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Genetic Variability Studies in F_2 Generations of Determinate High Yield Dry Bean Lines for Seed Yield and Yield Components

Nur Banu TEKİN [1], Ercan CEYHAN[2,*]

[1] Selçuk University, The Graduate School of Natural and Applied Science, Department of Field Crops, Konya, Türkiye
[2] Selçuk University, Faculty of Agriculture, Department of Field Crops, Konya, Türkiye

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ABSTRACT

Dry bean is the third most important pulse crop which is widely adapted and can improve soil fertility in Türkiye. The genetic variability and association studies help in selection which would increase the yield potential of dry bean. The F_2 generation and parents (Kınalı, Alberto, Great, Göynük, Özmen) obtained by diallel hybrid method (5 x 5 and 20 combinations were obtained) were sown in the experimental field of Selçuk University Faculty of Agriculture in 2021.In the research, measurement, counting, weighing and analysis of plant height, pod height, number of seeds per plant, number of seeds per pod, seed yield per plant, hundred-seed weight, protein ratio, protein yield in the plant were made. In the F_2 generation, the seed yield values in plant of the hybrids are between 23.63 g/plant (Kınalı x Özmen) and 97.45 g/plant (Alberto x Kinalı). Heterosis values of seed yield in plant range from -50.72% (Kınalı x Özmen) to 93.01% (Kınalı x Göynük), heterobeltiosis values varies from -58.92% (Kınalı x Özmen) to 77.26% (Göynuk x Özmen). The protein ratio of the crosses in the F_2 generation ranged from 23.05% (Alberto x G Northern 59) to 29.12% (Özmen x Alberto). Heterosis values of protein ratio are between -18.33% (Alberto x G Northern 59) and 7.23% (Özmen x Alberto), heterobeltiosis values are between -22.27% (Alberto x G Northern 59) and 5.82% (Özmen x Alberto). As a result of this research, a sufficient level of genetic variation was determined in the population, considering the agronomic characteristics examined. Determination of suitable parents and hybrids for green bean breeding in terms of sustainability of calcareous soils, agronomic characteristics and inheritance of these parents and hybrids were determined.

1. Introduction

The chemical inputs applied to increase production have brought about the problem of agricultural environmental pollution. One of the alternative agriculture systems that will reduce agricultural environmental pollution is sustainable agriculture (Cukur and Isın 2008; Disbudak 2008). Sustainable agriculture is a system in which agricultural technologies are used in a controlled manner from tillage to the last stage of production without harming the environment (Tan and Koksal 2004; Turhan 2005; Menalled et al. 2008; Eryılmaz and Kılıç 2018). It has been revealed how essential bean farming is for sustainable agricultural practices and a clean environment (Isık 2001). Since the sulfur-containing amino acid content of the bean is higher than that of other legumes, the biological value of its protein is high (Broughton et al. 2003).

It is close to meat protein due to the high protein content in its seeds and the amino acid composition of its proteins. It is abruption from other legumes due to its richness in carbohydrates, calcium, iron, phosphorus, vitamin B_1, prebiotics, various micronutrients and minerals. It has been determined that the protein, fiber, phosphorus, potassium, calcium, sulfur, iron, zinc and magnesium ratios in the bean seed vary depending on the genotype (Sprent et al. 1990; Onder and Ozkaynak 1994b; Broughton et al. 2003; Ceyhan 2007; Câmara et al. 2013; Duc et al. 2015).

In self-pollinating plants such as beans, seed yield is a quantitative trait and is governed by polygenes (Arunga et al. 2010). Selections made by considering only seed yield are not effective. In plant breeding programs, if selection is made with seed yield and other yield components, it is reliable and is thought to increase yield

* Corresponding author email: *eceyhan@selcuk.edu.tr*

(Muhammad et al. 1994; Shimelis 2006; Kwaye et al. 2008).

In the study conducted on hybrids for dry beans, they determined that (SCA) specific combination ability and (GCA) general combination ability were positive and important for plant height, pod height, number of seeds per pod, number of seeds per plant, seed yield per plant, hundred-seed weight, protein ratio, and protein yield in the plant (Zimmermann et al. 1985; Singh and Urrea 1994; Oliveira et al. 1997; Rodrigues et al. 1998; Barelli et al. 2000; Bozoglu and Sozen 2007; Ceyhan et al. 2014a;b). They determined the effect of additive and non-additive genes on plant height, seed yield and hundred-seed weight of bean plants (Ceyhan et al. 2014b). They determined that additive genes were effective on seed yield and harvest index (Zimmermann et al. 1985; Singh and Urrea 1994; Oliveira et al. 1997; Rodrigues et al. 1998; Barelli et al. 2000). They found that a single gene allele was effective on the number of ovaries in a pod (Al-Mukhtar and Coyne 1981), and non-additive genes were effective on the inheritance of pod traits and plant height (Rodrigues et al. 1998; Ceyhan et al. 2014b).

In this study aimed to select high yield and quality genotypes by determining the agronomic characteristics, heterosis and heterobeltiosis values of the F_2 generation, and heritability of the examined traits within the scope of sustainable agriculture.

2. Materials and Methods

The hybridization process was carried out according to Ceyhan (2003). Hybridization was done according to the diallel analysis method as 5 x 5 (20 combinations). Hybrid combinations was obtained by applying diallel hybridization method in Selcuk University plant breeding greenhouse. The obtained F_1 combinations were planted in the Selcuk University experimental field in 2020.

It was determined that the organic matter content of the trial field, which has a clayey soil structure, is at a medium level of 2.25% at a soil depth of 0-30 cm, and at a low level of 1.23% at a soil depth of 30-60 cm. The trial field, which has a high level of lime content (37.6%, 34.4%), has an alkaline structure (pH = 8.05 - 8.00), and there is no problem in terms of salinity. The amount of usable phosphorus (1.79 kg/da – 1.34 kg/da) and zinc (0.32 ppm – 0.34 ppm) in the trial field is quite low. Considering the analysis results of the trial field, it is sufficient in terms of iron (14.74 ppm – 8.74 ppm), copper (1.70 ppm – 1.74 ppm), and manganese (7.50 ppm – 5.76 ppm).

In the province of Konya, which corresponds to the research area, the average temperature was determined as 19.4 ^{0}C by the 21-year meteorological data, and 19.8 ^{0}C in 2021 when the parent and F_2 plants were grown. In the research, the total precipitation during the 21-year growing period was determined as 109.1 mm, and the total precipitation during the cultivation period in 2021 was determined as 134.3 mm. In the research, the average relative humidity was determined as 47.8% in the 21-year growing period and the average relative humidity in the growing period in 2021 was 44.4%.

F_2 generations were sowed on April 29, 2021. It was made on rows of 2 m in length, with a distance of 10 cm between rows of 40 cm. 20 seeds in each row were sown by hand at a depth of 5 cm. Parents and F_2 generations were sowed in the middle 3 rows of hybrids with 2 rows of parent. The experiment was established in the experimental field of the Selcuk University Faculty of Agriculture with 3 replications according to the randomized blocks trial design. To examine the soil characteristics, 15 kg of urea 46% N fertilizer was given at planting times. The trace element was applied to the leaves of the plants in which trace element deficiency was determined. Weed control was done manually and mechanically with a hoe. Harvesting of plants that reached harvest maturity was done in August-September. Measurement and counting of harvested plants were made separately for each plant. In the study, the data on plant characteristics were made according to Ceyhan (2003) and Akcin (1974).

