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# The effect of plant density on quantitative characteristics, optical extinction coefficient, and some physiological traits of faba bean cultivars

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**Key words:** Faba bean, grain yield, optical extinction coefficient, density, harvest index, varieties.

**Abstract**

In order to investigate the effect of density on Quantitative Characteristics, Optical Extinction Coefficient, and Some Physiological Traits of Faba Bean Cultivars, field experiment was carried out in the city of Ahwaz field healthy martyr in a factorial randomized complete block design with four replications in crop year of 2011-2012. These factors include density at three levels (8, 12, 16 plants per square meter) and three varieties (Barekat, Saraziri, local varieties dezful), respectively. The results showed that the density of 12 p/m$^2$ was significantly increased grain yield and yield components and Barekat variety it had the highest degree of yield grain and yield components compared with others varieties. High yield of Barekat cultivar is due to more accumulation of dry matter and greater number of pods and grains per pod in this cultivar rather than other cultivars.The highest biological yield belonged to Barekat cultivar which is due to higher leaf area index of this cultivar.The results showed that optical extinction coefficient was significantly affected by density and cultivar. As plant density increased from 8 to 16 plants per square meter, optical extinction coefficient decreased and its highest and lowest rate respectively belonged to Local and Barekat cultivars. The harvest index was also affected by plant density and cultivar and the highest harvest index was obtained in treatment with density of 12 plants per square meter and Barekat cultivar. The highest leaf area index belonged to Barekat cultivar and density of 16 plants per square.

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## Introduction

Legumes make the main diet of many poor people throughout the world since the noticeable amount of good quality protein in grains of such products in combination with grain cereals can make a valuable biological food composition (MajnounHosseini. 2008). Legumes grains by having 18-32% protein have an important role in supplying the required protein for human diet (Mazaheri, 2008).Optimal density to achieve maximum yield depends on genetic characteristics of hybrid, production objective, and also water and nutrients. However, it is a general principle that if appropriate number of plants is not used in the unit of land in fact the available potential has not been used optimally (Mazaheri, 2008). Determining optimal density is a very important factor of crops yield Biswas *et al*., (2012). Gan *et al*., (2007) stated that the use of very high densities would decrease current photosynthesis and increase grain yield dependency on assimilates in vegetative parts of plants. Frade *et al.,* (2005) claimed that the increase of grain yield, parallel to increased density, was due to the establishment of more plants and the increase of produced pods per area unit. Chaieb *et al.,* (2011) who stated that at high densities due to increase of leaf area, the absorption rate of solar radiation increased and consequently photosynthesis and synthesizing assimilates increased, as well. Therefore, the rate of dry matter accumulatio0n increased, too. Dordas *et al*., (2011) stated that the difference between dry matter production in broad bean cultivars at different growth stages probably indicate the difference in light penetration and efficiency of its use in the canopy. MalekMelki *et al.,* (2012) reported was due to increase of plant dry matter because there was a negative relationship between biological yield and harvest index. Bakry *et al*., (2013) in his experiments showed that there was a high positive correlation between economic and biological yield. High grain yield in Barekat cultivar and greater leaf area due to production and mobilization of more assimilates into grain in comparison to other cultivars led to increase of harvest index in this cultivar. Chaieb *et al.,* (2011) reported that at high densities due to greater number of plants per area unit, plant population has produced more leaf area. In general, increase of plant density is followed by increase of leaf area, and increase of light absorption. Kiniry *et al.,* (2009) stated that due to larger leaf area index and smaller optical extinction coefficient and or due to higher density of leaf area in top layers of canopy the plant will be able to absorb more light and will have more competition capability. Tawaha *et al.,* (2005) stated that leaf area index increases as the number of plants per area unit increased. However, the number and leaf area of each plant depended on the rate of light absorption. The aim of this study was to evaluate the effect of density on Quantitative Characteristics, optical Extinction Coefficient, and Some Physiological Traits of Faba Bean Cultivars and develop a best density and Cultivars in the Ahwaz region.

## Materials and methods

This research was conducted in crop year of 2011-2012 in the farm of martyr healthy located in the city of Ahwaz latitude 31° 36´ north and longitude 48° 53´ east and 51 m above the sea level.

*Experiment Soil*: The soil of experiment site has clay-loamy texture with 7.7 pH and electrical conductivity of 4.6. The experiment was conducted in the form of factorial and randomized complete block design with four replications. The factors in this experiment included three varieties of (v1=Barekat, v2=Saraziri, v3=Local varieties dezful)and density at three levels (D1= 8, D2=12, D3=16) plants per square meter, respectively.

*Fertilization:* Fertilization was calculated based on go $kg.ha^{-1}$pure phosphours from ammonium phosphate, as well as 100 $kg.ha^{-1}$ pure nitrogen from urea fertilizer. At the time of final leveling, all the phosphorus fertilizer was distributed uniformly on the farm surface, so fertilizer was thoroughly incorporated in to the soil by means of discs. In addition, urea fertilizer was added to the soil at two stages. One at the beginning planting and another top dressed at 4-6 leaf stage in the faba bean.

