

Effect of Plant Density and Shading Applications on Yield and Yield Components in Faba Bean (*Vicia faba* L.) VarietiesUmit ACAY^{1*} , Behiye Tuba BİCER¹ ¹Dicle University, Faculty of Agriculture, Department of Field Crops, Diyarbakır*Corresponding author: acay1907@gmail.com

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Abstract

This research was conducted over two years, from 2022 to 2023, in the trial area of Dicle University Faculty of Agriculture, Diyarbakır, Türkiye. The study was aimed to determine the effect of different plant densities and shading on the yield and yield components of some faba bean (*Vicia faba* L.) varieties. In the study used three faba bean varieties (Emiralem, Kuşadası, and Sorgun), two plant densities (10 plants m⁻² and 20 plants m⁻²) and four shading applications (0%, 40%, 75%, and 95%). The experiment was arranged to the randomized complete blocks in split-split plot design with three replications. Main plot treatments consisted of cultivars. Sub-plot treatments were plant density. Sub-subplots treatments were also plant shading treatments. Plant traits such as plant height (cm), number of pods per plant, weight of pods per plant (g), number of seeds per plant, number of seeds per pod, and grain yield (kg ha⁻¹) were examined. According to the combined analysis year, variety, plant density and shading treatments, year x variety, year x plant density, year x shading, variety x plant density and plant density x shading interactions for grain yield were significant. The highest grain yield of 1555.3 kg ha⁻¹ was obtained from 20 plants/m², while the highest values of the number of pods and seeds per plant were obtained from a density of 10 plants/m². However, as plant densities increased, yield characteristics decreased. For shading applications, the highest grain yield (1847.9 kg ha⁻¹) was in the 40% application, while the lowest seed yield (1070.6 kg ha⁻¹) was recorded in the 95% application. Intensive shading increased plant height but caused the plant stems to become spindly. Moderately shaded and unshaded plants had a higher number of pods, seeds per plant and grain yield than heavily shaded plants.

Keywords: Faba bean, *Vicia faba* L., plant density, shading, yield

1. Introduction

Faba bean have a cultivated area of approximately 2.5 million ha and a production of over 4.5 million tons in the world. China is one of the countries that produces the most faba bean in the world. Faba bean, of which our country is known to be one of the gene centers, rank 41st among the countries that produce the most (Faostat, 2023). Although the regions suitable for the maritime climate in our country have a very suitable ecological structure for faba bean cultivation, faba bean production for dry grains is not at the required level (Karakaya, 2023). The total cultivation area of dried faba bean in Türkiye is 176,40 ha, with a production of 4,234 tons and a yield of 2400 kg ha⁻¹. The cultivation area of fresh faba bean is 450,46 da, producing 38,163 tons. Çanakkale is the largest producer of dried faba bean in our country, with 1,432 tons, followed by Balıkesir, Kütahya, Bursa, and Manisa. For fresh faba bean production, Izmir is one of the provinces with the highest production of 4,779 tons. Other significant fresh faba bean producers include Mersin, Antalya, Adana, Bursa, and Balıkesir provinces (Tuik, 2023). Diyarbakır province doesn't produce any fresh or dried faba bean. Faba bean cultivation is not given due importance in our country, and in recent years, there has been a considerable decrease in faba bean cultivation areas worldwide. In underdeveloped and developing countries, local faba bean populations are used extensively as seeds, resulting in a decrease in production due to the inability to develop new varieties that can adapt to biotic and abiotic stress conditions, as stated by Oğuz (2023). Plant density has been considered an important factor determining agricultural yield. It is of great importance especially for large-seeded varieties (Matthews et al., 2001). Optimum plant density (i.e. minimum population producing maximum yield) and appropriate plant arrangement per unit area allow plants to use resources optimally and achieve high yields (Squire, 1993). However, optimum plant density

may vary depending on the plant type or differences in vigor, height and branching between varieties, planting time and season (Anderson et al., 2004). The response of plants to plant density tends to be less in high-yield environments than in low-yield environments. This may also depend on soil type, seedbed conditions and soil moisture, planting depth, planting time, fungicide content of the seeds, weed presence and seasonal rainfall (Matthews et al., 2001). Since plant density has a direct impact on seed cost and yield, information on this subject is extremely important when a new variety is introduced and growing environments change. The optimum density of a plant variety in one agricultural area may not be valid in other areas due to changes in soil type and other environmental conditions, so it is necessary to develop environmental and region-specific recommendations. Sıkca (1994) noted that plant height, number of pods and number of grains in faba bean decreased as plant density increased, but grain yield increased. Light is crucial for plants to grow and develop. When the intensity of light drops to around 40% of full sunlight, the process of carbon assimilation becomes restricted. However, plants can adapt to different light intensities by changing their leaf characteristics. These changes affect the growth rate, plant structure, and morphological characteristics of the plant (Nasrullahzadeh et al., 2007). Raai et al. (2020) discovered that unshaded plants have better growth and physiological responses than shaded plants. They also found that moderately shaded plants produced higher yields per plant than unshaded and heavily shaded plants. Similarly, Saryoko et al. (2021) reported that the combination of variety, shading, and density is important for grain yield. Faba bean is an edible legume plant with high adaptability and protein content that can grow in various climatic conditions. In this research, it was aimed to examine the effects of plant density and shading on yield

and yield characteristics of some faba bean varieties.