In the research, the measurements made in the F_2 hybrids were first calculated analysis of variance according to the “Random Blocks Trial Design”. Calculations were made using the Diallel Analysis Method for traits with significant variance values of 1% and 5% between hybrids. In the research, analysis and calculations were determined in TARPOPGEN PC Program (Ozcan and Acikgoz 1999).

3. Results and Discussion

The squares mean of diallel variance analysis of some agricultural characteristics examined in the F_2 population are given in the Table 1. General and specific combination variances and their genetic parameters are given in the Table 2. The results of full dialell variance analysis and the mean of squares of all the analyzed features were statistically significant in the study. SCA was important for the combination ability variance analysis in all traits except pod length, plant protein yield, and seed yield per plant. GCA was significant in all properties except protein yield in the plant. In the F_2 generation, υ^2GCA/υ^2SCA negative for plant height indicates an additive gene effect. For other traits, the variances of υ^2GCA/υ^2SCA were less than 1 and H/D$^{1/2}$ variances were more significant than 1, indicating that non-additive gene effect and superior dominance were effective. Our study agrees with other studies (Oliveira Junior et al. 1997; Barelli et al. 2000; Ceyhan et al. 2014b). Rodrigues et al. (1998), Barelli et al. (2000), Ceyhan et al. (2014b). They found is an additive gene effect for the number of pods per plant in beans. Zimmermann et al. (1985), Singh and Urrea (1994), Oliveira Junior et al. (1997), Rodrigues et al. (1998), Barelli et al. (2000), determined the additive gene effect and the dominant gene effect for seed yield in bean plant.

Table 1
Mean squares of initial variance analysis and combining ability variance analysis for investigated traits in a full-diallel hybrid set

Source of Variation	SD	Plant Height	Number of Pods	Number of Seeds per Pod	Number Seeds in Plant
Blocks	2	24,751	41,912	1,207	3527,575
Genotypes	24	827,032**	526,358*	1,855**	7527,468**
Error	48	307,666	258,311	0,421	2544,817
GCA	4	595,971**	146,928	0,941**	2669,416*
SCA	10	70,880	127,167	0,437**	928,961
Reciprocal Effect	10	352,357**	235,149**	0,671**	4025,247**
Error	48	102,555	86,104	0,140	848,272
Source of Variation	SD	Seed Yield per Plant	Hundred Seed Weight	Protein Ratio	Protein Yield in Plant
Blocks	2	1464,523	100,397	0,091	97,494
Genotypes	24	988,453**	107,657**	10,211**	64,37**
Error	48	373,774	16,982	0,104	26,635
GCA	4	339,252*	70,796**	3,797**	19,127
SCA	10	181,879	20,115**	2,449**	10,931
Reciprocal Effect	10	473,18**	37,693**	4,200**	32,918**
Error	48	124,592	5,661	0,035	8,878

* : significant at 5% level , ** : significant at 1% level

3.1. Plant height:

According to the plant height averages of the F_2 generation, parental values are between 49.64 (Göynük) and 93.41 (Kınalı), hybrids are between 35.00 cm (Göynük x Kınalı) and 102.10 cm (Kınalı x Alberto) (Table 2). Other studies show parallelism with our results (Ceyhan 2004; Peksen 2005; Ulker and Ceyhan 2008b; Ceyhan et al. 2009; Babagil et al. 2011; Ceyhan and Kahraman 2013; Ceyhan et al. 2014b; Elkoca and Cınar 2015; Girgel et al. 2018; Yolci 2020).

The plant height trait in the F2 generation of the parents GCA was negative and significant in the Göynük cultivar (Table 3). Kınalı, Alberto and G Northern 59 parents are recommended for use in growing tall plants as they have a positive effect. The Göynük genotype, which has a negative and important GCA effect value, is recommended for the development of short bean varieties in order to transfer resistance for lodging to the next generations. When the SCA effects of crosses in the F_2 generation were examined, it was found that G Northern 59 x Göynük, G Northern 59 x Alberto were positive and significant, Alberto x Kınalı, Göynük x Kınalı, Göynük x Alberto, G Northern 59 x Kınalı, Özmen x Alberto, Özmen x G Northern 59 were determined as negative and significant (Table 3) Among the hybrids, those with positive and significant SCA effects are tall plants. Those with negative and significant effects are combinations that can be used to develop short or medium height varieties. Barelli et al. (2000), Rodrigues et al. (1998), Arunga et al. (2010), Ceyhan et al. (2014b), Ceyhan and Simsek (2021), in their study on plant height, they found the GCA and SCA values of different numbers of parents and crosses to be significant.

The low average of heterosis and heterobeltiosis values in the F_2 generation indicates the presence of additive gene effect. F_2 generation heterosis values ranged from -51.06% (Göynük x Kınalı) to 38.54% (G Northern 59 x Göynük) (Table 4). Rodrigues et al. (1998); Arunga et al. (2010); Ceyhan et al. (2014a) researchers working on heterosis and heterobeltiosis values for plant height stated that they obtained high or low heterosis and heterobeltiosis values in this feature.

Table 2
Mean values for investigated traits in full-diallel hybrid set

Parents	Plant Height		Number of Pods		Number of Seeds per Pod		Number Seeds in Plant	
Kınalı	93,41	ab	50,11	a-f	4,98	b-f	57,52	a-e
Alberto	82,41	a-d	43,28	b-g	4,22	c-g	45,27	cde
Göynük	49,64	de	38,44	c-g	3,78	fg	43,11	cde
G Northern 59	84,70	0a-d	57,07	a-d	5,20	b-f	64,05	a-e
Özmen	65,25	b-e	38,86	c-g	4,33	b-g	38,40	cde
F_2 Hybrids								
Kınalı x Alberto	102,10	a	53,50	a-f	4,98	b-f	195,47	a-e
Kınalı x Göynük	75,17	a-d	56,33	a-e	4,22	c-g	251,83	a
Kınalı x G Northern 59	89,33	abc	51,89	a-f	3,78	fg	174,39	a-f
Kınalı x Özmen	78,00	a-d	22,00	g	5,20	b-f	74,00	fg
Alberto x Kınalı	70,17	a-e	55,00	a-e	7,00	a	219,00	abc
Alberto x Göynük	90,50	ab	28,00	fg	4,00	d-g	86,00	efg
Alberto x G Northern 59	67,46	a-e	31,17	d-g	4,58	b-g	123,08	b-g
Alberto x Özmen	77,67	a-d	39,50	c-g	4,00	d-g	119,83	c-g
Göynük x Kınalı	35,00	e	28,00	fg	3,33	g	62,33	g
Göynük x Alberto	56,67	b-e	42,17	c-g	3,92	efg	116,08	c-g
Göynük x G Northern 59	52,00	cde	37,00	d-g	4,00	d-g	113,00	c-g
Göynük x Özmen	49,10	de	70,67	a	5,00	b-f	180,33	a-f
G Northern 59 x Kınalı	72,53	a-e	48,55	a-f	4,78	b-f	183,11	a-f
G Northern 59 x Alberto	87,17	a-d	63,44	abc	4,89	b-f	232,55	ab
G Northern 59 x Göynük	93,06	ab	69,39	ab	4,39	b-g	196,00	a-e
G Northern 59 x Özmen	81,28	8a-d	45,50	a-g	5,39	bcd	151,16	a-g
Özmen x Kınalı	71,55	a-e	32,50	d-g	5,50	bc	210,00	a-d

Table 2 (Continue)
Mean values for investigated traits in full-diallel hybrid set

