

## Diallel analysis in chickpea

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**Summary:** This research was carried out at Dicle University, Faculty of Agriculture during the spring season in 2020. Four chickpea varieties (Cagatay, ILC 3279, Ak 71114 and Spanish chickpea) were used. Genetic parameters were estimated for plant and agricultural traits in 4 parents and their 6  $F_2$  combinations obtained from their half-diallel crossbreeding in chickpea. Half diallel genetic parameters, ratios and graphs ( $V_r, W_r$ ) were estimated using to methods of Hayman (1954a, 1954b, 1960) in the experiment. The study was carried out randomized complete blocks design with three replications. In the study, days to first flowering, plant height, internode length, the first flower node number, internode thickness was examined. Analysis of variance revealed that differences among genotypes were significant for days to first flowering days, plant height and first flower node number. However, internode length, 5th, 7th and 9th internodes thickness were non-significant. Dominant allele genes are more than the recessive allele genes in the days to first flowering, plant height and first flower node number. Epistatic gene effects were significant in the parents for days to first flowering. Cagatay and ILC 3279 had mostly dominant genes, but Ak 71114 had recessive genes. Additive genetic variance was significant for days to first flowering, plant height and internode length. Internode length for parents was mostly recessive genes, especially Spanish and Ak 71114. The dominant gene effect was significant for the first flower node number. In the narrow sense heritability degree was 42% for plant height and 45% for days to first flowering.

**Keywords:** additive gene action, chickpea, *Cicer arietinum* L., diallel analysis, dominance gene action, heritability, hybrid combinations

### Introduction

Chickpea (*Cicer arietinum* L.,  $2n=2x=16$ ), which is one of the important legumes grown in various countries of the world, belongs to Fabaceae family and Faboideae subfamily, it is edible, self-pollinated with foreign natural pollination varying between 0-1% (Singh et al., 1992), an annual herb. Chickpea, which contains high protein (13-31%) and carbohydrates (54-71%) in its seed, is also very rich in active components such as polyphenols (Kanas & Gazoulis 2022). It is an important source of protein for millions of people who are vegetarian in developing countries, both by choice and because of economic reasons.

In Turkey, chickpea production has a low yield, below the worldwide average. Various diseases such as *Fusarium* wilt and abiotic stress factors such as drought and cold are thought to be responsible for the low yield (Cobos et al., 2007). Therefore, knowledge of the genetic control and inheritance of plant resistance to disease and abiotic stress is essential for the development of strategies aimed at efficient selection and breeding.

Disease resistant and high yielding chickpea cultivars have been developed in Turkey and marketed by national agricultural research institutions in recent years, but there is no chickpea cultivar which has several good characteristics. Chickpea varieties that mature earlier and are tolerant to anthracnose (*Ascochyta rabiei* (Pass.) Labr.) have been developed for Turkey. However, these developed cultivars have small seeds and low market demands. In addition, some tall chickpea cultivars have also been developed, which generally have late-maturing and anthracnose-sensitive traits due to the length of the growing season in the region. In order to develop types that will have all the desired characteristics together, the genetic structure of chickpea should be known.

Cobos et al. (2007) reported that the highest heritability in chickpea was grain size (0.90), followed by the number of first flowering days (0.36) and yield

Acknowledgment:  
Financial support for this work was provided by the DÜBAP (FBE.21.001).

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Cite this article:  
Tunç M. & Biçer B. T. (2022). Diallel analysis in chickpea. Ratar. Povrt., 59 (2), 36-42. <https://doi.org/10.5937/ratpov59-37421>



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(0.14). Karami & Talebi (2013) found that both the additive gene effect and the dominance effect were important for the number of days first flowering. It was also found that additive variance in chickpea was effective in plant height, 100 seed weight, flowering time and number of pods (Gowda & Bahl 1978). It has been reported by Şakar & Biçer (2008) that the additive variance in chickpea is important for plant height, 100 seed weight, number of pods and number of days flowering.