2. Materials and Methods

2.1. Materials

This research was conducted in the research and trial area of Dicle University Faculty of Agriculture Department of Field Crops during the early spring growing periods in 2022 and 2023. Emiralem, Kuşadası and Sorgun faba bean varieties were used as a plant materials. Kuşadası variety is a local variety widely grown by producers in the Aegean region. Emiralem: It is an early variety recommended for cultivation in the Aegean and Mediterranean Regions. It is a variety with

a pod length of 15-20 cm and a yield of fresh pods per decare varying between 2-2.5 tons. Sorgun variety is a productive variety that can be grown in all regions of Turkey and used in the fresh food and feed industry. Its pod length is 25 - 30 cm and the number of seeds in the pod is approximately 7-9. For shading, 40% shading, 75% shading and 95% green shading tents were used. The soil samples of the research area were taken from 4 different points and 30 cm depth to represent the entire trial area before the research started. The samples were mixed and a blended sample was taken from them. Some physical and chemical analysis results of soil samples were given in Table 1.

Table 1. Soil analysis results

Saturation (%)	74
Ec dS/cm	1,09
Lime (CaCO3) (%)	9,8
pH	7,47
Phosphorus (kg/da)	1,48
Potassium (kg/da)	88,2
organic matter	1,05
Nitrogen N (%)	0,110

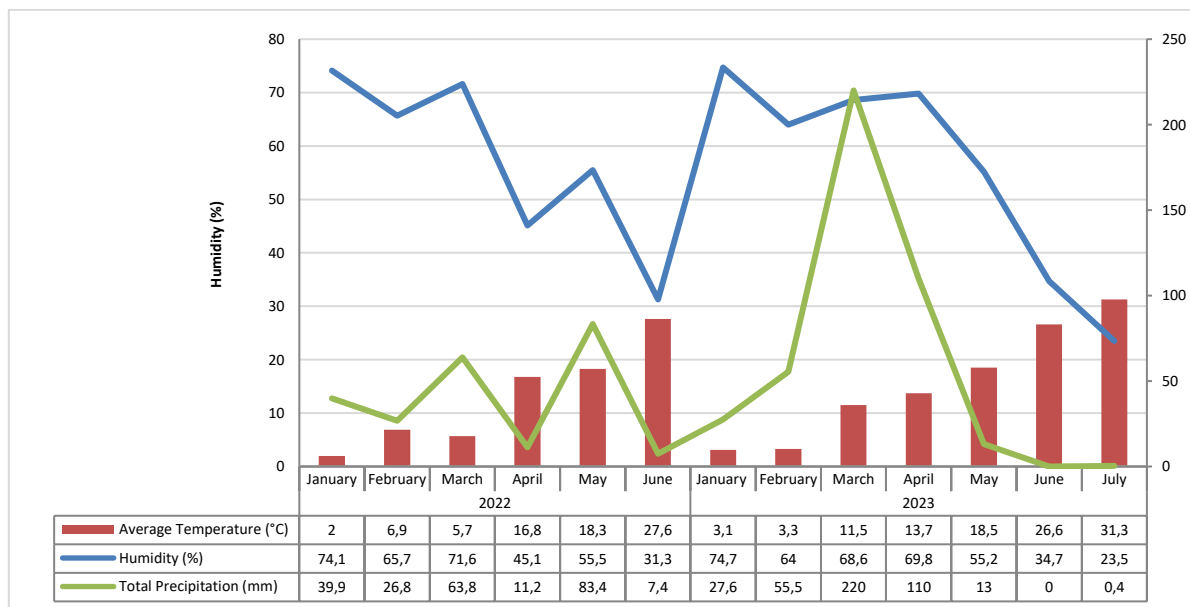


Figure 1. climate characteristics of the trial area

The data for the climate of Diyarbakır province in both 2022 and 2023 was shown in Figure 1. In 2022, the total rainfall from January to June was 232 mm, while in 2023 it was 426 mm. The amount of precipitation during the trial period (February to June)

was 192.6 mm in 2022 and 398 mm in 2023, which was higher than the previous year. In 2022, the total precipitation in February and April was low, but it was high in May. Conversely, in 2023, the total precipitation in February, March, and April was high, and

it was low in May. Due to the very low amount of rainfall in 2022, there was a drought. The average temperature recorded in March, April, and May in 2022 was 17.1 °C, while in the same months in 2023 it was 17.57 °C.

2.2. Methods

Soil cultivation was carried out using a mouldboard plow in the autumn, followed by plowing with a disc harrow in spring before planting. The planting rows were opened using a trial marker. The amount of seeds to be sown was calculated based on plant density of 10 seed/m², 20 seed/m², and open area of 40%, 75%, and 90% shading applications. The experiment was conducted with three replications using a split-plot experimental design divided into random blocks. In the experiment, the main factor was variety, the sub-factor was plant density, and the sub-sub-factor was shading practices. The plots consisted of 4 rows, 4 meters in length, with a distance of 45 cm between rows. The seeds were planted on February 12, 2022, in the first year and on February 7, 2023, in the second year. In this research, three different shading applications were carried out at 40%, 75%, and 90% levels. One of the applications was carried out in an open field. The shading was applied by determining the direction of sunrise and sunset, and then erecting poles to carry the shade nets. The poles had a non-flexible structure that was resistant to environmental effects like rain and wind. The height of the shading poles was kept at 2.0 m. The same shading material was used to cover the sunrise and sunset sides. However, the entire area was not covered, as it could increase humidity and temperature, leading to aphid formation in faba bean plants. The experiment did not involve any fertilization or irrigation practices, and weed control was conducted

manually. Plant height (cm), number of pods per plant, weight of pods per plant (g), number of grains per plant, number of seeds per pod, seed yield per plant (g) and seed yield (kg ha⁻¹) were observed. The data was analyzed using the Jump-Pro 13 statistical package programs and compared using.