Özmen x Alberto	57,25	b-e	30,67	efg	5,33	b-e	135,00	b-g
Özmen x Göynük	61,13	b-e	35,80	d-g	4,13	c-g	113,80	c-g
Özmen x G Northern 59	63,67	b-e	31,67	d-g	4,67	b-g	119,00	c-g
GCA	29,28		12,16		0,16		364,23	
SCA	39,23		123,19		0,89		242,07	
Reciprocal	18,59		149,05		0,53		3176,97	
υ^2GCA / υ^2SCA	0,75		0,10		0,18		1,50	
$H/D^{1/2}$	116,37		296,56		1,74		4147,50	
H^2	0,46		0,54		0,79		0,62	
h^2	0,23		0,04		0,15		0,11	

GCA: General Combining Ability; SCA: Specific Combining Ability; $H/D^{1/2}$: Mean Degree of Dominance; H^2: Broad Sense Heritability; h^2: Narrow Sense

3.2. Number of Pods:

Regarding the F_2 generation, the pod length values of the parents vary between 38.44 units/plant (Göynük) and 57.07 units/plant (G Northern 59), while those of the hybrids vary between 22.00 units/plant (Kınalı x Özmen) and 70.67 units/plant (Göynük x Özmen) (Table 2). Bozoğlu and Gülümser (2000); Ülker and Ceyhan (2008b); Varankaya and Ceyhan (2012); Elkoca and Çınar (2015); Girgel et al. (2018); Konuk and Uzun (2021) found similar results. The G Northern 59 genotype can be developed and used in breeding studies. It was determined that the recessive genes were effective in the Alberto and Özmen parents (Table 3). Conserning the SCA, hybrids G Nord 59 x Alberto, G Nord 59 x Göynük, Göynük x Özmen were positive and significant. While Göynük x Kınalı, Özmen x Göynük, Kınalı x Özmen hybrids were negative and significant (Table 3). It was determined that the hybrids with positive and significant SCA effect could be used to increase the number of pods (Table 3). In the F_2 generation, heterosis values are between -50.55% (Kınalı x Özmen) and 82.83% (Göynük x Özmen), and heterobeltiosis values are between -56.10% (Kınalı x Özmen) and 81.85% (Göynük x Özmen) (Table 4.5). The fact that the ratio of υ^2GCA / υ^2SCA was less than 1 in the F_2 generation indicates that the non-additive gene effect is effective in the inheritance of this trait. The heritability in the broad sense is high in the F_2 generation. The heritability in the narrow sense is low (Table 2). The results of Heterosis and heterobeltiosis obtained in hybrids show that this characteristic is affected by environmental conditions (Ceyhan 2003). In a study conducted for the number of pod characteristics, the positive and negative values of heterosis and heterobeltiosis were obtained and given (Barelli et al. 2000; Arunga et al. 2010; Ceyhan et al. 2014b). This result shows that the number of pod is affected by the environmentals conditions. Since non-additive gene effects are important in this study, it is thought that it would be appropriate to start selection after 3-4 generations.

Table 3
Genetic components for investigated traits in full-diallel hybrid set

Parents	Plant Height	Number of Pods	Number of Seeds per Pod	Number Seeds in Plant
Kınalı	5,818	0,780	0,350*	19,418
Alberto	5,132	-1,020	0,071	-1,975
Göynük	-11,058*	0,404	-0,490**	-18,123
G Northern 59	5,341	5,254	0,091	13,721
Özmen	-5,234	-5,418	-0,021	-13,042
F_2 Populations				
Kınalı x Alberto	2,933	10,471	1,112**	39,104*
Kınalı x Göynük	-11,925	-3,037	-0,049	5,099
Kınalı x G Northern 59	-2,477	0,167	-0,383	-5,080
Kınalı x Özmen	1,943	-12,132*	-0,268	-15,065
Alberto x Kınalı	-15,964**	0,750	0,778**	11,765
Alberto x Göynük	7,261	-8,321	-0,312	-29,549
Alberto x G Northern 59	-5,408	-0,949	-0,117	15,384
Alberto x Özmen	-4,686	-2,498	-0,072	-8,255
Göynük x Kınalı	-20,083**	-14,167**	-1,167**	-94,750**
Göynük x Alberto	-16,917**	7,083	-0,042	15,042
Göynük x G Northern 59	5,997	3,516	-0,096	8,213
Göynük x Özmen	-0,839	14,227*	0,389	27,543
G Northern 59 x Kınalı	-8,403*	-1,666	0,028	4,361
G Northern 59 x Alberto	9,854*	16,138**	0,152	54,735**
G Northern 59 x Göynük	20,528**	16,194**	0,194	41,500**
G Northern 59 x Özmen	0,117	-5,273	0,268	-16,286
Özmen x Kınalı	-3,225	5,250	0,750**	68,000**
Özmen x Alberto	-10,207*	-4,417	0,667**	7,583
Özmen x Göynük	6,017	-17,433**	-0,433*	-33,267*
Özmen x G Northern 59	-8,805*	-6,917	-0,361*	-16,082
G_i	8,204	6,888	0,011	67,862
S_{ij}	34,869	29,275	0,048	288,413
R_{ij}	51,278	43,052	0,070	424,136

G_i : GCA, S_{ij}: SCA; R_{ij}: Reciprocal effect, ** : significant at 1% level; * : significant at 5% level

3.3.Number of seeds per pod:

Parental values for the number of seeds per pod in the F_2 generation ranged from 3.78 units/pod (Göynuk) to 5.20 units/pod (G Northern 59), while the values of crosses were between 3.33 units/pod (Göynük x Kınalı) and 7.00 units. Pieces/pod (Alberto x Kınalı) (Table 2). Many studies conducted have similar results with the result we have obtained (Pekşen 2005; Ülker and Ceyhan 2008a; Varankaya and Ceyhan 2012; Elkoca and Çınar 2015; Girgel et al. 2018; Bildirici and Demir 2019; Gülnur 2019; Aydoğan et al. 2020a; Sirat 2020). In the F_2 generation, the GCA of the parents was positive and significant for Kınalı, and the Göynük genotype was found to be negative and significant. The Kınalı genotype, whose GCA is positive and significant, is considered the parent to be used to increase the number of seeds in the pod (Table 3). Crosses with positive and significant SCA have been determined as combinations that could be used to increase pod length (Table 3). In the studies carried out for the number of seeds in the broad bean, they determined that the GCA and SCA are important (Al Mukhtar and Coyne 1981; Rodrigues et al. 1998; Barelli et al. 2000; Arunga et al. 2010; Ceyhan et al. 2014b). In addition, they determined that SCA and GCA effects are important in determining additive and non-additive gene effects (Griffing 1956; Arunga et al. 2010). Heterosis values in the F_2 generation range from -23.84% (Göynük x Kınalı) to 52.23% (Alberto x Kınalı), and heterobeltiosis values are between -33.02% (Göynük x Kınalı) and 40.66% (Alberto x Kınalı) (Table 4,5). Ceyhan et al., (2014b) observed that heterosis and heterobeltiosis values were negative and positive for the number of grains in the pod. The heritability in the broad sense is high in the F_2 generation The heritability in the narrow sense is low (Table 2). This result shows that the environment affects the number of grains per pod. Since non-additive gene effects are important in this study, it is thought that it would be appropriate to start selection after 3-4 generations.

