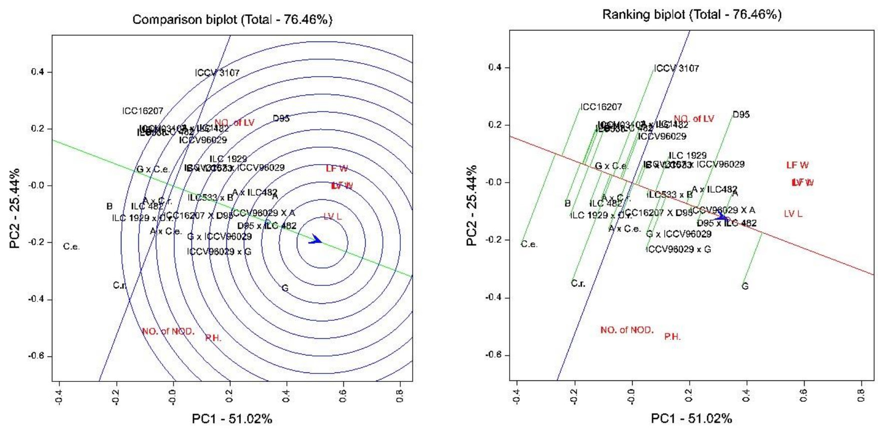

Fig. 2 Comparasion-biplot and Ranking-biplot F1s and parents

A: Azkan, G: Gokce, B: Black, Cr: *Cicer reticulatum*. Ce: *Cicer echinospermum*. D95: Diyar 95, LVL: leave length, LVW: leave width, LFL: leaflet length, LFW: leaf width, NO of LV: number of leaflet per leave, PH: plant height, No of NOD: number of nodes per plant, DAF: days to first flowering, DAP: days to flowering to podded, No of F: number of days from emergence to podded, No of P: number node for the first flower

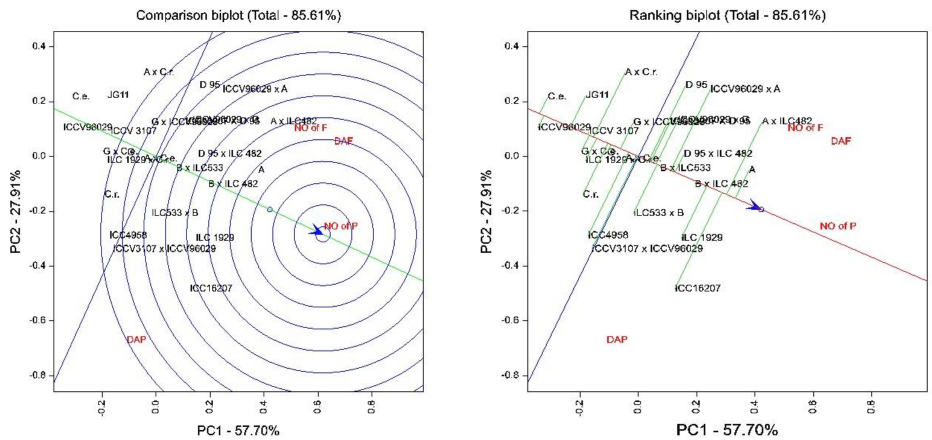

Fig. 3. Comparasion-biplot and Ranking-biplot for F1s and parents

A: Azkan, G: Gokce, B: Black, Cr: Cicer reticulatum. Ce: Cicer echinospermum. D95: Diyar 95, LVL: leave length, LVW: leave width, LFL: leaflet length, LFW: leaf width, NO of LV: number of leaflet per leave, PH: plant height, No of NOD: number of nodes per plant, DAF: days to first flowering, DAP: days to flowering to podded, No of F: number of days from emergence to podded, No of P: number node for the first flower

Generally, in crosses between the green foliaged parents and the dark green foliaged parents the F1s were green or dark green. In crosses between the green foliaged parents and the green or light foliaged parents the F1s were green or light green. BHAPKAR and PATIL (1962), green and other colors were found to be recessive to normal green foliage. SANDHU *et al*., (1993) suggested digenic inheritance of color with dominant and recessive epistasis in F1 normal green foliage is dominant over purple foliage.