3. Results and Discussion

3.1 Number of pods per plant

The combined analysis of the effects of different plant densities and shading applications on plant height in some faba bean varieties over two years was given in Table 2. The combined analysis showed that years, plant density, shading, year x plant density, year x shading and plant density x shading interaction were significant for plant height (Table 2). The plant height was in 46.28 cm for the first year, it was in 67.19 cm for the second year of the experiment. Plant height values of the varieties varied between 54.83 cm and 58.44 cm. The highest plant height (58.05 cm) for plant density was obtained from 20 plants/m². The effect of shading on plant height was significant. The highest value (65.13 cm) was in 95% shading application, and the lowest value (50.12 cm) was in control (Table 2). Burstall and Harris (1983) state that plant was response to light are at physiological and biochemical levels. They reported that increasing shading intensities may cause plant height to increase, but stem thickness and branch number to decrease. Poulain (1984) stated that as plant density (8, 15, 25 and 45 plants/m²) increases in winter faba bean, plant height is also increase. Xia (1995) stated that 50% and 20% shading intensities resulted in thinner and longer main stems than the control group, and Tamaki et al. (1973) reported that increasing the plant density caused the internodes in faba bean to lengthen.

Table 2. Effect of different plant densities and shading applications on plant height in faba bean varieties

Number of pods per plant		2022			2023		
Variety x plant density	Emiralem	Kuşadası	Sorgun	Emiralem	Kuşadası	Sorgun	
10	43,5 c	44,6 bc	43,9 bc	66,1	66,0	68,4	
20	44,8 bc	48,0 b	52,9 a	64,9	69,1	68,6	
Mean	44,4 ab	42,9 b	45,7 a	65,5	67,6	68,5	
		Emiralem	Kuşadası	Sorgun			
10		54,8	55,7	56,15	55,42 b		
20		54,8	58,1	60,75	58,05 a		
Mean		54,8	56,94	58,45			
Years x Shading	0	40	75	95	Mean		
2022	43,5 a	45,7 ab	47,4 a	48,5 a	46,28 b		
2023	56,8 d	62,3 c	67,9 b	81,8 a	67,19 a		
Mean	50,12 d	54,02 c	57,67 b	65,13 a			
		2022			2023		
Variety x Shading	Emiralem	Kuşadası	Sorgun	Emiralem	Kuşadası	Sorgun	
0	42,3 c	44,1 bc	44,1 bc	56,0	53,8	60,5	
40	44,4 bc	46,1 abc	46,6 abc	61,0	63,0	63,0	
75	44,7 bc	47,1 abc	50,5 ab	64,3	69,5	70,0	
95	45,2 bc	48,0 abc	52,4 a	80,8	84,0	80,5	
Plant density x Shading	10			20			
	2022	2023	Mean	2022	2023	Mean	
0	39,0 c	48,0 a	43,5	54,7 e	58,8 de	56,8	
40	41,7 bc	49,7 a	45,7	62,0 cd	62,7 cd	62,4	
75	45,5 ab	49,4 a	47,5	66,0 bc	69,8 b	67,9	
95	49,9 a	47,1 a	48,5	84,7 a	78,8 a	81,8	
Mean	44,0	48,6	66,9	67,5			

The difference between means indicated by the same letters is not statistically significant.

3.2. Number of pods per plant

The combined analysis of the effects of different plant densities and shading applications on number of pods per plant in some faba bean varieties over two years was given in Table 3. Year combined analysis showed that the year, variety, plant density, shading, year x variety, year x plant density, year x shading and plant density x shading interactions were significant for the number of pods per plant (Table 3; Figure 2). The number of pods on the plant was 10.34 in the first year and 10.73 in the second year. For the varieties, the highest number of pods per plant was in Emiralem variety (12.67 pods plant⁻¹), and the lowest value was in Sorgun (9.13 pods plant⁻¹). The highest number of pods per plant density (11.46) was obtained from 10 plants/m². The effect of shading on pod number was significant. As shading intensity increased, the number of pods per plant decreased.

Open area (control=10.26 pods plant⁻¹), low intense shading (40%=12.70 pods/plant) and medium intense shading (75%= 10.58 pods/plant) had high value. The lowest value was in high intense shading (95%= 8.57 pods plant⁻¹) (Table 3). Coelho and Pinto (1989) and López-Bellido (2005) emphasized that faba bean displays great flexibility in plant density applications. They found that the number of branches of the plants and the number of pods increased at low planting density. Xia (1995) stated that 50% and 20% shading intensities produced fewer flowers and pods in faba bean than in the control group. Lake et al. (2019) stated that shading application before flowering increased the number of flowers and pods per plant. Köseoğlu (2006) emphasized that the number of pods increased as the planting density decreased in different planting density applications (5, 10 and 15 cm).

Table 3. Effect of different plant densities and shading applications on number of pods per plant in faba bean varieties

Number of pods per plant		2022			2023		
Variety x plant density	Emiralem	Kuşadası	Sorgun	Emiralem	Kuşadası	Sorgun	
10	12,7	10,2	10,7	13,9	11,3	10,0	
20	12,1	8,5	7,8	12,1	9,1	8,0	
Mean	12,4 a	9,4 b	9,3 b	13,0 a	10,2 b	9,0 b	
Years x Shading	0	40	75	95	Mean		
2022	9,4 b	12,1 a	9,8 b	10,0 b	10,0 b		
2023	11,1 b	13,3 a	11,4 b	7,1 c	10,73 a		
Mean	10,26 b	12,70 a	10,58 b	8,57 c			
Variety x Shading	Emiralem	Kuşadası	Sorgun	Emiralem	Kuşadası	Sorgun	
0	12,1 a	8,4 bc	10,1 cd	13,6 b	7,7 c	9,7 cde	
40	13,1 a	11,1 ab	12,0 bc	16,5 a	12,2 a	11,3 bcd	
75	12,3 a	8,9 bc	11,5 bc	13,0 b	8,3 bc	9,5 cde	
95	12,1 a	9,1 bc	7,1 ef	8,7 de	8,9 bc	5,5 f	
Plant density x Shading	10			20			
	2022	2023	Mean	2022	2023	Mean	
0	11,6 ab	12,0 ab	11,79 b	7,2 c	10,3 bc	8,75 cd	
40	13,5 a	13,5 a	13,52 a	10,7 b	13,1 a	11,89 b	
75	9,6 b	13,2 a	11,37 b	10,1 b	9,6 cd	9,81 c	
95	10,1 b	8,3 d	9,17 cd	10,0 b	5,9 e	7,97 d	
Mean	11,2 a	11,7 a		9,5 b	9,7 b		

The difference between means indicated by the same letters is not statistically significant.

