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Growth and Yield Responses of *Vicia faba L.* Grown at Different Planting Densities under Greenhouse Condition for Vegetable Purpose

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ABSTRACT: The effect of planting densities on yield and plant morphology for fresh cooking faba bean (*Vicia faba* L.) were examined. This experiment was conducted during 2018-2019 growing season under plastic-covered high tunnel in Kocaeli city, Turkey. For this purpose between rows fixed at 30 cm while the plants were arranged within rows at 20 cm, 15 cm, 10 cm and 5 cm. The experimental design was set up as Randomized Complete Block with three replications. The results showed a significant positive effect on yield at high density (30×5 cm; 3207 kg da^{-1}) than all other densities. The plant height also statistically reached maximum in all monthly measurements in high density. Flower number statistically more in the lowest density (30 × 20 cm; 59.62 flowers plant^{-1}) at the beginning of the fruit formation. Pod length, pod width, pod weight and seed number were found between 15.85-16.88 cm pod^{-1}, 1.78-1.86 cm pod^{-1}, 19.83-22.14 g pod^{-1} and 4.46-4.69 seeds pod^{-1} respectively according to all treatments but none of these parameters showed significance statistically. Finally, seeding density at a rate of 30×5 cm yielded better for fresh fruit of faba bean in high tunnel cultivation.

Keywords: *Vicia faba* L., Fabaceae, spacing, fresh pod yield.

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INTRODUCTION

Vicia faba L. known as broad bean, faba bean, horse bean or field bean, is an important leguminous crop worldwide because of its commonly dual purpose usage with nutrient rich seeds or green fresh fruits (Ragaa and Safinaz, 2013; Li and Yang, 2014). Fresh faba fruit is the most important source of protein, carbohydrates, volute vitamins, folic acid, niacine, vitamin C, dietary fiber, macro and micro elements such as Ca, P, K, Mg, Na, S, Al, B, Ba, Co, Cr, Cu, Fe, Ga, Li, Mn, Ni, Pb, Sr, Zn and enriched with antioxidants, additionally was promising food for anticancer activity especially in colon cancer (Prabhu and Rajeswari, 2018). According to nutrient database; energy is 88 kcal, protein is 7.92 g, total dietary fiber is 7.5 g, niacine is 2.249 mg, folate is 148 µg in per 100 g pod, raw material (USDA, 2017). *Vicia faba* can be a useful plant of bioavailable bioactive molecules as different groups of polyphenols, to prevent of chronic degenerative diseases (Turco *et al*., 2016). Leaves, flowers and pod of fresh faba bean contain L-Dopa, can be curative Parkinson's disease (Topal and Bozoğlu, 2016). There are lots of studies and reviews focused on faba bean as pulse crops (Loss and Siddique, 1997; Toker, 2004; López-Bellido *et al*., 2005; Alan and Geren, 2007; Song *et al*., 2007; El-Metwally and Abdelhamid, 2008; Abbas, 2013; Saad, 2015; Temesgen *et al*., 2015). Actually faba bean is mostly considered and grown as dry grain legume in the world. Totally 2 463 966 ha area were harvested with yield of 4 840 090 tonnes from the area all over the world from sixty countries in all continentals except Antarctica in 2017 (Faostat, 2017). Similarly in Turkey 4772 ha area was under this crop which yielded 13 198 tonnes seed in 2018 (TUIK, 2018). According to vegetable data, fresh fruit yield was 38 921 tonnes and only 1 tonne of the yield obtained from all protected cover areas in 2018 in Turkey (TUIK, 2018). The plants requires cool conditions for best development and this can be grown in winter under temperate climate or in spring in cold climate and higher elevation because of no significant vernalization periods. At the same time low fertilizer and pesticide requirement and valuable genetic variability make this plant remarkable part of sustainable agriculture (Duc,1997).

Fresh faba bean is mostly grown locally, consumed for cooking fresh green pod or fresh seeds as vegetable and located in grocery stores in a short period.

There are few studies about *Vicia faba* postharvest behaviour (Logegaray *et al*., 2009; Kasım and Kasım, 2016) which may lead to the extending the consumption period and international fresh faba seed or fruit trade. For earliness or spreading over a long period of time faba bean cultivation in greenhouse or covered tunnel can be an alternative choice. Lots of studies were done about plant densities in vegetables in greenhouse because of harvested material quality, quantity, pests, diseases, weeds management and profitability in the invested area the densities can be a crucial role in agriculture. Besides plant density studies on other leguminous plant (Raei *et al*., 2015; Zirak *et al*., 2015) there are also some researches on plant densities effect in faba bean mostly focused on dry seed yield (Al-Rifaee *et al*., 2004; Idris, 2008). However there is lack of information on population densities of faba bean on its fresh pod yield and related traits. Hence the objectives of this rare study are to determine the some morphological and fresh fruit yield responses of faba bean which related with plant densities.