Desi chickpea varieties, JG 11, ICCV 96029, ICCV 16207, Black and ICCV 03107, were contained anthocyanin pigmentation in floral pedicel, rachis, and stem, whereas the kabuli chickpea cultivars, Azkan, ILC 482, Gokce, ILC 533 and ILC 1929, were not contain anthocyanin pigmentation in any plant part. When the white-flowered the kabuli parents to the pink-flowered the desi parents were crossed, the F1s showed the anthocyanin pigmentation on various plant parts. AUCKLAND and VAN DER MAESEN (1980) reported yet the genetics of pigmentation in floral and other plant parts is not well understood in hybridization kabuli to desi. MATHUR (1998) reported gene or genes involved in pigmentation have pleiotropic effects on plant stem and floral parts. Wild *Cicer* species showed anthocyanin pigmentation in any plant part. Anthocyanin pigmentation in intra-specific crosses, Azkan × C. *reticulatum*, Gokce × C. *echinospermum* and ILC 1929 × C. *reticulatum* was present or absent in F1s. MUEHLBAUER and SINGH (1987) reported that information on genetics of anthocyanin pigmentation in inter-specific crosses between C. *arietinum* and C. *reticulatum* is lacking. SINGH *et al*. (2006) suggested that anthocyanin pigmentation is produced by two complementary genes in intra-specific crosses and by two duplicate genes in inter-specific crosses in the genus *Cicer*. Further, the genes for anthocyanin pigmentation in corolla have pleiotropic effects on anthocyanin pigmentation in other plant parts.

The growth habit is a crucial determinant of plant architecture. It plays a key role in seed yield component and in adaptation of diverse agroecological environments in chickpea. In moisture limited areas, a prostrate or semi-prostrate growth habit plants is to be desirable to cover the soil surface, to reduce the evaporation from the soil surface and to compete with weeds. Erect plant types are desirable for mechanization (UPADHYAYA *et al*., 2017). E x SE crosses of Azkan × ILC 482, Azkan × JG 11, ICCV 96029 × Azkan, Gokce × ICCV 96029, ICCV 96029 x Gokce, ICCV 03107 × ILC 482 and ICCV 03107 × ICCV 96029 showed dominance of SE over E in F1. E x P crosses of Azkan × C. *reticulatum* showed dominance of SP over E in F1. E x P crosses of Gokce × *C. echinospermum* showed dominance of P over E in F1. SP X E crosses of ICCV 16207 × Diyar 95 and Black × ILC 482 showed dominance of SE over SP in F1. The cultivated desi and kabuli parents were exhibit erect to semi-erect growth habit, whereas wild species were prostrate growth habit. BENLLOCH *et al*., (2015) reported that the plant growth habit usually governed by convoluted interplay of multiple genes. Similarly, SINGH *et al*. (2008) indicated that semi-erect growth habit is dominant to prostrate non-ascending growth habit within C. *arietinum*, while prostrate ascending growth habit of *C. reticulatum* is epistatic to semi-erect and prostrate non-ascending growth habit of C. *arietinum*. SINGH and SHYAM (1959) noted spreading growth habit was dominant to erect growth habit.

Comparasion-biplot and ranking-biplot were created to determine the multivariate relationships between F1 genotypes and their parents, and the relationship between genotype and plant characteristics (Fig 2, 3). PC1 value was 51.02% and PC2 value is 25.44% in GGE Biplot. These two components constituted 76.46% of the total variance. The genotype rank according to an ideal genotype was shown in Fig 2. In Fig 2, ILC 533 × Black, ICCV 96029 × Azkan, Diyar 95 × ILC 482 are closest to ideal F1s.

The stability of F1 and its parents in terms of all traits by the ranking biplot method and the most suitable F1 and parents were shown in Fig 3. F1 crosses and their parents were evaluated for all traits. ICC 16207, ICCV 3107, C. *reticulatum*, C. *echinospermum*, Black, ILC 1929, Azkan × C. *reticulatum*, ILC 1929 × C. *reticulatum*, ILC 482, Azkan × C. *echinospermum*, ICCV03107 × ILC 482, Azkan x JG11, Gokce × C. *echinospermum*, ILC 533, Black × ILC 482, JG 11, ICCV 96029, F1 and their parents performed poorly with below average. Other F1 crosses and parents above the mean line were F1 crosses and parents that could be selected as priority in selection. ILC 533 × Black, ICCV96029 × Azkan, Gokce × C. *echinospermum* were more stable for all traits than other F1 hybrids and parents. The performances of the stable F1 hybrids ILC 533 x Black and ICCV96029 × Azkan were generally above average for all traits. Gokce × C. *echinospermum* was generally below average for all traits. Diyar 95 parent was highest for leave length and width, leaflet length and width, number of leaflets per leave. Gokce genotype had the highest plant height, number of nodes per plant as a parent.