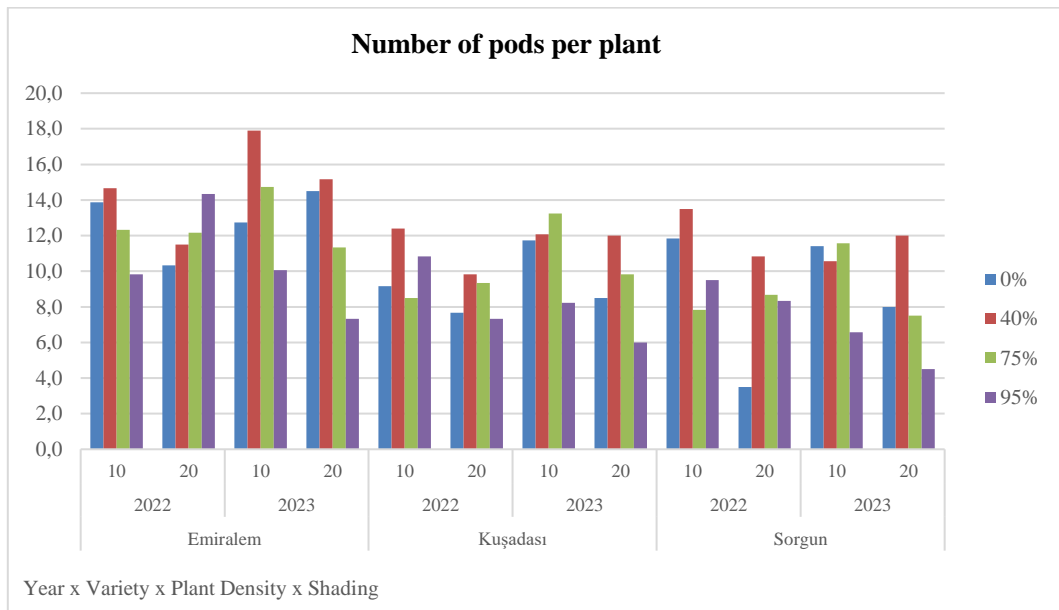


Figure 2. year x variety x plant density x shading for number of pods per plant

3.3. Pod weight per plant

The combined analysis of the effects of different plant densities and shading

applications on pod weight per plant in some faba bean varieties over two years was given in Table 4.

Table 4. Effect of different plant densities and shading applications on pod weight per plant in faba bean varieties

Pod weight per plant		2022			2023		
Variety x plant density	Emiralem	Kuşadası	Sorgun	Emiralem	Kuşadası	Sorgun	
10	18,1 ab	13,8 de	15,5 cd	20,2 a	17,2 bc	16,2 bc	
20	15,8 bcd	11,8 e	12,0 e	17,0 bc	12,7 e	13,6 de	
Mean	16,9 a	12,8 b	13,7 b	18,6 a	15,0 b	14,9 b	
		Emiralem	Kuşadası	Sorgun			
10		19,15	15,50	15,86	16,84 a		
20		16,41	12,25	12,77	13,81 b		
Mean		17,78 a	13,88 b	14,31 b			
Years x Shading	0	40	75	95	Mean		
2022	12,9 b	16,7 a	14,2 b	14,2 b	14,48 b		
2023	16,8 b	21,1 a	17,2 b	9,7 d	16,16 a		
Mean	14,8 b	18,9 a	15,7 b	11,9 c			
		2022			2023		
Variety x Shading	Emiralem	Kuşadası	Sorgun	Emiralem	Kuşadası	Sorgun	
0	17,3 ab	12,1 de	15,6 d	19,6 bc	9,3 e	15,1 d	
40	18,4 a	13,2 bcde	17,2 cd	25,3 a	18,5 a	20,7 b	
75	15,6 abcd	13,1 bcde	17,6 bcd	18,0 bcd	13,8 bcd	15,9 d	
95	16,5 abc	12,8 cde	9,4 ef	11,6 e	13,2 bcde	8,0 f	
Plant density x Shading	10			20			
	2022	2023	Mean	2022	2023	Mean	
0	15,8 ab	18,7 b	17,3 b	10,0 c	14,8 d	12,4 d	
40	18,7 a	23,3 a	21,0 a	14,8 b	18,8 b	16,8 bc	
75	13,8 b	18,9 b	16,3 bc	14,5 b	15,4 cd	15,0 c	
95	14,9 b	10,6 ef	12,8 d	13,4 b	8,7 f	11,0 d	
Mean	15,8 a	17,9 a		13,2 b	14,4 b		

The difference between means indicated by the same letters is not statistically significant.