*land preparation operation:* In order to carry out the experiment the land preparation operation was done including plowing to the depth of 30 cm, making holes to the depth of 15 cm and flatting. After preparation, the farming land was plotted according to the plan. Every plot contained 5 lines each 5 meters long and 60 cm apart from each other.

*Sowing operation:* Sowing operation was done manually on November 22, 2011. The land was irrigated immediately after sowing. The weeding was done manually after the seeds germinated and the stems got strong.

*Samples*: In order to measure biological yield, grain yield, and harvest index, at final harvest time several plants from each plot were randomly selected and harvested in an area of 1.5 $m^2$.

*Leaf area index:* In order to measure leaf area index, in each sampling method the leaf area was obtained through copying on $A_4$ paper.

The mean of leaf area in a plant was calculated and given the rate of density of each treatment, leaf area index was calculated.

Leaf area index = leaf area of plant / occupied ground by a plant

*grain yield*: The grain yield started from the three middle lines as long as 2 meter after eliminating the margins.

*Optical Extinction Coefficient*: In order to investigate the distribution of light among plant population and dissipation of light in the vegetation, at the beginning of podding stage when the leaf area index was maximized, the received radiation on the ground and above the vegetation was measured and calculated by means of a photometer (ACCPAR 80).

$$Ii/Io=e^{-LK} \qquad (1)$$

$$K=\frac{-Ln\frac{I}{I_0}}{LAI}$$

$I_0$: photosynthetically active radiation at the top of plant population

$I_i$: photosynthetically active radiation beneath the i layer of leaves

L: leaf area index in i layer

K: Optical Extinction Coefficient

*Statistical analysis*: Data variance analysis was done by means of SAS software the means were compared by Duncan's multi range tests at 5% and 1% probability levels.

## Results and discussion

### *Grain Yield*

The results from analysis of variance for the data showed that the levels of density and varieties have significant difference in 1% probability value on grain yield (Table 1). The mean comparison of the effect of different levels of density on grain yield showed that the highest rate of grain yield belonged to the density of 12 plants per square meter by 487.49 g/$m^2$ and the lowest rate of grain yield belonged to the density of 8 plants per square meter by 369.69 g/$m^2$ (Table 2). It seems that as Bakry *et al.,* (2013) reported, the decrease of grain yield at density of 8 plants/$m^2$ in spite of the higher number of grains per pod and number also higher number of pods per plant was due to inappropriate density and failure to make optimal use of nutrition space in plant population. Habibzadeh *et al.,* (2005) believed that the effect of plant density on the increase of grain yield was due to the increase of number of grains per square meter and consequently the increase of number of pods per square meter. These results are consistent with the findings of this research. MalekMelki *et al.,* (2012) reported that the number of grains per pod in higher densities of plants relatively decreased and these changes in sub branches were more than main branch. In this study, the increase of number pods per square meter in high densities resulted in relative decrease of number of grains per pod and increase of 100-grain weight, as well. These results are consistent with the findings of Dordas *et al.,* (2011). The mean comparison of the effect of cultivar on grain yield showed that the highest rate of grain yield belonged to Barekat cultivar by 535.76 g/m² and the lowest rate of grain yield belonged to local cultivar by 293.57 g/m² (Table 2). High yield of Barekat cultivar is due to more dry matter accumulation in this cultivar rather than other cultivars. Moreover, among the components of grain yield, the number of pods had greater role in the increase of grain yield and this feature in Barekat cultivar was more than other cultivars. These results are consistent with the findings of sharaan *et al.,* (2012).

**Table 1.** Analysis of variance of some recorded traits under the effect of density and variety.

| Source of variation | d.f | Grian yield(gr/m²) | Biological yield(gr/m²) | Harvest index(%) | Leaf area index(%) | Optical extinction coefficient (%) |
|---|---|---|---|---|---|---|
| Replication | 2 | 6515 | 15835 | 35.03 | 0.5443 | 0.011 |
| Density | 2 | 32004** | 13412n.s | 205.37** | 3.9443** | 0.10763** |
| Variety | 2 | 142033** | 110041** | 537.99** | 2.5396** | 0.1735** |
| D*H | 4 | 1946n.s | 10554ns | 24.13ns | 0.0646ns | 0.00207n.s |
| Error | 16 | 2269 | 10941 | 16.2 | 0.0757 | 0.001852 |
| Coefficient of Variation (%) | | 10.9 | 9.2 | 10.6 | 5.9 | 11.8 |

**And* ns respectively significant at the one percent and five percent level, and no significant difference.

*Biological Yield*

According to mean comparison table it is observed that as density increased, biological yield increased, too; so that, the highest biological yield belonged to treatments with density of 12 and 16 plants/m² which was significantly different from the lowest yield that belonged to treatment with density of 8 plants/m² by 1004.30 g/m² (Table 2).