The purpose of diallel analysis is to investigate the genetic structure of hybrid progeny populations, and analyze the genetic structure by estimating the parameters of the inheritance of characters. This analysis method is a powerful technique for compartmentalizing phenotypic variance, and it provides a better understanding of the extent and rate of variation resulting from additive gene action and a particular combination of these genes (Danehlouepour et al., 2007).

The aim of this study was to estimate the genetic parameters of the agricultural and vegetative characters of four chickpea cultivars and perform easier and faster studies by knowing the genetic management of these characters in future studies.

## Material and Methods

This research was carried out in the experimental farm of Field Crops, Faculty of Agriculture at Dicle University during 2020 spring season. Four chickpea varieties (Cagatay, ILC 3279, Ak 71114 and Spanish chickpea) were used.

Ak -71114 is semi erect grow habit, earlier, and its hundred seed weight was 30 g. Cagatay is semi erect grow habit, and its hundred seed weight was 47-50 g, leaves and seed color are lighter than other varieties. ILC 3279 is late matured and with small seeded about 28 g in a hundred seed weight, Spanish variety is semi-prostrate growth habit and with large seeded.

The soil structure of the experimental area is loamy, the soil reaction is slightly alkaline, moderately calcareous, and has low organic matter content. The total precipitation amount was recorded 461.2 mm in February, March, April, May and June for the trial field. The maximum temperatures were 10.5 °C, 13.5 °C and 19.2 °C in March, April and May, respectively.

During 2016, Cagatay, ILC 3279, Ak 71114 and Spanish chickpea cultivars were crossed through the reciprocal half diallel method and 9  $F_1$  combinations were grown in the 2017 to obtain  $F_2$  seeds. Experiment was set out randomized complete blocks design (RCBD) with 3 replications.  $F_2$  combinations were sown by hand in 2 m long rows with 45 cm inter-row spacing. Irrigation water and fertilizer were not applied. The number of days first flowering, plant height, first flower node number, the internodes length and the internodes thickness the 5th, 7th and 9th were analyzed in the experiment.

Statistical analyses were performed by TARPOGEN statistical package program developed by Ozcan (1999). Half diallel genetic parameters, ratios and graphs ( $V_r, W_r$ ) were estimated using to methods of Hayman (1954a, 1954b, 1960) in the experiment. In this method, Hayman (1960) has assumed that there is: diploid segregation, no difference between reciprocal crosses, independent action of non-allelic genes, and in the diallel cross, no multiple allelism, homozygous parents and genes independently distributed between the parents.

## Results and discussion

In the 4×4 half-diallel analysis, the variance analysis calculated in the  $F_2$  generation for days to first flowering, plant height, first flower node number, the internodes length and the internodes thickness the 5th, 7th and 9th nodes of the cultivars are given in Table 1.

Table 1. Analysis of variance for properties of chickpea in the  $F_2$  generation

Examined Traits	Means of Square	F Value	Significance
Days to first flowering	71.11	11.31	**
Plant height	1032301.74	16.20	**
First flower node number	17.13	7.16	**
Internodes length	3.98	2.11	ns
Internodes thickness			
The 5 <sup>th</sup> internodes	2119.48	0.82	ns
The 7 <sup>th</sup> internodes	1741.26	0.83	ns
The 9 <sup>th</sup> internodes	1510.38	0.62	ns

\*\* = significant at 1%, \* = significant at 5%, ns = not significant

Variance analysis revealed that, the differences among the genotypes were significant ( $P < 0.01$ ) for the first flowering days, plant height and first flower node number characteristics, but non-significant for internode length, 5th, 7th and 9th node thickness.

In the  $4 \times 4$  half-diallel analysis, the genetic parameters calculated in the  $F_2$  generation for days to first flowering, plant height, the node number of the first flower, the internodes length and the thickness between the 5th, 7th and 9th nodes, the ratios obtained from the parameters, the standard errors of the parameters and t value used in the accuracy of the assumptions were given in Table 2 and Table 3.

