MAS Journal of Applied Sciences Uygulamalı Bilimler Dergisi ISSN: 2757-5675 masjaps.com

DOI: http://dx.doi.org/10.5281/zenodo.6791786

Araştırma Makalesi / Research Article

The Effects of Yield And Yield Components of Bacteria Inoculation And Different Plant Densities In Broad Bean (*Vicia faba* L.)

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Geliş Tarihi (Received): 20.06.2022 **Kabul Tarihi (Accepted)**: 20.07.2022

Abstract

The study was conducted to determine effects of bacterial inoculation and different plant densities on the yield and some yield components in broad bean in Fethiye ecological conditions. Experiment was laid out in Factorial Randomized Complete Blocks Design with three replicates at the fields of farmer 2021-22 growing years in Fethiye. In the study were investigated the plant height, seed number per plant, grain yield per unit area, harvest index, hundred grain weight, protein ratio number of nodules, and weight of nodules. According to results of the study, the highest value was determined as 292.3 kg da^{-1} from bacterial inoculation and plant density of 60 m^2 $plant^{-1}$, which is statistically in the same group as 50 m^2 $plant^{-1}$ density. The lowest value in terms of grain yield per unit area was found to be 183.6 kg da^{-1} without graft and 20 m^2 $plant^{-1}$.

Keywords: Broad bean, bacteria ınoculation, plant density, yield component, quality

INTRODUCTION

The world population is increasing day by day, while agricultural areas are decreasing. This increases the importance of agricultural products. Edible grain legumes have been used in human and animal nutrition and green manure since ancient times. For a balanced diet, the production of vegetable and animal products with high protein content should be increased. In underdeveloped and developing countries, people suffer from physical and mental diseases and even die as a result of malnutrition. Proteins, one of the building blocks of the human body, are very important in human nutrition. Edible legumes, which contain 18-31.6% protein in their composition, are also rich in vitamins A, B and D (Şehirali, 1988). Legumes are used to increase soil fertility as well as for nutrition. Edible grain legumes are a good alternative crop in areas where monoculture farming is done with grains. This increases the importance of legumes in the world and in our country. Organic matter plays an important role in the vitality and fertility of the soil. The effect of organic matter can be direct or indirect (Gor ve Togay, 2022). In terms of production area and amount, broad bean ranks fourth after chickpeas, lentils and dry beans, which are edible legumes grown in our country (Uçar et al., 2020). Generally, medium and small-seeded pods are used as animal feed, while large-seeded pods are used as green vegetables for human consumption (Çoşkun and Topçu, 2022). Soil should be considered as a living element in which living things can continue to operate, and encouraging Rhizobium bacteria vaccination is one of the most important issues for our country and our farmers, taking into account the needs of not only the plant, but also the soil and plants. The broad bean plant is the most nitrogen-fixing plant among the edible legumes. It can fix 45-552 kg/ha of nitrogen per year. In this way, the broad bean provides 80% of the total nitrogen requirement. It is accepted that approximately 25% of the Rhizobium bacteria population naturally found in the soil are effective in biological nitrogen fixation. In order to increase this rate, seeds should be inoculated with specially prepared bacterial cultures (Pekşen and Gülümser, 1996). Soil moisture has a significant effect on the survival and reproduction of Rhizobium bacteria added to the soil by grafting. Too little or too much moisture in the soil causes the bacteria to disappear to a great extent (Sepetoğlu, 1992). In addition to agricultural processes such as the use of appropriate varieties, fertilization, irrigation and plant protection, the optimum number of plants per unit area is of great importance in increasing the yield per unit area. In this study, it was aimed to compare the effects of different plant frequencies on yield and some yield elements on Salkım broad bean cultivar under Fethiye conditions, with and without bacterial inoculation.