Table 4
Heterosis (%) values for investigated traits in full-diallel hybrid set

F_2 Populations	Plant Height	Number of Pods	Number of Seeds per Pod	Number seeds in plant
Kınalı x Alberto	16,13	14,58	18,38**	32,29
Kınalı x Göynük	5,09	27,23	29,47**	87,51
Kınalı x G Northern 59	0,31	-3,18	-7,24**	2,17
Kınalı x Özmen	-1,67	-50,55	-14,04**	-51,02
Alberto x Kınalı	-20,19	17,79	52,23**	48,21
Alberto x Göynük	37,07	-31,47	0,04	-26,24
Alberto x G Northern 59	-19,27	-37,88	-2,69*	-19,54
Alberto x Özmen	5,20	-3,82	-6,43**	-10,14
Göynük x Kınalı	-51,06	-36,76	-23,84**	-53,59
Göynük x Alberto	-14,17	3,20	-2,04*	-0,44
Göynük x G Northern 59	-22,58	-22,52	-10,88	-19,01
Göynük x Özmen	-14,52	82,83	23,36**	50,4
G Northern 59 x Kınalı	-18,56	-9,39	-6,15**	7,28
G Northern 59 x Alberto	4,32	26,45	3,75**	52,02
G Northern 59 x Göynük	38,54	45,30	-2,22*	40,48
G Northern 59 x Özmen	8,41	-5,14	13,07**	-3,28
Özmen x Kınalı	-9,81	-26,94	18,19**	39,01
Özmen x Alberto	-22,45	-25,33	24,76**	1,23
Özmen x Göynük	6,43	-7,38	1,97*	-5,09
Özmen x G Northern 59	-15,08	-33,98	-2,06*	-23,86
Mean	-4,39	-3,85	5,38	7,42

** : significant at 1% level; * : significant at 5% level

3.4. Number of Seeds per Plant:

Parental values for the number of seeds in plant in the F_2 generation ranged from 103.14 number/ plant (Göynük) to 175.90 number/ plant (G Northern 59), hybrid data from 62.33 number/plant (Göynük x Kınalı) to 251.83 number/plant (Kınalı x Göynük) (Table 2). Many researchers have obtained results similar to our studies (Ülker and Ceyhan, 2008a; Varankaya and Ceyhan 2012; Bildirici and Demir 2019; Ceyhan and Şimşek 2021). When the GCA of the parents in the F_2 generation is examined, Kınalı and G Northern 59 genotypes are recommended as parents to be used in breeding studies to increase the number of seeds in the plant (Table 3). When the SCA of the crosses were examined for the number of seeds per plant in the F_2 generation, the combinations of Özmen x Kınalı, G Northern 59 x Alberto, G Northern 59 x Göynük, Kınalı x Alberto were found positive and significant, while the combinations of Göynük x Kınalı, Özmen x Göynük were found to be negative and significant (Table 3). Positive and significant hybrids in the F_2 generation can be suggested as combinations to be used to increase the number of seeds in the plant. Heterosis values in the F_2 generation range from -53.59% (Göynük x Kınalı) to 87.51% (Kınalı x Göynük) and heterobeltiosis values range from -62.33% (Göynük x Kınalı) to 52.20% (Kınalı x Göynük) is changing (Table 4,5). The low values of mean heterosis in the F_2 generation indicates that there is an additive gene effect. It shows that complex genes manage this trait. It has been determined that the heritability of the broad sense is high and the heritability is low in the narrow sense, and that the number of seeds per pod is affected by the environment (Table 2). In addition, it was determined that the effect of genotype variance on this trait was low. The high and low heritability in the broad and narrow sense indicates that the non-additive gene effect effectively inherits this trait. Therefore, it would be appropriate to start selection in advanced generations.

3.5. Seed Yield per Plant:

Seed yield values per plant of the parents in the F_2 generation are between 38.40 g/plant (Özmen) and 64.05 g/plant (G Northern 59), hybrids values are between 23.63 g/plant (Kınalı x Özmen) and 97.45 g/plant (Alberto x Kınalı) (Table 6). Many studies on seed yield in plants are similar to our results (Yeken et. al. 2018; Bildirici and Demir 2019; Taşkesen 2019; Ceyhan and Şimşek 2021). When the GCA of the parents for the seed yield per plant in the F_2 generation was examined, the Özmen cultivar was found to be negative and significant. Kınalı and G Northern 59, which were determined as positive, can be recommended for use in breeding studies for seed yield in the plant (Table 7). When the SCA of the hybrids in the F_2 generation was examined, Alberto x Kınalı, Özmen x Kınalı, G Northern 59 x Alberto, Kınalı x Alberto, G Northern 59 x Göynük were positive and significant, Göynük x Kınalı, Özmen x Göynük were negative and significant (Table 7). Positive and important like Alberto x Kınalı, Özmen x Kınalı, G Northern 59 x Alberto, Kınalı x Alberto, G Northern 59 x Göynük can be used as hybrids that will increase the seed yield of the plant in advanced generations. In a study they carried out for GCA and SCA for seed yield, they determined that there were in different numbers and significant effects of SCA and GCA in the generations they obtained (Zimmermann et al. 1985; Singh and Urrea 1994; Oliveira Junior et al. 1997; Rodrigues et al. 1998; Barelli et al. 2000; Arunga et al. 2010; Ceyhan et al. 2014b). Heterosis values in the F_2 generation range from -50.72% (Kınalı x Özmen) to 93.01% (Kınalı x Göynük), heterobeltiosis values range from -58.92% (Kınalı x Özmen) to 77.26% (Göynük x Özmen) (Table 8,9). Generally, seed yield is quantitative feature and is governed by polygenes (Arunga et al. 2010). The low heritability in the narrow sense for the seed yield trait shows that the non-additive gene effect is effective in the inheritance of this trait (Table 6). This reduces the success of selection to be made in early generations for seed yield. For this reason, it would be more appropriate to select for traits with high heritability and easily evident rather than seed yield in early generations.

Table 5
Heterobeltiosis (%) values for investigated traits in full-diallel hybrid set

F_2 Populations	Plant Height	Number of Pods	Number of Seeds per Pod	Number Seeds in Plant
Kınalı x Alberto	9,30	6,77	9,38	18,13
Kınalı x Göynük	-19,53	12,42	13,86	52,20*
Kınalı x G Northern 59	-4,36	-9,08	-9,23	-0,86
Kınalı x Özmen	-16,50	-56,10*	-19,62*	-55,28*
Alberto x Kınalı	-24,88	9,76	40,66**	32,35
Alberto x Göynük	9,81	-35,30	-5,21	-33,87
Alberto x G Northern 59	-20,36	-45,39*	-11,86	-30,03
Alberto x Özmen	-5,76	-8,73	-7,62	-12,32
Göynük x Kınalı	-62,53**	-44,12*	-33,02**	-62,33**
Göynük x Alberto	-31,24*	-2,56	-7,19	-10,74
Göynük x G Northern 59	-38,61*	-35,16	-23,08*	-35,76
Göynük x Özmen	-24,75	81,85*	15,47	31,95
G Northern 59 x Kınalı	-22,36	-14,92	-8,16	4,10
G Northern 59 x Alberto	2,91	11,17	-6,03	32,21
G Northern 59 x Göynük	9,86	21,59	-15,60	11,43
G Northern 59 x Özmen	-4,04	-20,27	3,61	-14,06
Özmen x Kınalı	-23,40	-35,14	10,52	26,91
Özmen x Alberto	-30,53*	-29,14	23,17*	-1,22
Özmen x Göynük	-6,30	-7,87	-4,54	-16,73
Özmen x G Northern 59	-24,83	-44,51*	-10,26	-32,35
Mean	-16,40	-12,24	-2,24	-4,81