MATERIAL AND METHODS

The experimental site was horticultural plastic-covered high tunnel which was 20 m in length, 6 m in width and 3.7 m in maximum height, of Kocaeli University, Arslanbey Agricultural Vocational School in Arslanbey Campus in Kocaeli Province, Turkey. The research was conducted from 6th of November 2018 to 20th of May 2019. The experimental location lies at 40°42' N latitude and 30°01' E longitude with an elevation of 77.4 m from sea level. Climate of the city is a transition between Mediterranean and Black Sea climates. Table 1 shows long-term (1929-2018) meteorological parameters of the city (TSMS, 2019) to giving a perspective about climate.

The experimental soil was plowed with power tiller 2 days before seed sowing. Hand sowing was practiced approximately to 4 cm depth of soil on November 6th in 2018. The area were irrigated twice in first month and ones in a month during 2nd to 6th month. No weed control, pesticide usage or fertilization was done.

Soil samples of the trial area at a depth of 0-30 cm were analysed before faba bean seed sowing. The soil pH was slighly alcalic (7.52), E.C. was 660 µS cm^{-1}, the $CaCO_3$ content was 11.8%, organic material at medium level (2.63%), nitrogen at 0.17%, P_2O_5 level was 115 kg ha^{-1}, K_2O level was 426 kg ha^{-1}.

Seeds of determinate-type for fresh cooking cv. 'Sevilla' faba bean (*Vicia faba* L.) were purchased from registered seed seller shop and measured randomly selected 100 seeds just before sowing. According to measurements the average of a seed was 20.54 mm in length, 14.49 mm in wider side of width, 8.19 mm in narrow side of width and 1.37 g in weight.

Area of 14.4 × 1.6 m was divided into 12 equal sub-plots. The experiment consisted of four treatments. For this plant density study, between rows fixed 30 cm while the seed were arranged within rows at 20 cm, 15 cm, 10 cm and 5 cm. These were equal to 16666 plants da^{-1} (22.8 kg seeds da^{-1}), 22222 plants da^{-1} (30.4 kg seeds da^{-1}), 33333 plants da^{-1} (45.7 kg seeds da^{-1}) and 66666 plants da^{-1} (91.3 kg seeds da^{-1}) respectively. 1 da (decare) is equal to 0.1 hectare and used for small-scale farming areas as known.

Starting from the seed sowing from eight initially marked plants, in the middle of each plot to avoid the side effects from each replications, data were taken at the end of the every months. Plant height (cm plant^{-1}) was taken with the help of measuring tape from the ground level to tip of the main stem at the end of the each month (1st to 6th month). Leaf number (leaves plant^{-1}) was counted from the ground to tip of the all main and side stem from each plant at the end of the each month (1st to 5th month) except last month because of the months leaves start to drop and turning yellow at base level. Stem number (stems plant^{-1}) at the ground level were counted at the beginning of fruit formation in 5th month of growth. Flower number (flowers plant^{-1}) were counted at the beginning of fruit formation in 5th month of growth. Pod length (cm pod^{-1}), pod width (cm pod^{-1}) and pod weight (g pod^{-1}) were measured from harvested 15 cm and longer fruits after each harvest from selected plants. Harvest criteria was decided by asking for their ideas to 22 people who has greengrocer shopping and cooking skills, considering differences in fruit length. Fruit of 15 cm length were chosen 77.3% by the people. Seed number (seeds pod^{-1}) were counted from the harvested fruit via cutting the green pod. All healthy visiable seeds counted without considering the size.

Table 1: Monthly long-term meteorological parameters in Kocaeli city from 1929 to 2018.

	Jan.	Feb.	Ma.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Average Air Temp. (°C)	6.2	6.9	8.8	13.2	17.7	21.9	23.9	23.8	20.4	16.1	12.0	8.3
Average Max. Air Temp.(°C)	9.6	10.5	13.2	18.5	23.3	27.4	29.5	29.7	26.1	20.9	16.4	11.7
Average Min. Air Temp. (°C)	3.1	3.4	4.8	8.5	12.8	16.5	18.9	19.1	15.9	12.4	8.6	5.3
Aver. Sunshine Duration(h)	2.5	3	4	5.7	7.3	8.9	9.6	9.1	7.1	4.8	3.6	2.6
Total Precipitation (mm)	93.7	71.7	72.6	53.7	49.3	54.0	38.5	44.4	54.0	89.4	81.6	114.0

Fruit yield (kg da^{-1}) and all pod measurements were calculated from harvested 15 cm and longer marketable fruits after each weekly (1st harvest in 29th April 2019, 2nd harvest in 6th May 2019, 3rd harvest in 13th May 2019 and 4th harvest in 20 May 2019) harvest from selected plants along 4 weeks. The study design as Completely Randomized Design replicated thrice and statistical analyzes were done by using SPSS 16.0 programme, analysis of variance with Duncan Multiple Range Test method at $P< 0.05$ was performed.