Combined analysis over years for pod weight per plant showed that, year, variety, plant density and shading, year x plant density, year x shading and plant density x shading interaction were significant (Table 4; Figure 3). The weight of pods on the plant changed between years, from 14.48 g (in 2022) to 16.16 g (in 2023). The highest pod weight was in Emiralem with 17.78 g, and the lowest pod weight was in Kuşadası with 13.88 g. A plant density of 10 plants/m² gave the highest pod weight (16.84 g). Shading affected pod weight. At low shading intensity (40%), pod weight was more effective than both open field and medium and high intensity shading. The highest pod weight, 18.9 g, was obtained from low (40%) shading application (Table 4). Muli (1995) found that dry matter accumulation in the leaves, stems and pods

of bean crops decreased with increasing planting density. Alharbi and Adhikari (2020) stated that the dry matter production in the stems decreased when plant density increases, but when the number of plants decreased, the weight of dried pods per plant increased. Sprent et al. (1977) stated that the ripening process of faba bean accelerates with increasing plant density, but shading slows down the ripening process. They emphasized that the interaction between shading and plant density occurred because the stem dry weight was important. As a result, they reported that the effects of shading and plant density on faba bean were independent of each other. Xia (1995) emphasized that 50% and 20% shading intensities reduced the weight of faba bean compared to the control group.

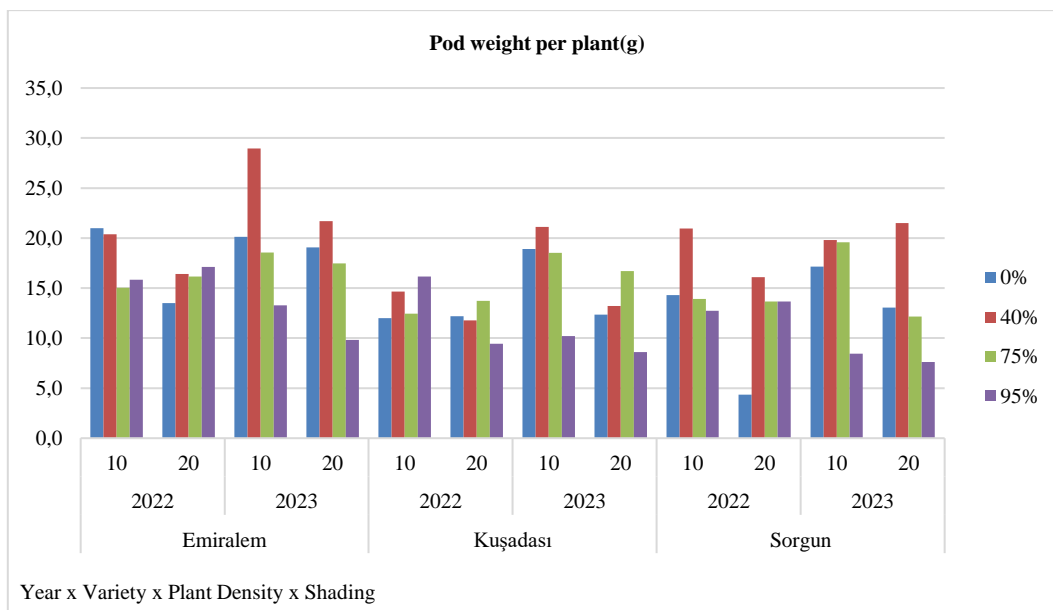


Figure 3. year x variety x plant density x shading for pods weight per plant

3.4. Number of seeds per plant

The combined analysis of the effects of different plant densities and shading

applications on number of seeds per plant in some faba bean varieties over two years was given in Table 5.

Table 5. Effect of different plant densities and shading applications on number of seeds per plant in faba bean varieties

Number of seeds per plant	2022			2023		
Variety x plant density	Emiralem	Kuşadası	Sorgun	Emiralem	Kuşadası	Sorgun
10	18,2 bc	12,6 efg	13,7 de	21,1 a	15,8 cd	12,8 ef
20	15,9 cd	12,0 efg	10,3 g	18,5 bc	13,1 ef	10,9 fg
Mean	17,02 b	12,27 d	12,03 d	19,79 a	14,47 c	11,89 d
	Emiralem	Kuşadası	Sorgun	Mean		
10	19,65	14,18	13,28	15,70 a		
20	17,16	12,56	10,63	13,45 b		
Mean	18,40 a	13,37 b	11,96 c			
Years x Shading	0	40	75	95	Mean	
2022	13,6 b	15,5 a	13,4 b	12,6 b	13,78 b	
2023	16,5 b	19,7 a	15,8 b	9,5 c	15,38 a	
Mean	15,04 b	17,60 a	14,64 b	11,07 c		
	2022			2023		
Variety x Shading	Emiralem	Kuşadası	Sorgun	Emiralem	Kuşadası	Sorgun
0	18,3 ab	13,0 c-f	9,4 g	22,3 b	13,8 de	13,3 de
40	18,8 a	12,2 d-g	15,5 a-d	25,8 a	17,9 c	15,5 cd
75	15,8 abc	12,3 d-g	12,1 efg	18,1 c	17,4 c	11,9 e
95	15,3 b-e	11,6 fg	11,1 fg	13,0 de	8,8 f	6,8 f
Plant density x Shading	10			20		
	2022	2023	Mean	2022	2023	Mean
0	16,9 a	18,0 a	17,44 a	10,3 d	15,0 b	12,63 cd
40	16,8 a	19,8 a	18,29 a	14,1 bc	19,7 a	16,91 b
75	12,1 cd	17,8 a	14,97 b	14,7 ab	13,8 b	14,23 bc
95	13,4 bc	10,8 c	12,11 d	11,8 cd	8,2 d	10,03 e
Mean	14,8 a	16,6 a		12,7 b	14,2 b	

The difference between means indicated by the same letters is not statistically significant.