The "t" value was not significant ( $t = 1 - b / SH_b$ ) for days to first flowering, plant height, first flower node number and internode length, and the assumption was accepted as valid in  $4 \times 4$  half diallel analysis. An interaction was determined among the genes affecting the number of days of first flowering, plant height, node number of first flower, internode length for allele, and also all genetic parameters were not significant.

Genetic parameters,  $(H_1/D)^{0.5}$  showed that days to first flowering (1.43), plant height (1.45), first flower node number (1.43) and internode length

(2.36) were over-dominance. The frequency of dominant and recessive alleles,  $(H_2/4H_1)$ , was very close to 0.25 for days to first flowering (0.23), plant height (0.25), first flower node number (0.19) and internode length (0.27). This result showed that the genes showed a very close distribution to each other, and the selection for these traits might be highly successful.  $KD/KR$  was greater than 1 (one) and F value being positive indicates that the dominant allele genes are more than the recessive allele genes in the days to first flowering, plant height and first flower node number.

The number of effective genes ( $K = h^2/H_2$ ) could not be determined, because the value was less than 1 for days to number of first flowering ( $K = 0.30$ ), plant height, first flower node number ( $K = 0.15$ ) and internode length ( $K = 0.19$ ). Narrow sense heritability values were low for days to first flowering (45%), plant height (42%), first flower node number (55%) and internode length (11%). Correlation coefficient values were low in Cagatay, ILC 3279 and Spanish parents for days to first flowering ( $r = -0.87$ ), plant height ( $r = 0.80$ ), first flower node number ( $r = 0.98$ ). Dominant genes for internode length were in Cagatay and ILC 3279 parents.

Table 2. Genetic parameters and rates calculated in  $F_2$  generation in terms of first flowering days, plant height, first flower node number and internode length in  $4 \times 4$  half-diallel analysis

Parameters	First Flowering Days		Plant Height		First Flower Node Number		Internodes Length	
	Estimate	Standard Error	Estimate	Standard Error	Estimate	Standard Error	Estimate	Standard Error
E	2.70	±16.26	19755.72	±158784.35	0.81	±3.90	0.60	±1.05
D	46.16	±36.36	595742.1	±355052.59	14.52	±8.72	1.26	±2.34
F	49.38	±93.40	533485.8	±912146.6	21.08	±22.40	-0.35	±6.02
$H_1$	94.06	±105.69	1260049.2	±1032098.2	29.75	±25.34	7.03	±6.82
$H_2$	85.84	±97.56	1252366.3	±952706.07	22.11	±23.39	7.52	±6.29
$D-H_1$	-47.89	±94.90	-664307.1	±926714.47	-15.23	±22.76	-5.77	±6.12
$(H_1/D)^{0.5}$	1.43		1.45		1.43		2.36	
$H_2/4H_1$	0.23		0.25		0.19		0.27	
$KD/KR$	2.20		1.89		3.06		0.89	
$h^2$	25.98	±66.17	316383.46	±646205.47	3.39	±15.69	-0.31	±4.27
K	0.30		0.25		0.15		-0.04	
$H_G$	0.48		0.64		0.40		0.48	
$H_b$	0.45		0.42		0.55		0.11	
$r (Y_r, W_r + V_r)$	0.87		0.80		0.98		0.66	
$t = (1 - b) / SH_b$	0.77		0.49		-0.16		0.67	

\*\* = significant at 1%, \* = significant at 5%, ns = not significant

Table 3. Genetic parameters and ratios calculated in F<sub>2</sub> generation in 5<sup>th</sup>, 7<sup>th</sup> and 9<sup>th</sup> internodal thickness in 4×4 half diallel analysis