** : significant at 1% level; * : significant at 5% level

3.6. Hundred-seed weight:

In the F_2 generation, the values for the 100 seed weight of the parents are between 25.11 g (Özmen) and 36.57 g (Göynük), the values for the hundred seed weight of the crosses are between 24.50 g (Özmen x Kınalı) and 43.33 g (Özmen x G Northern) (Table 6). The work done by many researchers for hundred seed weight is consistent with our results (Bıyıklı et al. 2015; Elkoca and Çınar 2015; Yeken et al. 2018b; Bildirici and Demir 2019; Soydaş et al. 2019; Ceyhan and Şimşek 2021). In the F_2 generation, when the GCA of the parents was examined, the Göynük genotype was determined as positive and significant, Özmen as negative and significant. Göynük cultivar, which was found to be positive and important, was determined as the parent to be used to increase the hundred seed weight (Table 7). When the SCA of one hundred seed weight of the crosses in the F_2 generation were examined, the combinations Alberto x Kınalı, Göynük x Kınalı, Alberto x Göynük, Özmen x G

Northern 59, G Northern 59 x Özmen were positive and significant, G Northern 59 x Kınalı, Özmen x Alberto, G Northern 59 x Göynük, Özmen x Göynük, Kınalı x Özmen were negative and significant (Table 7). Hybrids with positive and significant SCA effect were determined as suitable combinations that can be used to increase hundred seed weight. In a study conducted for hundred seed weight, they determined that the GCA and SCA values of the crosses and parents examined were positive and significant (Ceyhan et al. 2014b; Ceyhan and Şimşek 2021; Kepildek and Ceyhan 2021). It has been observed that the heritability extent in the broad sense is high, and the heritability in the narrow sense go out low, there is an environmental effect in the emergence of hundred seed weight (Table 6). The fact that non-additive gene effects are important in the inheritance of hundred seed weight indicates that it would be appropriate to start selection in late generations.

Table 6
Mean values for investigated traits in full-diallel hybrid set

Parents	Seed Yield per Plant		Hundred Seed Weight		Protein Ratio		Protein Yield in Plant	
Kınalı	57,52	a-e	31,47	c-f	25,83	j-m	14,86	a-d
Alberto	45,27	cde	33,70	b-e	26,80	gh	12,13	bcd
Göynük	43,11	cde	36,57	abc	26,39	hıj	11,38	bcd
G Northern 59	64,05	a-e	31,33	3c-f	29,66	a	19,00	abc
Özmen	38,40	cde	25,11	ef	27,52	ef	10,58	bcd
F_2 Populations								
Kınalı x Alberto	65,38	a-e	30,05	c-f	24,32	n	15,98	a-d
Kınalı x Göynük	97,12	ab	35,17	a-d	25,17	m	24,44	a
Kınalı x G Northern 59	67,79	a-d	35,55	a-d	24,42	n	16,55	a-d
Kınalı x Özmen	23,63	e	25,00ef	ef	23,19	op	5,48	d
Alberto x Kınalı	97,45	a	42,00ab	ab	25,38	klm	24,74	a
Alberto x Göynük	44,11	cde	43,00	a	25,95	ı-l	11,45	bcd
Alberto x G Northern 59	48,55	cde	35,25	a-d	23,05	p	11,20	bcd
Alberto x Özmen	52,60	cde	38,83	abc	23,89	no	12,57	bcd
Göynük x Kınalı	31,67	de	41,00	ab	24,40	n	7,72	cd
Göynük x Alberto	55,11	b-e	42,83	a	26,08	ıjk	14,37	a-d
Göynük x G Northern 59	47,38	cde	37,00	abc	27,17	fg	12,87	bcd
Göynük x Özmen	76,41	abc	38,33	abc	26,11	hıj	19,99	ab
G Northern 59 x Kınalı	61,87	a-e	30,22	c-f	27,88	de	17,25	abc
G Northern 59 x Alberto	78,74	abc	31,89	c-f	24,31	n	19,11	ab
G Northern 59 x Göynük	65,14	a-e	30,33	c-f	26,59	ghı	17,28	abc
G Northern 59 x Özmen	48,10	cde	26,89	def	25,32	lm	12,15	bcd
Özmen x Kınalı	57,58	a-e	24,50	f	28,11	cde	16,19	a-d
Özmen x Alberto	38,25	cde	25,55	ef	29,12	ab	11,15	bcd
Özmen x Göynük	39,94	cde	31,57	c-f	28,25	cd	11,29	bcd
Özmen x G Northern 59	57,00	a-e	43,33	a	28,80	bc	16,45	a-d
GCA	42,93		13,03		0,75		2,05	
SCA	171,86		43,36		7,24		6,16	
Reciprocal	348,59		32,03		4,17		24,04	
σ^2GCA/σ^2SCA	0,25		0,30		0,10		0,33	
$H/D^{1/2}$	606,32		101,45		12,91		34,30	
H^2	0,59		0,83		0,99		0,54	
h^2	0,08		0,21		0,12		0,06	

GCA: General Combining Ability; SCA: Specific Combining Ability; $H/D^{1/2}$: Mean Degree of Dominance; H^2: Broad Sense Heritability; h^2: Narrow Sense

3.7. Protein content:

In the F_2 generation, the protein ratio of the parents is between 25.83% (Kınalı) and 29.66% (G Northern 59), and the protein ratio of the crosses is between 23.05% (Alberto x G Northern 59) and 29.12% (Özmen x Alberto) (Table 6). The results of our study are consistent with the results of other researchers (Varankaya and Ceyhan 2012; Gülnur 2019; Aydoğan et al. 2020; Sirat 2020; Yolci 2020; Kepildek and Ceyhan 2021). When the GCA of the parents for the protein ratio in the F_2 generation was examined, G Northern 59, Özmen cultivars were found to be positive and significant, while Kınalı and Alberto cultivars were found to be negative and significant (Table 7). GCA positive and significant genotypes in F_2 generations can be used to increase the protein ratio in breeding studies. When examining the SCA for protein ratio in the F_2 generation, Alberto x Kınalı, G Northern 59 x Kınalı, Özmen x Kınalı, G Northern 59 x Alberto, Özmen x Alberto, Alberto x Göynük, Özmen x Göynük, Özmen x G Northern 59, Alberto x Özmen, Göynük x Özmen were positive and significant, Göynük x Kınalı, Kınalı x Göynük, G Northern 59 x Göynük, Alberto x G Northern 59, Kınalı x Özmen, G Northern 59 x Özmen were negative and significant (Table 7). It has been determined that hybrids that are positive and important in the F_2 generation are combinations that can be used to increase the protein ratio. Heterosis values in the F_2 generation ranged from -18.33% (Alberto x G Northern 59) to 7.23% (Özmen x Alberto), heterobeltiosis values were between -22.27% (Alberto x G Northern 59) and 5.82% (Özmen x Alberto) (Table 8,9). All values calculated for heterosis and heterobeltiosis were found to be significant. The negative mean heterosis and heterobeltiosis values determined for the protein ratio generally affect the protein ratio in a decreasing way. The heritability in the broad sense was high and the heritability in the narrow sense is low (Table 6). As a result, it is thought that genetic variance and environment are effective in the inheritance of protein ratio. Considering the non-additive gene effects in the inheritance of protein ratio, selection should be started in advanced generations.