Year combined analysis showed that year, variety, plant density and shading, year x

variety, year x plant density, year x shading and plant density x shading interaction were

significant for the number of seeds per plant (Table 5; Figure 4). The number of seeds per plant was ranged from 13.78 in the first year to 15.38 in second year. The highest number seeds per plant was in Emiralem variety (18.40), and the lowest in Sorgun variety (11.96). The highest number of seeds per plant for plant density was 15.70, and it obtained from a density of 10 plants/m². The effect of shading on the number of pods was significant, with the highest value being 17.60 in the 40% shading application, and the lowest value being 11.07 in the 95% shading application

(Table 5). Tamaki et al. (1973) stated that as the plant density increased, the number of pods and grains in the plant increased, but the number of branches decreased. Lake et al. (2019) reported that the number of seeds per plant grown in open areas seriously decreased due to the negative effects of environmental conditions, but shading practices increased the number of seeds per plant. Koseoğlu (2006) emphasized that the number of seeds per plant in faba bean increased as the planting density decreased from the applications of different planting densities (5, 10 and 15 cm).

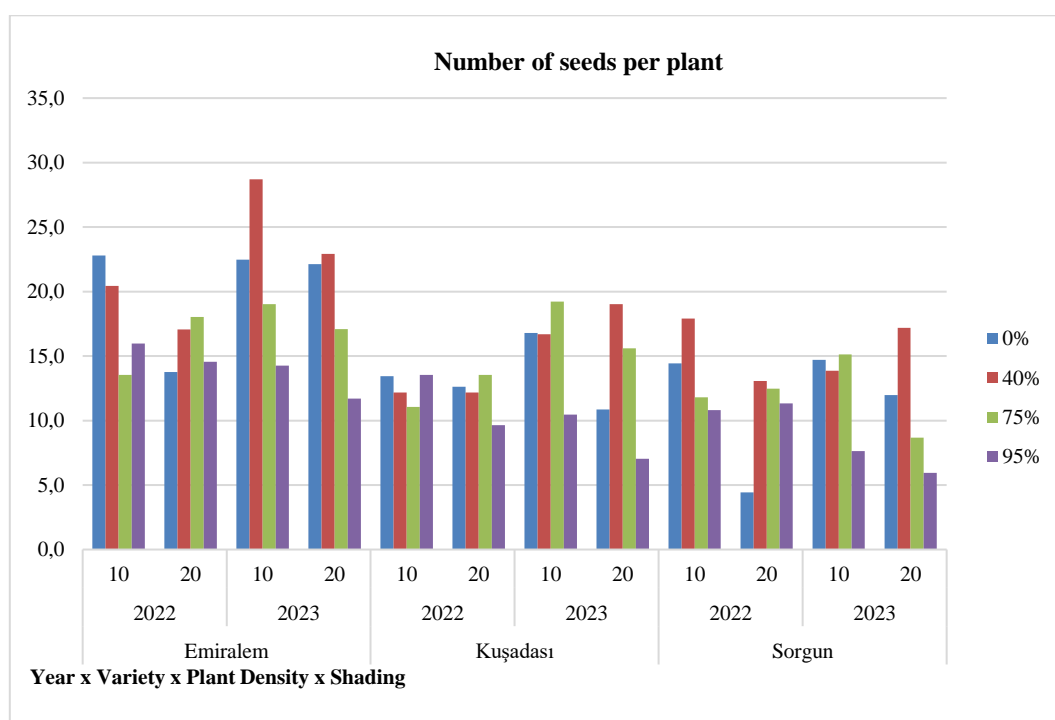


Figure 4. year x variety x plant density x shading for number of seeds per plant

3.5. Seed yield per plant

The combined analysis of the effects of different plant densities and shading

applications on seed yield per plant in some faba bean varieties over two years was given in Table 6.

Table 6. Effect of different plant densities and shading applications on seed yield per plant in faba bean varieties

Seed yield per plant		2022			2023		
Variety x plant density	Emiralem	Kuşadası	Sorgun	Emiralem	Kuşadası	Sorgun	
10	12,4	10,0	11,3	16,6	13,9	12,8	
20	10,8	8,0	8,0	13,5	12,0	10,5	
Mean	11,6 a	9,0 b	9,7 b	15,0 a	12,9 b	11,6 b	
	Emiralem	Kuşadası	Sorgun	Mean			
10	14,49	11,96	12,05	12,83 a			
20	12,15	10,00	9,23	10,46 b			
Mean	13,32 a	10,98 b	10,64 b				
Years x Shading	0	40	75	95	Mean		
2022	9,1 de	11,6 c	9,8 d	9,9 d	10,09 b		
2023	18,1 a	13,5 b	13,4 b	7,8 e	13,19 a		
Mean	11,26 b	14,84 a	11,65 b	8,83 c			
Variety x Shading		2022			2023		
Variety x Shading	Emiralem	Kuşadası	Sorgun	Emiralem	Kuşadası	Sorgun	
0	11,5 abc	8,7	7,2 d	16,2 bc	12,4 d	11,7 de	
40	12,6 ab	9,3 bcd	12,8 a	20,5 a	17,8 ab	16,1 bc	
75	10,7 abcd	9,1 cd	9,7 a-d	14,2 cd	14,1 cd	12,2 de	
95	11,6 abc	9,0 cd	9,0 cd	9,4 ef	7,6 fg	6,4 g	
Plant density x Shading	10			20			
Plant density x Shading	2022	2023	Mean	2022	2023	Mean	
0	11,6 def	15,2 bc	13,4 b	6,6 h	11,6 def	9,1 e	
40	13,1 cd	18,7 a	15,9 a	10,1 efg	17,5 ab	13,8 b	
75	9,8 efg	15,0 bc	12,4 bc	9,9 efg	12,0 de	10,9 cd	
95	10,6 defg	8,7 gh	9,6 de	9,1 fgh	6,9 h	8,0 e	
Mean	11,26	14,41		8,93	11,98		

The difference between means indicated by the same letters is not statistically significant.