MATERIALS and METHOD

In the study, Salkım broad bean variety was used as plant material. The average number of seeds per pod of this variety is 3-4, and the weight of one hundred seed is 132-154 g. and its average yield is 355-448 kg da^{-1}, and it is also resistant to -8.6 degrees. The grafted cultivars were *Rhizobium leguminosarum* biovar. viceae bacteria culture was inoculated. This study was carried out in a summer cottage in Fethiye District of Muğla, in the 2021-22 growing season. The field where the research was carried out is located in the Kayaköy neighborhood of Fethiye District and 2 km from the main road. The altitude of the trial area is 146 m and

it is located at 36° 34′ 44.8356" north latitude, 29° 5′ 17.4228" east longitude. In the Fethiye District of Mugla Province, the winter season is rainy and mild, and the summers are dry. Mediterranean temperate climate prevails in Fethiye district of Muğla province. Due to its location on the Mediterranean coast, the district is temperate due to its maritime influence. The annual precipitation amount for the long-term average of the growing season of the region where the research was conducted is 885.1 mm, the average temperature is 15.2 °C, and the average relative humidity is 66.6%. According to the results of soil analysis of soil samples obtained from 0-20 cm depth of the study area, clay loamy textured, slightly alkaline reaction, organic matter content was found to be medium, lime content was found to be slightly calcareous, unsalted, phosphorus content was moderate, and potassium content was sufficient. In the autumn of 2021, crowbar plow was applied to the trial area, then a disc harrow was pulled and duplication was made and the seed bed was made ready for planting. The trial was conducted in Fethiye in 2021-22. The experiment was carried out in randomized blocks according to the factorial design with three replications. There are 30 parcels in the experiment. Each plot consists of 4 rows, the row spacing of the parcels is 50 cm. parcel area; It is planned to be 2 m x 5 m = 10 m^2. The amount of seeds to be planted in the parcel was determined so that 50 seeds per square meter. Before sowing, base fertilization was made with 2 kg da^{-1} N and 4 kg da^{-1} P_2O_5. Before sowing, seeds were inoculated into each plot using Rhizobium culture prepared at a density of 106 cells g^{-1} (Vincent, 1970). All processes were carried out on 1.5 m x 4 m = 6 m² areas, leaving the plants within 50 cm from the top of the row and one row on each side from the 5 rows that make up the parcel, as an edge effect. Sowing was done on 25 November 2021. Nodule wet weights were calculated by counting the nodules formed on the roots during the flowering period. The effects of vermicompost on the soil and the environment were investigated by making soil analyzes. The planting activity was carried out manually by drawing lines with a marker on 25.11.2021. Weed control in the experimental area was done with a hoe twice, before and after flowering. The harvest of the experiment was carried out on 02.06.2022. Measurement, counting and threshing processes of the harvested plants were made and their average values were taken. Plot yields were calculated by threshing the plants after they were dried in bunches. Since the study was carried out in winter, irrigation was not done.

RESULTS and DISCUSSION

In the determination of the difference between bacterial inoculation and different plant densities in the broad bean tested in the study in terms of yield and yield components, factorial trial design variance analysis method was used in random blocks, and in the determination of different groups, the Multiple Comparison Test (Düzgüneş et al., 1987) used.

Plant heights

The average plant heights per pod of the plant frequencies varied between 133.5-164.5 cm. The highest plant height was obtained from the application of 164.5 cm and 60 plants/m^2 plant density, and the lowest plant height was obtained from the application of 133.5 cm and 20 plants/m^2 plant density. When the plant height was examined in terms of Rhizobium bacteria inoculation, the highest plant height was obtained from the grafting application with 156.6 cm,

and the lowest plant height was obtained from the non-grafted application (144.1 cm) (Table 1). Kitiki et al. (1992), in their study with broad bean, examined different plant densities and determined that the most appropriate plant density was 30 plants/m^2 according to technical and economic evaluation. In addition, they determined that there is a positive correlation between plant height and yield. Admasu et al. (2017) reported that the effect of inoculation on plant height was positive in a field study they conducted to investigate the effect of rhizobium bacteria inoculation and the integrated effect of NP fertilizers on the yield of broad bean. The results obtained by the researchers from their studies and the findings we obtained are similar.