Table 7
Genetic components for investigated traits in full-diallel hybrid set

Parents	Seed Yield per Plant	Hundred Seed Weight	Protein Ratio	Protein Yield in Plant
Kınalı	5,667	-1,217	-0,694**	1,160
Alberto	0,986	1,822	-0,579**	-0,163
Göynük	-1,777	3,378**	0,103	-0,430
G Northern 59	4,179	-0,546	0,537**	1,439
Özmen	-9,055*	-3,437**	0,634**	-2,006
F_2 Populations				
Kınalı x Alberto	18,673*	1,562	-0,024	4,716*
Kınalı x Göynük	4,416	2,063	-0,770**	0,703
Kınalı x G Northern 59	-1,104	0,791	0,160	-0,348
Kınalı x Özmen	-12,089	-4,456**	-0,436**	-2,967
Alberto x Kınalı	16,034**	5,973**	0,534**	4,377**
Alberto x Göynük	-5,682	3,858*	0,346**	-1,143
Alberto x G Northern 59	2,395	-1,566	-2,427**	-0,766
Alberto x Özmen	-2,594	-0,051	0,300*	-0,621
Göynük x Kınalı	-32,725**	2,917*	-0,387**	-8,363**
Göynük x Alberto	5,500	-0,083	0,064	1,462
Göynük x G Northern 59	-2,232	-3,024	0,093	-0,579
Göynük x Özmen	12,921	1,149	0,296*	3,427
G Northern 59 x Kınalı	-2,958	-2,666*	1,730**	0,349
G Northern 59 x Alberto	15,099**	-1,682	0,626**	3,958**
G Northern 59 x Göynük	8,880*	-3,333**	-0,289**	2,203
G Northern 59 x Özmen	1,339	5,234**	-0,261*	0,217
Özmen x Kınalı	16,975**	-0,250	2,462**	5,354**
Özmen x Alberto	-7,172	-6,640**	2,617**	-0,709
Özmen x Göynük	-18,238**	-3,383**	1,069**	-4,350**
Özmen x G Northern 59	4,452	8,223**	1,744**	2,149
G_i	9,967	0,453	0,003	0,710
S_{ij}	42,361	1,925	0,012	3,019
R_{ij}	62,296	2,830	0,017	4,439

G_i : GCA, S_{ij}: SCA; R_{ij}: Reciprocal effect, ** : significant at 1% level; * : significant at 5% level

3.8. Protein yield:

The parents values of protein yield in the F_2 generation are between 11.38 g/plant (Göynuk) and 19.00 g/plant (G Northern 59), hybrid values are between 5.48 g/plant (Kınalı x Özmen) and 24.74 g/plant (Alberto x Kınalı) (Table 6). Our results are similar to those of other researchers (Ülker and Ceyhan 2008a; Varankaya and Ceyhan 2012; Kepildek and Ceyhan 2021). When we examine the data of the parents' GCA's on protein yield in the plant in the F_2 generation, G Northern 59 and Henna parents are suggested as varieties that can be used in breeding studies (Table 7). When we examine the SCA of hybrids in the F_2 generation, Alberto x Kınalı, Özmen x Kınalı, Kınalı x Alberto, G Northern 59 x Alberto have positive and significant value, and Göynük x Kınalı and Özmen x Göynük combinations have negative and significant value (Table 7). Crosses with positive and significant SCA in the F_2 generation can be recommended for use in breeding studies. Heterosis values in the F_2 generation range from -56.92% (Kınalı x Özmen) to 86.29% (Kınalı x Göynük) heterobeltiosis values range from -48.09% (Göynük x Kınalı) to 75.66% (Alberto x Özmen) (Table 8,9). For protein yield in the plant, heritability in the broad sense was high and heritability in the narrow sense have low (Table 6). This shows that in addition to the genotype variance effect, the environment also has an effect on protein yield. Considering the non-additive gene effects in the inheritance of protein yield, starting selection in late generations is recommended.

Table 8
Heterosis (%) values for investigated traits in full-diallel hybrid set

F_2 Populations	Seed Yield per Plant	Hundred Seed Weight	Protein Ratio	Protein Yield in Plant
Kınalı x Alberto	27,21	-7,76	-7,59**	18,40
Kınalı x Göynük	93,01	3,38	-3,59**	86,29
Kınalı x G Northern 59	11,52	13,23	-11,98**	-2,27
Kınalı x Özmen	-50,72	-11,62	-13,06**	-56,92
Alberto x Kınalı	89,60	28,90	-3,53**	83,25
Alberto x Göynük	-0,17	22,39	-2,40**	-2,62
Alberto x G Northern 59	-11,18	8,41	-18,33**	-28,07
Alberto x Özmen	25,73	32,06	-12,04**	10,65
Göynük x Kınalı	-37,06	20,52	-6,55**	-41,19
Göynük x Alberto	24,73	21,91	-1,92**	22,25
Göynük x G Northern 59	-11,57	8,98	-3,04**	-15,26
Göynük x Özmen	87,50	24,30	-3,12**	82,05
G Northern 59 x Kınalı	1,78	-3,75	0,50**	1,85
G Northern 59 x Alberto	44,07	-1,94	-13,89**	22,78
G Northern 59 x Göynük	21,57	-10,66	-5,10**	13,76
G Northern 59 x Özmen	-6,10	-4,73	-11,45**	-17,87
Özmen x Kınalı	20,06	-13,39	5,40**	27,25
Özmen x Alberto	-8,56	-13,10	7,23**	-1,83
Özmen x Göynük	-2,01	2,36	4,81**	2,81
Özmen x G Northern 59	11,28	53,55	0,75**	11,19
Mean	16,53	8,65	-4,95	10,83

** : significant at 1% level; * : significant at 5% level

Table 9
Heterobeltiosis (%) values for investigated traits in full-diallel hybrid set

F_2 Populations	Seed Yield per Plant	Hundred Seed Weight	Protein Ratio	Protein Yield in Plant
Kınalı x Alberto	13,66	-10,82	-9,25**	7,53
Kınalı x Göynük	68,83**	-3,84	-4,61**	64,44*
Kınalı x G Northern 59	5,84	12,99	-17,66**	-12,91
Kınalı x Özmen	-58,92*	-20,55*	-15,73**	-63,13*
Alberto x Kınalı	69,40**	24,63**	-5,26**	66,43*
Alberto x Göynük	-2,55	17,58*	-3,14**	-5,65
Alberto x G Northern 59	-24,20	4,60	-22,27**	-41,07
Alberto x Özmen	16,19	15,23	-13,20**	3,56
Göynük x Kınalı	-44,95	12,11	-7,54**	-48,09*
Göynük x Alberto	21,75	17,13*	-2,66**	18,44
Göynük x G Northern 59	-26,03	1,18	-8,38**	-32,26
Göynük x Özmen	77,26**	4,82	-5,11**	75,66*
G Northern 59 x Kınalı	-3,40	-3,96	-5,99**	-9,24
G Northern 59 x Alberto	22,95	-5,38	-18,05**	0,59
G Northern 59 x Göynük	1,70	-17,05*	-10,33**	-9,06
G Northern 59 x Özmen	-24,90	-14,19	-14,64**	-36,07
Özmen x Kınalı	0,10	-22,14*	2,17*	8,91
Özmen x Alberto	-15,50	-24,17*	5,82**	-8,12
Özmen x Göynük	-7,36	-13,68	2,66**	-0,79
Özmen x G Northern 59	-11,00	38,30**	-2,88**	-13,45
Mean	3,94	0,64	-7,80	-1,71

** : significant at 1% level; * : significant at 5% level

4. Conclusions

It has been determined that the plant height trait has an additive gene effect. Non-additive gene effects were identified for other traits. The majority of the hybrids showed positive heterosis and heterobeltiosis values for seed yield, indicating that they are suitable for seed yield. The generation we obtained determined that gifted genotypes could be selected and used in advanced generations to develop new bean varieties and increase yield and quality.