Parameters	5 <sup>th</sup> Internodal Thickness		7 <sup>th</sup> Internodal Thickness		9 <sup>th</sup> Internodal Thickness	
	Estimate	Standard Error	Estimate	Standard Error	Estimate	Standard Error
E	817.46	±1430.38	632.83	±854.74	752.87	±1058.72
D	1143.52	±3198.44	2558.03	±1911.25	2387.55	±2367.37
F	768.07	±8216.93	2207.19	±4910.10	2696.88	±6081.37
H <sub>1</sub>	7703.72	±9297.50	4688.33	±5555.80	5936.81	±6881.67
H <sub>2</sub>	6971.93	±8582.30	4146.40	±5128.43	4724.51	±6352.31
D-H <sub>1</sub> )	-6560.21	±8348.16	-2100.31	±4988.52	-3549.26	±6179.01
(H <sub>1</sub> /D) <sup>0.5</sup>	2.60		1.35		1.58	
H <sub>2</sub> /4H <sub>1</sub>	0.23		0.22		0.20	
KD/KR	1.30		1.93		2.12	
h <sup>2</sup>	-275.45	±5821.24	-263.16	±9478.53	-563.38	±4308.67
K	-0.04		-0.06		-0.12	
H <sub>G</sub>	0.40		0.42		0.37	
H <sub>D</sub>	0.10		0.34		0.28	
r (Yr, Wr+Vr)	0.91		-0.46		-0.87	
t=(1-b)/SH <sub>b</sub>	6.30*		-0.06		3.78	

\*\* = significant at 1%, \* = significant at 5%, ns = not significant

The 5th internode thickness, the “t” value was significant ( $t=1-b/S\bar{H}_b=6.30$ ), but 7th ( $t=1-b/S\bar{H}_b=-0.06$ ) and the 9th internode thickness ( $t=1-b/S\bar{H}_b=3.78$ ) were not significant in the 4 × 4 half-diallel analysis. Interaction among the genes for the 5th node thickness was not determined. Therefore, the parent and F<sub>2</sub> hybrids of high standard deviation should be from the analysis, and diallel analysis should be repeated 3 × 3. However, these procedures were ignored due to the insufficient number of parents and replications. For this reason, by examining the genetic parameters and their ratios and the Wr-Vr graph, only the existing genetic structures of the parents used and the F<sub>2</sub> hybrids were examined, not to select for the 5th internode thickness. The 5th [(H<sub>1</sub>/D)<sup>0.5</sup>=2.60], 7th (1.35) and 9th (1.58) internode thickness traits were overdominance. The 5th (KD/KR=1.30), 7th

node (1.93) and 9th internode thickness (2.12) values had more dominant genes than recessive genes. Heritability (10%, 34% and 28%, respectively) was quite low. Correlation coefficient value for 5th internode thickness ( $r=0.91$ ) in Spanish parent were short noded compare to other parents.

Wr-Vr graph of variance (Vrx) and covariance (Wry) values calculated were given in Figures 1 and 2. Wr-Vr graph showed that the regression line for days to first flowering ( $a=-5.474$ ) and plant height ( $a=-120153.09$ ), first flower node number ( $a=-4.514$ ) and internode length ( $a=-0.301$ ) traits were cut the y-axis on the negative side, thus, the inheritance of these traits governed by overdominance.

Epistatic gene effects for days to first flowering were significant in parents. Çagatay and ILC 3279 had mostly dominant genes, but Ak 71114 had