PC1 value in the GGE Biplot graph was 57.70%, PC2 value was 27.91%, and these two components were 85.61% of the total variance (Fig 3). In the comparison biplot, the Black × ILC 533, Black × ILC 482 were the closest to ideal F1s. The stability of F1 and its parents and the most suitable F1 and parents were shown for all traits in the ranking biplot method. Black × ILC 533, Black × ILC 482, Azkan × C. *echinospermum*, ICCV3107 were more stable than other F1s and parents for all traits. The performances of the stable F1 hybrids Black × ILC 533 and Black × ILC 482 were generally above average in terms of all features. Azkan × C. *echinospermum* and ICCV 3107 were generally below average for all traits.

CONCLUSION

In conclusion, the differences due to parents and their F1 crosses were highly significant for all traits. Early F1s were determined with late flowering genotype x early flowering parental cross. It was also determined that days to first flowering had high heritability value. Some F1 crosses exhibited partial-dominance for days to first flowering. Heterosis for tall plant height ranged from 3.70 to 28.80%. Heritability estimate for plant height was medium. The estimated values of potence ratios in F1 crosses for the plant height were positive and negative with over-dominance and partial-dominance. The differences among genotypes for leave length and width, leaflet length and width were significant. The heterosis and heterobeltiosis for these traits positive and negative in positive directions among F1s. Heritability estimates for leave length and width were medium. The differences among genotypes for internode length and thickness were significant. The internode thickness is high in the lower parts of the stem, while the internode length is high in the middle and upper parts of the stem. The white-flowered parents × the pink-flowered parents were generated the pink flowers in F1s. In foliage color, when the green foliaged x dark green foliaged were crossed, the F1s were green or dark green. Also, when Desi x kabuli and kabuli x wild cicer were crossed, the anthocyanin pigmentation was determined on various plant parts in F1s.

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KARAKTERIZACIJA U F1 GENERACIJI GENOTIPOVA KABULI, DESI I DIVLJI *CICER* ZA OSOBINE BILJAKA

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Izvod

Važno je razumeti veličinu promena u varijaciji nastalih ukrštanjem sorti gajene leblebije sa uskom genetskom osnovom, tipova desi i kabuli, i *C. reticulatum* i *C. echinospermum*, koje su blisko srodne vrste sa kultivisanom leblebijom. Studija je sprovedena na Univerzitetu Dikle, Poljoprivredni fakultet, Dijarbakir, Turska, 2023. godine. Eksperiment je postavljen u randomizovanom kompletnom blok dizajnu sa tri ponavljanja. Desi × kabuli, kabuli × kabuli i kabuli × divlji *Cicer* F1 ukr[tanja i njihovi roditelji su ocenjeni da bi se procenili heterozis, heterobeltioza, odnos potencije i naslednost za dane do prvog cvetanja, visina biljke, broj nodusa po biljci, cvet i boju lišća, pigmentaciju antocijana i navike rasta biljaka. Razlike među genotipovima bile su značajne za sve ove osobine. Veličina heterozisa se razlikovala između osobina i ukrštanja. Za dane do prvog cvetanja, heterozis za rano ukrštanje se kretao od -2,56% do -7,13%. Azkan (kasni) × *C. reticulatum* (srednje rani) (-14,06%) imao je najveću negativnu heterobeltiozu za dane do prvog cvetanja. Visoka heritabilnost je procenjena za dane do prvog cvetanja, dane od nicanja do pojave mahuna i dane od cvetanja do pojave mahuna. Procenjene vrednosti odnosa potencije u većini F1 ukrštanja bile su negativne za broj dana do prvog cvetanja. Kod ukrštanja roditelja sa belim cvetovima Azkan, Gokce, ILC 533, ILC 1929 i ILC 482 i roditelja sa ružičastim cvetovima JG 11, ICCV 96029, ICCV 03107, crne i divlje vrste *Cicer*, F1 su bile ružičaste. Kada su ukršteni roditelji kabuli sa belim cvetovima i roditelji sa ružičastim cvetovima, F1 su pokazali pigmentaciju antocijana na različitim delovima biljke.

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