RESULTS AND DISCUSSION

Plant height were statistically or numerically affected by plant densities. High densities gave the tallest plants (Table 2, Fig. 1, 2). At the end of the study the plant height was 114.5 cm in the highest density and 92.75 cm in the lowest density. Similarly Al-Rifaee *et al*., (2004) studied on plant densities (12.5, 25, 50, 100 and 150 plants m^{-2}) and they also found plant height maximum to minimum in higher densities to lower. Ece *et al*., (2004) found the plant height 96.51 cm in cv. Luz de otono and 117.30 cm in cv. Lara in November sowing in glasshouse. In another study Mady (2009) plant height was found 90.25 cm in control in 95 days old faba bean in cv. Giza 3 in November sowing in the field experiment. Our results in 90 days old plant were between 31.33-39.75 cm. This can be cultivar and experimental area differencies. In the study about water deficit stress on faba bean Abid *et al*., (2017) used 11 genotypes and plant height changed between 52.90–83.15 cm in control at flowering stage in greenhouse in pot experiment. Our results also were between 62.67–87.63 cm at flowering stage.

Table 2: Monthly plant height after seed sowing in *Vicia faba* (cm $plant^{-1}$)

Seed Distances	1st Month	2nd Month	3rd Month	4th Month	5th Month	6th Month
30 × 20 cm	13,11 ab*	24,43 b*	31,33 b*	37,44 b*	62,67 b*	92,75 b*
30 × 15 cm	13,36 ab	22,73 b	30,63 b	38,25 b	73,83 ab	101,34 ab
30 × 10 cm	12,57 b	23,36 b	32,92 b	42,36 b	84,05 a	111,13 a
30 × 5 cm	15,27 a	27,13 a	39,75 a	51,00 a	87,63 a	114,50 a

*Means within the same column with the different letters are significantly different according to Duncan's Multiple Range Test at ($p<0.05$).

Fig. 1. *Vicia faba* L. growth one month after seed sowing (A) 30 × 20 cm plant distance, (B) 30 × 15 cm plant distance, (C) 30 × 10 cm plant distance, (D) 30 × 5 cm plant distance.

Fig. 2. Experimental area under plastic-covered high tunnel (A) *Vicia faba* L. growth three month after seed sowing, (B) *Vicia faba* L. growth six month after seed sowing at the end of the experiment.

Leaf and flower numbers in the study were the highest in low density at the beginning of fruit formation in the 5th month of experiment (Table 3, 4). Karayel *et al*., (2016) also studied on plant densities under field condition and they similarly found that when the density is high the leaf number found as 103.20 plant^{-1} and low leaf number reached to 125.25 plant^{-1}. In present experiment 101.75 leaves plant^{-1} from high density and 196.21 leaves plant^{-1} of low density. In a study (Mwanamwenge *et al*., 1999) about water stress in glasshouse-pot experiment with 3 genotypes, flower numbers were found between 35-60. In our study flower number was the highest in low density (59.62 plant^{-1}) and the lowest in highest density (33.41 plant^{-1}).

Table 3: Monthly leaf number after seed sowing in *Vicia faba* (number plant^{-1})

Seed Distances	1st Month	2nd Month	3rd Month	4th Month	5th Month
30 × 20 cm	7,04 a	10,71 a	31,13 a*	74,17 a	196,21 a*
30 × 15 cm	6,59 a	11,34 a	30,38 a	72,17 a	149,71 ab
30 × 10 cm	6,88 a	11,13 a	29,09 ab	65,25 a	129,30 ab
30 × 5 cm	6,29 a	8,50 a	20,50 b	45,29 a	101,75 b

*Means within the same column with the different letters are significantly different according to Duncan's Multiple Range Test at ($p<0.05$).

Table 4: Stem number (stems plant^{-1}) and flower number (flowers plant^{-1}) at the beginning of fruit formation in 5th Month and pod length (cm pod^{-1}), pod width (cm pod^{-1}), pod weight (g pod^{-1}) and seed number (seeds pod^{-1}) in *Vicia faba.*

Seed Distances	Stem number	Flower number	Pod length	Pod width	Pod weight	Seed number
30 × 20 cm	3,46 a	59,62 a*	15,85 a	1,78 a	20,08 a	4,69 a
30 × 15 cm	3,13 a	47,54 ab	16,12 a	1,81 a	19,83 a	4,46 a
30 × 10 cm	2,46 a	47,96 ab	16,47 a	1,78 a	20,31 a	4,71 a
30× 5 cm	2,29 a	33,41 b	16,88 a	1,86 a	22,14 a	4,47 a

*Means within the same column with the different letters are significantly different according to Duncan's Multiple Range Test at ($p<0.05$).