Table 1. Plant height averages of bacterial inoculation and plant density in broad bean and Duncan groups formed (cm)*

		Plant Densities					
		20 m^2 $plant^{-1}$	30 m^2 $plant^{-1}$	40 m^2 $plant^{-1}$	50 m^2 $plant^{-1}$	60 m^2 $plant^{-1}$	Mean
Bacterial Inoculation	Uninoculation	126.2	134.5	144.0	156.3	159.0	144.7 b
	Inoculation	140.7	146.1	161.3	165.0	170.3	156.0 a
	Mean	133.5 e	140.2 d	152.6 c	168.7 b	164.6 a	

*Values belonging to the same letter group are not different according to Duncan 5%

Number of pods per plant

The average number of pods per plant of different plant densities ranged from 13.5 to 18.9 numbers/pod, and the highest value was obtained from the application of 18.9 numbers /pod and 20 m^2/plant density. The lowest value was found at 60 m^2/plant density and 50 m^2/plant density (13.5 numbers /pod), which was found to be statistically indifferent. As the spacing between rows narrowed, the number of pods in the plant decreased (Karayel et al.). Bozoğlu (1989), in his two-year study on bean varieties planted at different times in Samsun ecological conditions, reported that the number of pods per plant of varieties/lines varied between 16.00-21.99. When the effect of different inoculation applications on the number of pods per plant is examined in Table 4.8, it has been determined that the average values vary between 14.3 and 17.5 units/plant. Karahan and Şehirali (1999) found that inoculation with bacterial culture and fertilizer application caused a significant increase in the number of pods in the plant compared to the control process, and as a result of the path analysis made by selecting the dependent variable of grain yield, the factors that directly and positively affect the grain yield are the number of pods per plant and the weight of 100 seeds. have reported. Fufa and Amdemariam (2021), in their study in Ethiopia, reported that the highest number of pods in a pod plant was obtained from Rhizobium application. (Table 2).

Table 2. Average number of pod bacterial inoculation and plant density in broad bean and Duncan groups formed (number/plant)*

		Plant Densities					
		20 m^2/plant	30 m^2/plant	40 m^2/plant	50 m^2/plant	60 m^2/plant	Mean
Bacterial Inoculation	Uninoculation	16.5	15.0	14.6	13.2	12.1	14.3 b
	Inoculation	21.4	19.3	16.8	14.7	15.0	17.5 a
	Mean	18.9 a	17.2 b	15.7 c	13.9 d	13.5 d	

*Values belonging to the same letter group are not different according to Duncan 5%

Grain yield per unit area

In terms of plant density, the average grain yield per unit area in the pod varied between 200.5 - 268.0 kg/da, and the highest unit area grain yield was determined from the application of 268.0 kg/da and 50 m^2/plant density. It is in the same group with 60 m^2/plant density. The lowest grain yield per unit area was obtained as 20 m^2/plant density of 200.5 kg/da. Pilbeam et al. (1990), in their study investigating the effect of plant density on broad bean (*Vicia faba*) planted in spring, reported that yield increased as plant density increased. Alan and Gören (2006) used 40x10 cm sowing density in their study to determine the seed yield and some other characteristics of some broad bean (*Vicia faba* var. major) cultivars grown in Ödemiş-İzmir conditions. As a result of the study, as the average of two years, the 1000 seed weight of Filiz-99 broad bean variety was determined as 1221 g and the grain yield as 299 kg/da. High grain yield is obtained from different planting frequencies depending on different climate, soil and genotype used. For this reason, it is necessary to decide on the planting frequency, taking into account the regional conditions (Table 3).

Table 3. Variance analysis results on the effect of bacterial inoculation and plant density practices on grain yield per unit area (kg/da)*

		Plant Densities					
		20 m^2/plant	30 m^2/plant	40 m^2/plant	50 m^2/plant	60 m^2/plant	Mean
Bacterial Inoculation	Uninoculation	183.6 f	211.0 e	233.3 d	240.2cd	240.6 c	221.7 B
	Inoculation	217.3 e	238.0 cd	251.6 b	292.3 a	295.4 a	258.9 A
	Mean	200.5 D	224.5 C	242.4 B	268.0 A	266.2 A	

*Values belonging to the same letter group are not different according to Duncan 5%