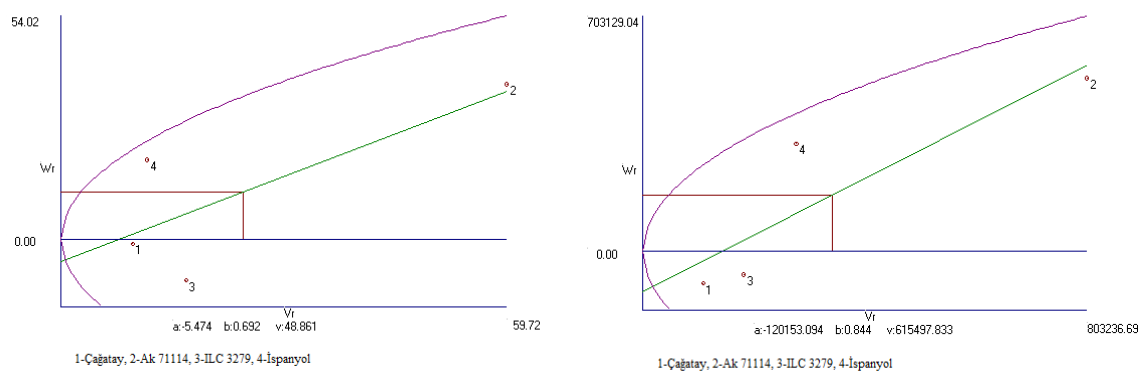


Figure 1. Wr/Vr graph for first flowering days and plant height

recessive genes. Anbessa et al. (2006) reported that late flowering was dominant over early flowering and there was additive  $\times$  additive digenic interactions. Bicer & Sakar (2008) reported that the number of flowering days was controlled by two double dominant genes. Whereas, Sundaram et al. (2018) found that days to first flower governed by additive  $\times$  additive, and dominance  $\times$  dominance effects, also Kivrak et al. (2020) estimated that its narrow sense heritability value was as 80%.

Epistatic gene effect for plant height was significant in Cagatay, Ak 71114, ILC 3279 and Spanish parents, and Cagatay and ILC 3279 parents had dominant genes. Bicer & Sakar (2008) found that this character was controlled by at least one double-acting gene. Singh et al. (1992) reported that there was predominantly additive inheritance. Researchers reported that the heritability in the narrow sense ranged from 42% (Karami, 2011; Karami & Talebi, 2013) to 43% (Kivrak et al. 2020).