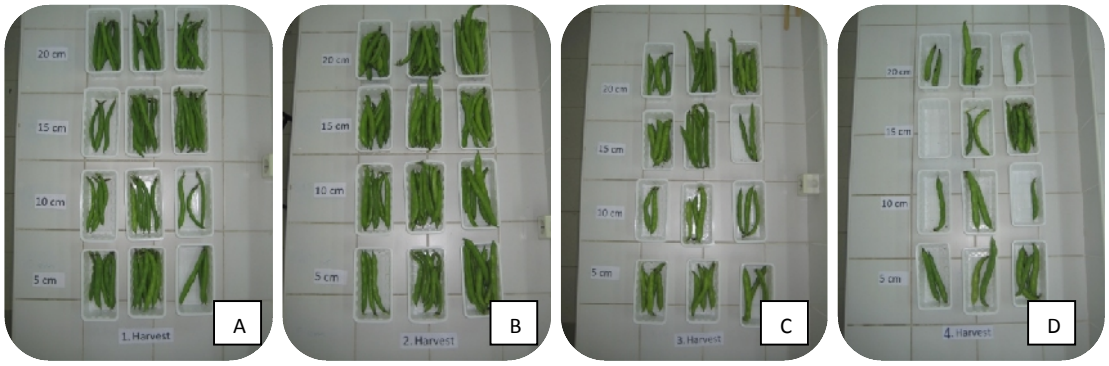

Fig. 3. *Vicia faba* L. fresh fruit harvest from marked plants from each repetition. (A) 1st harvest, (B) 2nd harvest, (C) 3rd harvest, (D) 4th harvest.

Table 5: Weekly harvest percentage (%) in total harvest and total green pod yield in *Vicia faba* (kg da^{-1})

Seed Distances	1st Harvest (%)	2nd Harvest (%)	3rd Harvest (%)	4th Harvest (%)	Total (kg da^{-1})
30 × 20 cm	18,9 a	44,5 ab*	27,4 a	9,2 a	1 139 b*
30 × 15 cm	22,7 a	39,3 ab	23,7 a	14,3 a	1 404 b
30 × 10 cm	16,5 a	53,0 a	17,6 a	12,9 a	1 272 b
30 × 5 cm	24,9 a	31,5 b	24,1 a	19,5 a	3 207 a

*Means within the same column with the different letters are significantly different according to Duncan's Multiple Range Test at ($p<0.05$).

Stem number numerically affected by plant density in our study. Stem number was 3.46 in low density and 2.29 in high density (Table 4). Karayel *et al*., (2016) found 3.07-3.24 stems plant^{-1} in faba bean and they emphasized that the data were not affected by plant densities. The finding is supported to our study.

Pod length, pod width, pod weight and seed number per pod were not statistically affected by plant densities in our study (Table 4). Similarly Ece *et al*., (2004) found the maximum fresh pod length and pod width as 13.31 cm and 11.88 mm respectively in November sowing. Seed number found 4.46-4.71 pod^{-1} in our study. Karayel *et al*. (2016) found the parameters as 3.47-3.84 seeds pod^{-1}, Mwanamvenge *et al*., (1999) found as 1.4-2.2 seed pod^{-1} in 3 genotypes and Al-Rifaee *et al*., (2004) found 2.3-2.6 seeds pod^{-1} in their first year and 1.6-1.9 seeds pod^{-1} in second year and they emphasized that plant population is not significantly effected that parameters.

Fresh green pod (fruit) yield was greater in high density (30 cm × 5 cm) as 3207 kg da^{-1} in our study and statistically superior to the other densities (Table 5, Fig. 3). There is only one reached study (Ece *et al*., 2004) about fresh pod yield and total pod yield was found as 3259 .85 kg da^{-1} and 3573.80 kg da^{-1} in two different cultivar when seed sown in 40 × 10 cm in November sowing along 6 harvests and the data were more than December, January and February sowing under greenhouse condition. The study was partly supported our experiment that harvests were lasted along 4 weeks. After than pods lengthening stopped, expansion started, seed became too much visible and visual quality dropped that is not preferred in vegetable purpose.

CONCLUSION

It could be concluded that *Vicia faba* higher green pod (fruit) yield were obtained by 30 × 5 cm density along 4 harvests under high-plastic tunnel cultivation according to our harvest criteria that 15 cm and longer pod harvest as vegetable purpose. Further studies should be continued on different cultivars, soil fertility and profitability because of high amount of seed to be used.

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