In terms of inoculation, the average grain yield per unit area varied between 221.7 -258.9 kg/da. Elkoca et al., (2008), in their study on microbial and chemical fertilizer applications, reported that there was a difference between applications, the lowest grain yield was obtained from the control plots, and the highest grain yield was obtained from the microbial fertilizer application. Admasu et al. (2017) stated the yield and yield components of bacterial inoculation in a field study in which they investigated the effect of the integrated effect of rhizobium inoculation and NP fertilizers on the yield of broad bean. Fufa and Amdemariam (2021), in their study examining the effects of NPS and bio-organic fertilizers on yield and yield components in broad bean plants, 4 NPS doses (0, 50, 100 and 150 kg/ha) and 4 different bioorganic fertilizers (commercial organic fertilizer, Rhizobium crossing, farm manure and farm manure+Rhizobium inoculation) and their combinations were applied. At the end of the study, while they reported that the farm manure Rhizobium application + 100 kg/ha NPS application gave the most grain yield, Birhanu (2021), Rhizobium bacteria inoculation (Inoculated and uninoculated), vermicompost doses (0, 3, 6 and 9 t/ha) and reported that inorganic fertilization (0, 60, and 120 kg/ha) significantly affected yield and yield components. The results obtained in this study are similar to the findings of the researchers.

Harvest index

In Table 4, in terms of plant density, the average harvest index in pods varied between 22.8% and 25.3%, and the highest harvest index was determined at 25.3% to 60 $m^{2/}$plant plant

density. The lowest harvest index was obtained with 22.8% at 20 m^2/plant plant density. As seen in Table 4.16, harvest index averages in terms of vaccination vary between 25.7% and 25.7%. Fufa and Amdemariam (2021), in their study conducted in Ethiopia in 2016, examined the effects of NPS and bio-organic fertilizers on yield and yield components in broad bean plants, with 4 NPS doses (0, 50, 100 and 150 kg/ha) and 4 different bioorganic fertilizers (commercial organic fertilizer, Rhizobium inoculation, farm manure and farm manure+Rhizobium grafting) and their combinations were applied and they reported that at the end of the study, farm manure + Rhizobium application + 100 kg/ha NPS application gave the harvest index value. The results of the researcher and the results obtained in this study are partially similar.

Table 4. Harvest index averages of bacterial inoculation and plant density applications in broad bean and Duncan groups (%)*

		Plant Densities					
		20 m^2/plant	30 m^2/plant	40 m^2/plant	50 m^2/plant	60 m^2/plant	Mean
Bacterial Inoculation	Uninoculation	22.2 g	22.5 f	23.7 de	24.3 d	23.5 e	23.2 B
	Inoculation	23.5 e	25.0 c	26.3 ab	26.7 ab	27.0 a	25.7 A
	Mean	22.8 D	23.9 C	25.0 B	25.3 AB	25.5 A	

*Values belonging to the same letter group are not different according to Duncan 5%

The highest value was determined as 27.0% from bacterial inoculation and plant density of 60 m^2/plant and plant density of 50 and 40 m^2/plant, which were statistically in the same group. The lowest value in terms of harvest index was 22.2% without inoculation and 20 m^2/plant.

100 seed weight

While the highest 100 grain weight was obtained from 20 m^2/plant density application (137.6 g), the lowest 100 grain weight was obtained from 60 m^2/plant density application (130.7 g). In terms of bacterial inoculation, the highest 100 grain weight was 136.3 g without inoculation, and the lowest value was 132.2 g in the unvaccinated application. Arslan and Anlarsal (1996) reported that higher 1000 grain weight was obtained at low seed amounts. Göksu (2012) reported that the lowest 100 grain weights of peas in Bursa were obtained from the control plots, while the values close to the control were determined in bacterial applications compared to other applications, the highest values were obtained from chicken manure applications. Karayel et al. (2016) reported that the 100-grain weight (161.17 g) in 2016 was the highest at 75 cm row spacing, and the 100-grain weight decreased as the row spacing narrowed. Kumar et al. (2014), in their study investigating the effect of biofertilizers and chemical fertilizer combinations, stated that the highest 100 grain weight was obtained from the combination of chemical fertilizer + 5 tons/ha vermicompost + Rhizobium + phosphate solvent bacteria.