Year combined analysis showed that the effect of year, variety, plant density and shading, year x variety, year x shading, year x plant density, year x shading and plant density x shading interaction were significant for seed yield per plant (Table 6; Figure 5). Seed yield per plant varied between 10.09 g in the first year of the experiment and 13.19 g in the second year. The highest grain yield per plant of the varieties was Emiralem variety with 13.32 g, and the lowest was Sorgun variety with 10.64 g. For plant

density, the highest seed yield per plant, 12.83 g, was obtained from a density of 10 plants/m². The effect of shading on seed yield per plant was significant. Values varied between 8.83 g and 14.84 g. Dark shading (95%) reduced seed yield per plant. The highest value was detected in the 40% shading application (Table 6). Lake et al. (2019) stated that shading before flowering increased the number of flowers, number of pods, and number of seeds per pod.

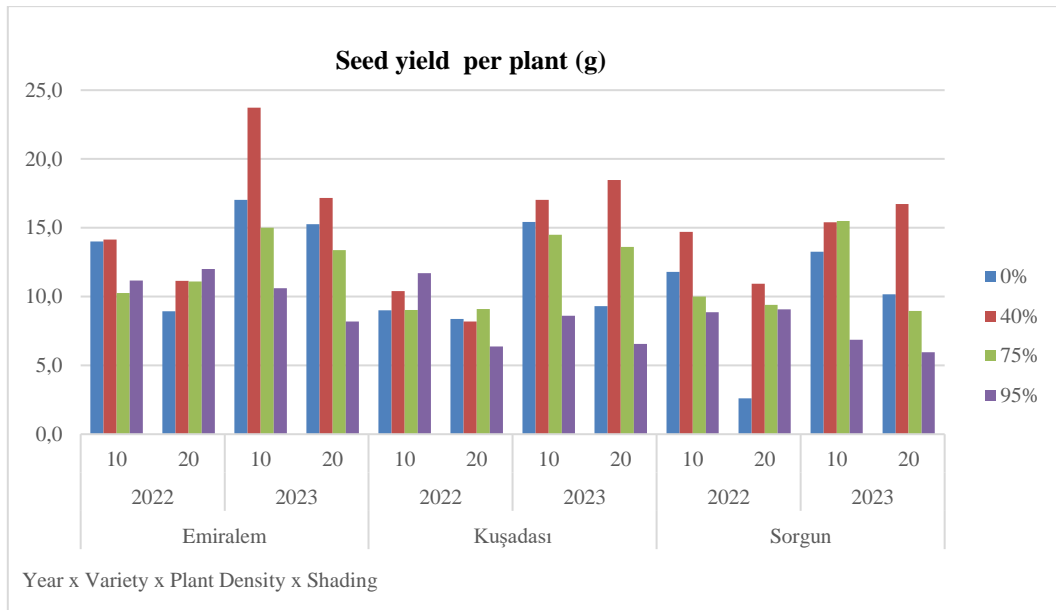


Figure 5. year x variety x plant density x shading for seed yield per plant

3.6. Number of seeds per pod

The combined analysis of the effects of different plant densities and shading

applications on number of seeds per pod in some faba bean varieties over two years was given in Table 7.

Table 7. Effect of different plant densities and shading applications on number of seeds per pod in faba bean varieties

Number of seeds per pod	2022			2023			
	Variety x plant density	Emiralem	Kuşadası	Sorgun	Emiralem	Kuşadası	Sorgun
10		3,13	2,70	2,87	2,82	2,63	2,42
20		2,88	3,01	2,73	3,25	2,69	2,48
Mean		3,00 a	2,85 ab	2,80 ab	3,03 a	2,66 bc	2,45 c
		Emiralem	Kuşadası	Sorgun	Mean		
10		2,98	2,67	2,64	2,76		
20		3,06	2,85	2,60	2,84		
Mean		3,02 a	2,76 b	2,62 b			
Years x Shading	0	40	75	95	Mean		
2022		3	2,7	3	2,8	2,88 a	
2023		2,6 b	2,7 ab	2,9 a	2,6 ab	2,71 b	
Mean		2,81 ab	2,70 b	2,98 a	2,70 b		
Variety x Shading	2022			2023			
	Emiralem	Kuşadası	Sorgun	Emiralem	Kuşadası	Sorgun	
0	3,2 ab	3,3 a	2,6 ab	2,9 ab	2,5 ab	2,3 b	
40	3,1 ab	2,3 b	2,7 ab	3,1 ab	2,6 ab	2,4 ab	
75	2,8 ab	3,0 ab	3,3 a	3,3 a	3,1 ab	2,5 ab	
95	3,0 ab	2,8 ab	2,6 ab	2,9 ab	2,5 ab	2,5 ab	
Plant density x Shading	10			20			
	2022	2023	Mean	2022	2023	Mean	
0	3,1	2,5 ab	2,85 ab	3,0	3,0 b	2,78 ab	
40	2,6	2,7 b	2,55 b	2,8	3,2 ab	2,86 ab	
75	3,0	2,7 ab	2,83 ab	3,1	2,5 a	3,13 a	
95	2,9	2,6 ab	2,82 ab	2,6	2,5 b	2,59 ab	
Mean	2,90	2,62		2,87	2,81		

The difference between means indicated by the same letters is not statistically significant.