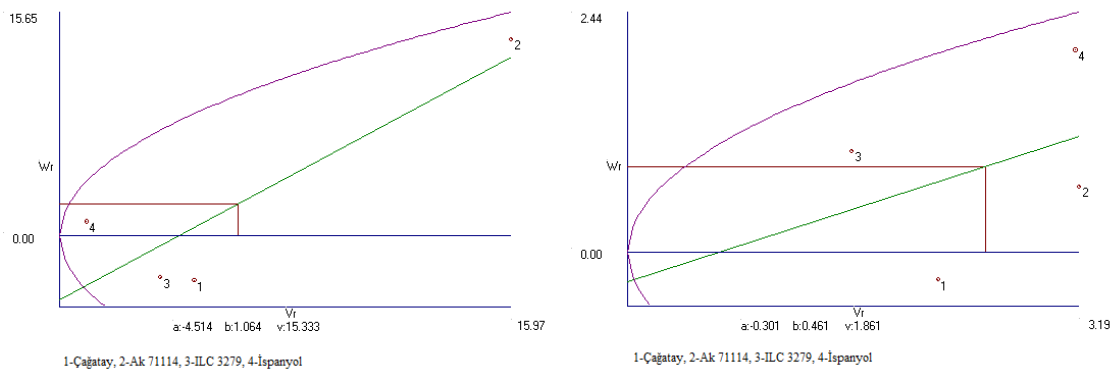


Figure 2. Wt/Vr graph of first flower node number and internode length

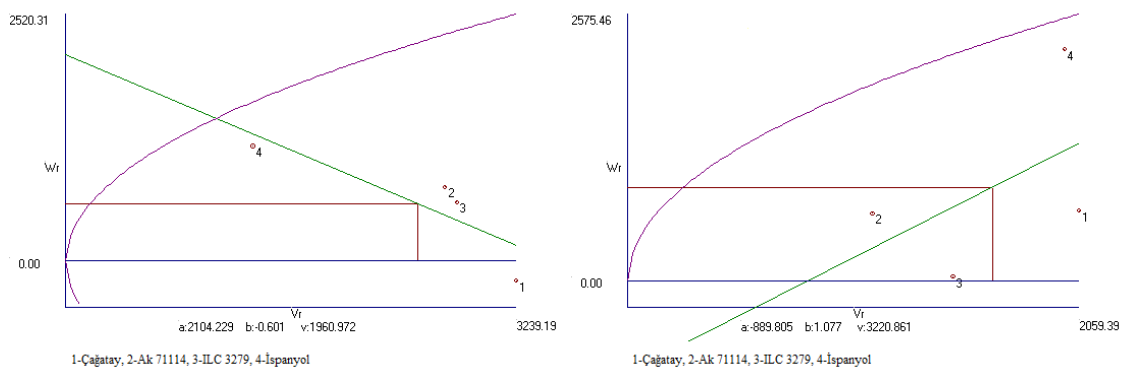


Figure 3. Wt/Vr graph of 5th and 7th internodes thicknesses

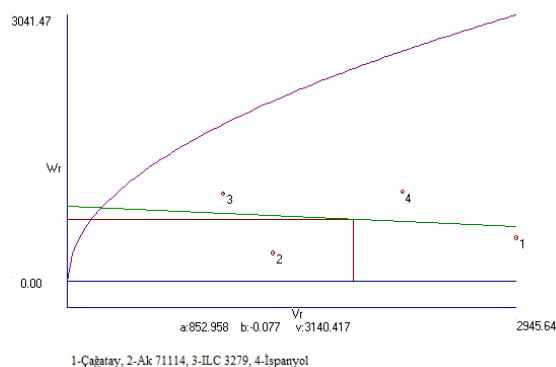


Figure 4. Wt/Vr graph of 9th internodes thickness

Epistatic gene effects among parents were significant for first flower node number and internode length. Spanish parent had more dominant genes for the node number of the first flower, and ILC 3279 had recessive and dominant genes, but Ak 71114 had more recessive genes. Internode length for parents was mostly recessive genes, especially Spanish and Ak 71114 parents (Figure 2).

Partial dominance in inheritance was significant 5th ( $a=2104.229$ ) and 9th internode thickness ( $a=852.958$ ) traits. Overdominance was in 7th internode thickness ( $a=889.805$ ) traits. Epistatic gene effects were significant in parents, and they had recessive genes rather than dominant genes (Figures 3 and 4).

## Conclusions

This study investigated days to first flowering, plant height, first flower node number, internode length and 5th, 7th and 9th internode thickness in chickpea. Genetic parameters were analyzed by the half diallel method, and regression graphs were created.

Analysis of variance revealed that differences among genotypes were significant for days to first flowering days, plant height and first flower node number. However, internode length, 5th, 7th and 9th internodes thickness were non-significant. Therefore, it confirmed that significant variation the genotypes analyzed for traits and could be used as materials in breeding program.

Epistatic gene effects were significant in the parents for days to first flowering. The inheritance was governed by over-dominance for days to first flowering, plant height, node number and internode length of the first flower. The frequency of the dominant and recessive alleles showed that the values were very close to 0.25 for days to first flowering, plant height, first flower node number and internode length characteristics show that the genes were very close to each other, and thus the selection to be made for these traits had a high chance of success for selection program.

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## Dijalelna analiza nauta

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**Sažetak:** Ogled je postavljen na Poljoprivrednom fakultetu Dicle Univerziteta u Turskoj u prolećnoj sezoni 2020. Genetički parametri su određeni za osobine 4 roditelja i njihovih 6 F<sub>2</sub> kombinacija dobijenih poludijalelnim ukrštanjem nauta. Ogled je ispitao broj dana do cvetanja, visinu biljke, dužinu i debljinu internodije. Sabirna genetska varijansa je bila značajna za broj dana do cvetanja, visinu biljke i dužinu internodije. U užem smislu, stepen naslednosti je bio 42% za visinu biljke i 45% za broj dana do cvetanja.

**Ključne reči:** Cicer arietinum L., dijalelna analiza, hibridne kombinacije, inhibitorno dejstvo gena, naslednost, naut, sabirno dejstvo gena

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