Table 5. 100 Seed Weight averages of bacterial inoculation and plant density applications in broad bean and Duncan groups (g)*

		Plant Densities					
		20 m^2/plant	30 m^2/plant	40 m^2/plant	50 m^2/plant	60 m^2/plant	Mean
Bacterial	Uninoculation	135.3	134.2	132.4	131.0	128.0	132.2 b
Inoculation	Inoculation	140.0	137.7	136.0	134.6	133.3	136.3 a
	Mean	137.6 a	136.0 b	134.1 c	132.8 d	130.7 e	

*Values belonging to the same letter group are not different according to Duncan 5%

Protein ratio in seed

According to Duncan Multiple Comparison results, it was determined that different groups were formed among plant density in terms of protein ratio in grain. The average protein ratio in the grain obtained from different plant density ranged between 23.7% and 24.8%. The highest protein content in grain was found with 24.8% from 60 m^2/plant density application. The lowest protein ratio in grain was obtained from 20 m^2/plant density with 23.7% (Table 5). In Rhizobium bacteria inoculation, the highest protein rate in the seed was found in the inoculation application with 25.1%, while the lowest protein rate in the seed was found in the unvaccinated application (23.1%). Elkoca et al. (2008), in their study with chickpea plant, in their study on microbial and chemical fertilizer applications, there was a difference between the applications, the average protein rate obtained in the first year was 24.8%, the average of the second year was 25.5%, and the lowest protein rate was 23.9% from the control plots, reported that the highest protein ratio was obtained from Rhizobium + nitrogen-fixing microbial fertilizer application (26.2%), while N and NP applications followed these values with a rate of 25.4%. Alsina et al. (2016), in the study they carried out by applying four different rhizobium strains to two broad bean cultivars in Latvia, they found that strain productivity depends on the interaction between strain, soil conditions and cultivar, and protein contents vary according to cultivars. They reported that 407 promoted protein aggregation in the seeds of both cultivars.

Table 6. Protein ratio in seed averages of bacterial inoculation and plant density applications in broad bean and Duncan groups (%)*

		Plant Densities					
		20 m^2/plant	30 m^2/plant	40 m^2/plant	50 m^2/plant	60 m^2/plant	Mean
Bacterial	Uninoculation	22.8 h	22.9 gh	23.3 fg	23.4 ef	23.4 e	23.1 B
Inoculation	Inoculation	24.6 cd	24.5 d	24.9 c	25.6 b	26.3 a	25.1 A
	Mean	23.7 D	23.7 D	24.1 C	24.5 B	24.8 A	

*Values belonging to the same letter group are not different according to Duncan 5%

Densities x inoculation interaction was found to be statistically significant in terms of protein content in grain. The highest value was determined as 26.3% from bacterial inoculation and application of 60 m2/plant density. The lowest value in terms of protein ratio in grain was found to be 22.8% from 60 m2/plant density application.

Nodule number

The highest number of nodules was obtained from the application of 20 plant/m^2 plant density with 90.6 units, and the lowest nodule number was obtained from the application of 60