Years combined analysis for the number of seeds per pod showed that year, variety and shading, year x variety, year x variety x shading, plant density x shading and variety x plant density x shading interaction were significant (Table 7). The number of seeds per pod was 2.88 in the first year and 2.71 in the second year. The highest number of seeds per pod of the varieties were determined in the Emiralem variety with 3.02, and the lowest in the Sorgun variety with 2.62. For plant density, the highest number of seeds per pod was 2.84, obtained from a density of 20 plants/m². The effect of shading on the number of seeds per pod was significant, with the highest value was 2.98 in the 75% shading application, and the lowest values were 2.70 in the 40% and

95% shading applications (Table 7). Lake et al. (2019) emphasized that shading applications increase seed size and that the negative effects of environmental conditions are reduced by shading applications. Koseoglu (2006) emphasized that the number of pods per plant increased as the planting density (5, 10 and 15 cm) decreased, and as a result, the number of seeds per pod increased.

3.7. Seed yield

The combined analysis of the effects of different plant densities and shading applications on seed yield in some faba bean varieties over two years was given in Table 8.

Table 8. Effect of different plant densities and shading applications on seed yield in faba bean varieties

Seed yield		2022			2023		
Variety x plant density	Emiralem	Kuşadası	Sorgun	Emiralem	Kuşadası	Sorgun	
10	1503 b	1236 f	1264 ef	1695 b	1531 c	1202 f	
20	1815 a	1379 d	1336 de	1892 a	1530 c	1380 d	
Mean	1659,1 b	1307,3 d	1299,9 d	1793,6 a	1530,7 c	1290,7 d	
	Emiralem	Kuşadası	Sorgun	Mean			
10	1598,9 b	1383,5 d	1232,9 e	1405,1 b			
20	1853,8 a	1454,4 c	1357,7 d	1555,3 a			
Mean	1726,4 a	1419,0 b	1295,3 c				
Years x Shading	0	40	75	95	Mean		
2022	1425 b	1581 a	1362 c	1321 c	1422,1 b		
2023	1588 b	2115 a	1630 b	821 c	1538,3 a		
Mean	1506,5 b	1847,9 a	1495,9 b	1070,6 c			
	Emiralem	Kuşadası	Sorgun	Emiralem	Kuşadası	Sorgun	
Variety x Shading							
0	1598 fg	1622 efg	1056 jk	1906 c	1540 g	1318 i	
40	1756 de	1152 j	1835 de	2577 a	2061 b	1706 def	
75	1794 cd	1147 j	1144 j	1754 de	1750 de	1385 hi	
95	1489 gh	1309 i	1160j e	937 k	772 l	753 l	
Plant density x Shading	10			20			
	2022	2023	Mean	2022	2023	Mean	
0	1390 d	1719 c	1554,3 d	1460 cd	1457 d	1458,8 e	
40	1657 a	1901 b	1779,2 b	1505 bc	2328 a	1916,6 a	
75	1154 e	1539 d	1346,6 f	1570 ab	1721 c	1645,1 c	
95	1136 e	744 f	940,3 h	1505 bc	897 e	1200,8 g	
Mean	1334,4 c	1475,9 b		1509,8 b	1600,8 a		

The difference between means indicated by the same letters is not statistically significant.

Year combined analysis showed that year, variety, plant density and shading, year x variety, year x plant density, year x shading, variety x plant density and plant density x shading were significant for seed yield (Table 8). Seed yield values varied between

1422.1 kg ha⁻¹ and 1538.3 kg ha⁻¹ in the first and second years of the experiment. Among the varieties, the highest seed yield (1726.4 kg ha⁻¹) was in the Emiralem variety, but the lowest seed yield (1295. kg ha⁻¹) was in the Sorgun variety. The highest value for seed

yield, 1555.3 kg ha⁻¹, was obtained from a density of 20 plants/m². The effect of shading on seed yield was significant. Seed yield varied between 1070.6 kg ha⁻¹ and 1847.9 kg ha⁻¹. The highest value was found in the 40% shading application, and the lowest values were determined in the 95% shading application (Table 8). Moderately shaded plants exhibited higher seed yield than unshaded and heavily shaded plants. Similarly, Raai et al. (2020) observed that unshaded plants had superior growth and physiological responses than shaded plants. Nasrullahzadeh et al. (2011) emphasized that the seed filling time of bean grown in the shade was longer than the seed filling time of faba bean grown in the open field, and that faba bean with larger grains were obtained from bean grown in the shade. As a result, they stated that shading applications increased the average grain yield of faba bean per unit area compared to open field applications. Poulain (1984) reported that plant density at 25 plants/m² in winter faba bean had higher seed yield than other plant densities (8, 15, 25 and 45 plants/m²). Burstall and Harris (1983) emphasize that increasing shading intensities may cause a decrease in the number of branches and, accordingly, a decrease in seed yield.

4. Conclusions

This research was conducted over two years in 2022-2023 to examine the response of faba bean varieties to plant density and shading practices. When the effect of plant density on yield and yield components was examined; as the plant density decreased, the number of pods per plant, the number of seeds per plant, and the seed yield per plant increased. However, the highest yield was obtained from a density of 20 plants/m². The results showed that the plant density per unit area was more important for yield than the number of pods and seeds per plant. When the effect of shading application on yield and yield factors was examined; as shading intensity increased, only plant height increased. Open area and low and moderately shading increased the number

of pods per plant, number of seeds per plant, seed yield per plant and seed yield. Likewise, the highest efficiency was obtained from low and moderately shading. It is known that open field conditions will reveal some stress factors in the plant. Therefore, plant shading is important for the plant to cope with stress factors, but the intensity of shading should not reverse the situation. It will important to investigate the color and application time of the shadow material as well as the density of the shadow material.

Author Contributions

Umit ACAY: Contributed to the conduct of the research, plant cultivation, analysis, data collection and writing of the article.

Behiye Tuba BİCER: Contributed to the development of the main conceptual ideas of the research, planning of the methods, execution of the research, collection and evaluation of data, and editing of the current article.

Conflicts of Interest

The authors declare that there is no conflict of interest for this study.

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