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6. References

Akçin A (1974). Erzurum Şartlarında Yetiştirilen Kuru Fasulye Çeşitlerinde Gübreleme, Ekim Zamanı ve Sıra Aralığının Tane Verimine Etkisi ile Bu Çeşitlerin Bazı Fenolojik, Morfolojik ve Teknolojik Karekterleri Üzerinde Bir Araştırma, Atatürk Üniversitesi Ziraat Fakültesi Yayın No: 157, S:1-112, Erzurum, Türkiye.

Al Mukhtar FA and Coyne D (1981). Inheritance and Association of Flower, Ovule, Seed, Pod, and Maturity Characters in Dry Edible Beans *(Phaseolus vulgaris L.), Journal American Society for Horticultural Science*.

Arunga EE, Van Rheenen, HA, Owuoche JO (2010). Diallel Analysis of Snap Bean *(Phaseolus vulgaris L.)* Varieties for Important Traits, *African Journal of Agricultural Research*, 5 (15), 1951-1957.

Aydoğan C, Elkoca E, Haliloğlu K, Aydın M (2020). Bazı İspir Kuru Fasulye *(Phaseolus vulgaris L.)* Hatlarının Seleksiyonu Üzerine Bir Ön Çalışma, *Anadolu Ege Tarımsal Araştırma Enstitüsü Dergisi*, 30 (2), 251-265.

Babagil GE, Tozlu E ve Dizikısa T (2011). Erzincan ve Hınıs Ekolojik Koşullarında Yetiştirilen Bazı Kuru Fasulye *(Phaseolus vulgaris L.)* Genotiplerinin Verim Ve Verim Unsurlarının Belirlenmesi, *Atatürk Üniversitesi Ziraat Fakültesi Dergisi*, 42 (1), 11-17.

Barelli MAA, Goncalves Vidigal MC, Amaral Junior ATD, Vidigal Filho PS, Scapim CA, Sagrilo E (2000). Diallel analysis for seed yield and yield components in *Phaseolus vulgaris* L.. *Acta Scien-tiarum* 22(4), 883-887.

Bıyıklı B, Elkoca E, Aydin M (2015). İspir Kuru Fasulye *(Phaseolus vulgaris L.)* Popülasyonunun Karakterizasyonu ve Seleksiyon Yoluyla Islahı, *Anadolu Tarım Bilimleri Dergisi*, 36 (1), 20-33.

Bildirici N, Demir S (2019). Hakkâri Ekolojik Koşullarında Bazı Kuru Fasulye *(Phaseolus vulgaris L.)* Çeşitlerinin Verim ve Verim Özelliklerinin Belirlenmesi, *Bitlis Eren Üniversitesi Fen Bilimleri Dergisi*, 8 (4), 1250-1257.

Bozoğlu H ve Gülümser A (2000). Kuru Fasulyede *(Phaseolus vulgaris L.)* Bazı Tarımsal Özelliklerin Genotip Çevre Interaksiyonları ve Stabilitelerinin Belirlenmesi Üzerine Bir Araştırma, *Turkish Journal Agriculture and Forestry*, 24, 211-220.

Bozoğlu H, Sözen Ö (2007). Some Agronomic Properties of The Local Population of Common Bean *(Phaseolus vulgaris L.)* of Artvin Province, *Turkish Journal of Agriculture and Forestry*, 31 (5), 327-334.

Broughton WJ, Hernandez G, Blair M, Beebe S, Gepts P, Vanderleyden J. J. P, (2003). Beans (Phaseolus spp.)–model food legumes, 252 (1), 55-128.

Çukur T, Işın F (2008). İzmir İli Torbalı İlçesinde Sanayi Domatesi Üreticilerinin Sürdürülebilir Tarım Uygulamaları, *Ege Üniversitesi Ziraat Fakültesi Dergisi*, 45 (1), 27-36.

Câmara CR, Urrea CA, Schlegel V (2013). Pinto beans *(Phaseolus vulgaris L.)* as a Functional Food, *Agriculture Implications on Human Health*, 3 (1), 90-111.

Ceyhan E (2003). Bezelye Ebeveyn ve Melezlerinde Bazı Tarımsal Özelliklerin ve Kalıtımlarının Çoklu Dizi Analiz Metoduyla Belirlenmesi, *Selçuk Üniversitesi Fen Bilimleri Enstitüsü*. Selçuk Üniversitesi, Konya, 103.

Ceyhan E (2004). Effect of Sowing Dates on Some Yield Components and Yield of Dry Bean *(Phaseolus vulgaris L.)* Cultivars, *Turkish Journal of Field Crops*, 9 (2), 87-95.

Ceyhan E (2007). Yemeklik Tane Baklagiller Ders Notları, *Selçuk Üniversitesi Ziraat Fakültesi Tarla Bitkileri Bölümü*. 33-141.

Ceyhan E, Önder M, Kahraman A (2009). Fasulye Genotiplerinin Bazı Tarımsal Özelliklerinin Belirlenmesi, *Selcuk Journal of Agriculture and Food Sciences*, 23 (49), 67-73.

Ceyhan E, Kahraman A (2013). Genetic analysis of yield and some characters in peas, *Legume Research-An International Journal*, 36 (4), 273-279.

Ceyhan E, Harmankaya M, Kahraman A (2014a). Combining ability and heterosis for concentration of mineral elements and protein in common bean (*Phaseolus vulgaris* L.), *Turkish Journal of Agri-culture* and Forestry 38(5): 581-590.

Ceyhan E, Kahraman A, Avcı MA, Dalgıç H (2014b). Combining ability of bean genotypes estimated by line x tester analysis under highly-calcareous soils. *The Journal of Animal and Plant Sciences* 24(29): 579-584.

Ceyhan E, Şimşek D (2021). Fasulyede Tarımsal Özelliklerin Kalıtımlarının Çoklu Dizi Analiz Metoduyla Belirlenmesi, *Türk Tarım ve Doğa Bilimleri Dergisi*, 8 (1), 215-225.

Dişbudak K (2008). Avrupa Birliği'nde Tarım Çevre İlişkisi ve Türkiye'nin Uyumu.

Duc G, Agrama H, Bao S, Berger J, Bourion V, De Ron AM, Gowda CL, Mikic A, Millot D, Singh KBJC-RiPS (2015). Breeding annual seed legumes for sustainable agriculture: new methods to approach complex traits and target new cultivar ideotypes, 34 (1-3), 381-411.

Elkoca E, Çınar T (2015). Bazı Kuru Fasulye *(Phaseolus vulgaris L.)* Çeşit ve Hatlarının Erzurum Ekolojik Koşullarına Adaptasyonu, Tarımsal ve Kalite Özellikleri, *Anadolu Tarım Bilimleri Dergisi*, 30 (2), 141-153.

Eryılmaz GA, Kılıç O (2018). Türkiye'de Sürdürülebilir Tarım ve İyi Tarım Uygulamaları, *Tarım ve Doğa Dergisi*, 21 (4), 624.

Falconer DS (1980). Introduction to Quantitative Genetics. London. *Oliver and Boyd Ltd.*, 365.