plants/m^2 plant density with 64.8 units. When the number of nodules was examined in terms of Rhizobium bacteria inoculation, the highest number of nodules was obtained from the vaccination application with 104.2, and the lowest number of nodules was obtained from the unvaccinated application (52.3 units). Argaw and Mnalku (2017) applied five different doses of vermicompost and two levels of Rhizobium inoculation (inoculated and non-inoculated) in their study in which they investigated the effectiveness of vermicompost and Rhizobium inoculation on nodulation, yield and yield characteristics of broad bean plant in Haramaya, east of Ethiopia. Over the years, they reported that the highest average nodule number (98.00 units) was obtained from 4 tons ha of vermicompost application, with Rhizobium inoculation increasing the mean nodule number and non-inoculated 6% and 11%, respectively. Birhanu (2021), the effects of Rhizobium bacteria inoculation (grafted and non-grafted), vermicompost doses (0, 3, 6 and 9 t/ha) and inorganic fertilization (0, 60, and 120 kg/ha) on yield and yield components in broad bean. reported that nodulation was significantly affected by the applications at the end of the study they investigated with the pot experiment. He reported that the highest number of nodules (101.8 units) was obtained in 6 t/ha application of vermicompost, and Rhizobium inoculation increased the average nodule number by 35% compared to the uninoculated. Our findings support the results of the researchers. Density x inoculation interaction was found to be statistically significant in terms of the number of nodules. The highest value was determined as 122.3 units/plant from bacterial inoculation and 20 m^2/plant application. The lowest value in terms of the number of nodules was found as 0.654 out of 60 m^2/plant application, which was not inoculated and was in the same group with 50 m^2/plant and 40 m^2/plant.

Table 7. Variance analysis results on the effect of bacterial inoculation and plant density applications on the number of nodules in broad bean (number)*

		Plant Densities					
		20 m^2/plant	30 m^2/plant	40 m^2/plant	50 m^2/plant	60 m^2/plant	Mean
Bacterial Inoculation	Uninoculation	59.0 cd	57.6 cd	51.7 d	47.5 d	45.3 d	52.3 B
	Inoculation	122.3 a	120.5bcd	102.6 ab	91.0abc	84.3bcd	104.2 A
	Mean	90.6 A	89.2 A	77.1 B	69.3 C	64.8 D	

*Values belonging to the same letter group are not different according to Duncan 5%.

Nodule wet weight

The highest nodule wet weight was obtained from 1.122 g and 20 m^2/plants plant density application, and the lowest nodule weight was obtained from 0.886 g and 60 m^2/plants plant density application. When the nodule weight was examined in terms of rhizobium bacteria inoculation, the highest nodule weight was obtained from the rhizobium bacteria inoculation application with 1.122 g, and the lowest nodule weight was obtained from the unvaccinated application (0.981 g) (Table 7). Argaw and Mnalku (2017) and Birhanu (2021) reported that Rhizobium bacteria inoculation in broad bean (Inoculated and uninoculated) increased nodule weights.

Table 8. Average nodule wet weight of bacterial inoculation and plant density applications in pods and Duncan groups formed (g)*

		Plant Densities					
		20 m^2/plant	30 m^2/plant	40 m^2/plant	50 m^2/plant	60 m^2/plant	Mean
Bacterial Inoculation	Uninoculation	1.118 ab	1.116 ab	1.067 b	0.950 c	0.654 d	0.981 B
	Inoculation	1.126 a	1.125 ab	1.123 ab	1.120 ab	1.118ab	1.122 A
	Mean	1.122 A	1.121 A	1.095 A	1.035 B	0.886 C	

*Values belonging to the same letter group are not different according to Duncan 5%

In addition, density x inoculation interaction was found to be statistically significant in terms of nodule wet weight. The highest value was determined as 1.126 g from bacterial inoculation and 20 m^2/plant application. The lowest value in terms of nodule wet weight was found as 0.654 g in the application without grafting (60 m^2/plant).

CONCLUSION RECOMMENDATIONS

This research was carried out to determine the effects of different bacterial inoculation and plant density applications on quality, yield and yield elements in broad bean cultivation in Muğla-Fethiye ecological conditions. In this study, to determine the effect of bacterial inoculation and different plant densities, plant height, first pod height, number of branches per plant, number of pods per plant, number of seeds per plant, number of seeds per pod, grain yield per unit area, harvest index, hundred grain weight, protein ratio per grain were investigated. The number of nodules and the wet weight of the nodules were examined. The highest value was determined as 292.3 kg/da from bacterial inoculation and plant density of 60 m^2/plant, which is statistically in the same group as 50 m^2/plant plant density. The lowest value in terms of grain yield per unit area was found to be 183.6 kg/da without graft and 20 m^2/plant.

ACKNOWLEDGEMENT

The study is part of the master's thesis. Mugla S. K. University Institute of Natural and Applied Sciences Department of Field Crops.

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