Fonseca S, Patterson FL (1968). Hybrid vigor in a seven parent diallel cross in common winter wheat. *Crop Science* 8: 85-88

Genchev D (1995). Assessment of Tolerance to Stress Factors in Breeding Material of Kidney Beans *(Phaseolus vulgaris L.), Bulgarian Journal of Agricultural Science*, 1 (4), 415-422.

Gülnur Ç (2019). Bazı Kuru Fasulye *(Phaseolus vulgaris L.)* Genotiplerinin Eskişehir Ekolojik Koşullarına Adaptasyonu ile Tarımsal ve Kalite Özelliklerinin Belirlenmesi, *ESOGÜ, Fen Bilimleri Enstitüsü*.

Girgel Ü, Çokkizgin A, Çölkesen M (2018). Bayburt Koşullarında Organik Olarak Yetiştirilen Bazı Yerel Fasulye *(Phaseolus vulgaris L.)* Genotiplerinin Bazı Morfolojik ve Agronomik Özelliklerinin Belirlenmesi Üzerine Bir Araştırma, *Türk Tarım-Gıda Bilim ve Teknoloji dergisi*, 6 (5), 530-535.

Griffing B (1956). Concept of general and specific combining ability in relation to diallel crossing systems, *Australian journal of biological sciences*, 9 (4), 463-493.

Işık M (2001). Yemeklik Dane Bitkiler Yetiştirme Tekniği, *Anadolu Tarımsal Araştırma Enstitüsü, Eskişehir*.

Kepildek R, Ceyhan E (2021). Determination of Some Agronomic Traits of Fresh Bean Parents and Hybrids and Their Heritability with Diallel Analysis Method, *Selcuk Journal of Agriculture and Food Sciences*, 35 (2), 71-82.

Konuk A ve Uzun T (2021). Kuru Fasulye Genotiplerinde Bazı Tarımsal Özelliklerinin Belirlenmesi, *Bahri Dağdaş Bitkisel Araştırma Dergisi*, 10 (2), 161-168.

Kwaye GR, Shimelis H, William PM (2008). Combining ability analysis and association of yield and yield components among selected cowpea lines. Euphytica, 162: 205–210.

Menalled F, Bass T, Buschena D, Cash D, Malone M, Maxwell B, McVay K, Miller P, Soto R, Weaver DJMSU (2008). An introduction to the principles and practices of sustainable farming.

Muhammad G, Ramazan CM, Aslam M, Chaudhry GA (1994). Performance of cowpea cultivars under rain fed conditions. Journal of Agricultural Research (Pakistan), 32:55–61

Oliveira Junior A, Miranda G, Cruz C (1997). Evaluation of the combining ability of dry bean cultivars based on unbalanced circulating and partial diallel crossing systems, *Revista Ceres (Brazil)*.

Önder M, Özkaynak İ (1994). Bakteri Aşılaması ve Azot Uygulamasının Bodur Kuru Fasulye Çeşitlerinin Tane Verimi ve Bazı Özellikleri Üzerine Etkileri, *Tr. J. of Agricultural and Forestry*, 18, 463-471.

Özcan K ve Açıkgöz N (1999). Populasyon genetiği için bir istatistik paket program geliştirmesi. 3. Tarımda bilgisayar uygulamaları sempozyumu, Çukurova üniversitesi, 3(6).

Pekşen E (2005). Samsun Koşullarında Bazı Fasulye (*Phaseolus vulgaris L.*) Genotiplerinin Tane Verimi ve Verimle İlgili Özellikler Bakımından Karşılaştırılması, *Anadolu Tarım Bilimleri Dergisi*, 20 (3), 88-95.

Rodrigues R, Leal NR, Pereira MG (1998). Diallel analysis of six agronomic traits in *Phaseolus vulgaris* L. *Bragantia* 57(2): 241-250.

Singh SP, Urrea CA (1994). Selection for Seed Yield and Other Traits Among Early Generations of Intra and Interracial Populations of the Common Bean, *Revısta Brasıleıra De Genetıca*, 17, 299-299.

Sirat A (2020). Yerel Kuru Fasulye *(Phaseolus vulgaris L.)* Genotiplerinin Tane Verimi, Verim Unsurları ve Bazı Kalite Özelliklerinin Belirlenmesi, *Adnan Menderes Üniversitesi Ziraat Fakültesi Dergisi*, 17 (2), 245-254.

Soydaş V, Aydın M, Elkoca E, İlhan E (2019). Gümüşhane İli Yerel Fasulye Genotiplerinin Morfolojik ve Tarımsal Özellikler Yönünden Karakterizasyonu Üzerine Bir Ön Çalışma, *Anadolu Ege Tarımsal Araştırma Enstitüsü Dergisi*, 31 (2), 143-160.

Shimelis HA (2006). Associations of yield and yield components among selected durum wheats (*Triticum turgidum L.*). South African Journal of Plant and Soil, 23(4), 305–310.

Sprent JI, Sprent PJNFOP (1990). Nitrogen fixing organisms: pure and applied aspects.

Tan S, Köksal H (2004). Sürdürülebilir Tarım. Tarımsal Ekonomi ve Araştırma Enstitüsü. TEAE-BAKIŞ Sayı 5 Nüsha:2, 4 s.

Taşkesen S (2019). Bazı Kuru Fasulye *(Phaseolus vulgaris L.)* Genotiplerinin Erzincan Koşullarındaki Verim ve Verim Özelliklerinin Belirlenmesi, *Fen Bilimleri Enstitüsü*.

Turhan Ş (2005). Tarımda Sürdürülebilirlik ve Organik Tarım, *Tarım Ekonomisi Dergisi*, 11 (1 ve 2), 13-24.

Ülker M, Ceyhan E (2008a). Orta Anadolu Ekolojik Şartlarında Yetiştirilen Fasulye *(Phaseolus vulgaris L.)* Genotiplerinin Protein ve Bazı Mineral Oranlarının Belirlenmesi, *Selcuk Journal of Agriculture and Food Sciences*, 22 (46), 90-97.

Ülker M, Ceyhan E (2008b). Orta Anadolu Ekolojik Şartlarında Yetiştirilen Fasulye *(Phaseolus vulgaris L.)* Genotiplerinin Bazı Tarımsal Özelliklerinin Belirlenmesi, *Selcuk Journal of Agriculture and Food Sciences*, 22 (46), 77-89.

Varankaya S, Ceyhan E (2012). Yozgat Ekolojik Şartlarında Yetiştirilen Fasulye *(Phaseolus vulgaris L.)* Genotiplerinin Bazı Tarımsal Özelliklerinin Belirlenmesi, *Selcuk Journal of Agriculture and Food Sciences*, 26 (1), 27-33.

Yeken MZ, Kantar F, Çancı H, Özer G, Çiftçi V (2018). Türkiye'deki Yerel Phaseolus vulgaris Populasyonlarını Kullanarak Kuru Fasulye Çeşitlerinin Islahı, *Uluslararası Tarım ve Yaban Hayatı Bilimleri Dergisi*, 4 (1), 45-54.

Yolci MS (2020). Erciş (Van) ekolojik koşullarında bazı fasulye (Phaseolus Vulgaris L.) çeşitlerinin verim ve verim unsurlarının belirlenmesi, *Avrupa Bilim ve Teknoloji Dergisi* (18), 562-567.

Zimmerman MJO, Rosielle AA, Foster KW, Waines JG (1985). Gene action for seed yield and harvest index of common bean grown as sole crop and in intercrop with maize. *Field Crops Research* 12: 319-329.