**Table 2.** Mean comparison of Grain yield, biological yield, harvest index, Leaf area index, optical extinction coefficient.

| Treatment | | Grian yield(gr/m²) | Biological yield(g/m²) | Harvest index(%) | Leaf area index(%) | Optical extinction coefficient (%) |
|---|---|---|---|---|---|---|
| Density | D1 | 369.69b | 1094.72a | 32.43b | 3.869b | 0.6698a |
| | D2 | 487.49a | 1171.92a | 40.96a | 4.875a | 0.5844b |
| | D3 | 444.73a | 1134.3a | 39.2a | 4.117a | 0.4527c |
| Variety | V1 | 535.76a | 1208.23a | 44.42a | 4.983a | 0.5567b |
| | V2 | 472.58b | 1186.11a | 40.02b | 4.868a | 0.5770b |
| | V3 | 293.57c | 1006.61b | 29.38c | 4.010b | 0.5931a |

Means with same letters in each column are not significantly different at 5% probability level.

It seems like that at higher density specially 12 plants/m², the plant has been able to make use of sun light and moisture and fertility of soil and other factors affecting the growth and consequently the yield has increased in area unit. The results are consistent with the findings of Dahmardeh *et al.,* (2010) who stated that at high densities due to increase of leaf area, the absorption rate of solar radiation increased and consequently photosynthesis and synthesizing assimilates increased, as well. Therefore, the rate of dry matter accumulatioon increased, too. It seems like that at density of 8 plants

/ $m^2$ the rate of biological yield decreased because a part of land was not used and the space and nutrition were not optimally used by plants and also the grain yield in area unit decreased. These results were consistent with the findings of Bakry *et al.,* (2013). Mean comparison results of different cultivars showed that the highest biological yield belonged to Barekat cultivar by 1208.23 g/$m^2$ and the lowest biological yield belonged to local cultivar by 1006.61 g/$m^2$. The superiority of Barekat cultivar can indicate higher grain yield of this cultivar rather that other cultivars of the experiment. The results were consistent with the findings of Rifaee *et al.,* (2004) stated that the difference between dry matter production in broad bean cultivars at different growth stages probably indicate the difference in light penetration and efficiency of its use in the canopy. His findings were similar to the results of this research.

*Harvest Index*

Harvest index of faba bean was significantly influenced by the varieties at 1% probability level as well as planting density at 1% probability level. The interaction of varieties and planting density was not significant (Table 1). Mean comparison of the effect of plant density showed that as the density increased from 8 to 12 plants per square meter the harvest index increased and as the density increased from 12 to 16 plants per square meter it had a decreasing trend. The highest harvest index belonged to treatment with density of 12 plants/$m^2$ by 40.96% and the lowest one belonged to treatment with density of 8 plants/$m^2$ by 32.43% (Table 2).It seems like that the increase of harvest index at density of 12 plants/$m^2$ was due to further increase of grain yield than total dry matter which indicates assimilate mobilization from vegetative parts to grain due to optimal use of peripheral conditions and more absorption of light that has increased the grain yield. At density of 8 plants / $m^2$ due to decrease of leaf area index, the decrease of grain yield was more than that of total dry matter and thus it had the lowest harvest index compared with higher densities. The decrease of harvest index at higher densities as MalekMelki *et al.,* (2012) reported was due to increase of plant dry matter because there was a negative relationship between biological yield and harvest index. One of the major reasons of increase of harvest index in low densities is the weak competition of plants for growth factors particularly radiation absorption during the season. In such conditions assimilates mobilization to reproductive organs is more than structural assimilates which stay in leaves and stalks. In high densities there is an opposite state. That is, there is an intense competition between plants and in such circumstances due to decrease of each grain contribution to production of assimilates the harvest index has declined. The results were consistent with the findings of Dahmardeh *et al.,* (2010).Usually after the pods, assimilates are allocated to filling the grains and heavier grains are expected to increase the grain yield and consequently the harvest index. Bruin *et al.,* (2013) has referred to similar results in soybean. Biswas *et al.,* (2012) has stated that at higher densities, even though leaf area index and dry matter yield increase, the harvest index will decrease because of serious competition among plants. Mean comparison of the effect of cultivar showed that the highest harvest index belonged to Barekat cultivar by 44.42% and the lowest harvest index belonged to local cultivar by 29.38% which was probably due to genetic differences between the studied cultivars. Moreover, the difference in distribution pattern and allocation of assimilates to different cultivars often leads to difference in harvest index between different cultivars. Bakry *et al.,* (2013) in his experiments showed that there was a high positive correlation between economic and biological yield. High grain yield in Barekat cultivar and greater leaf area due to production and mobilization of more assimilates into grain in comparison to other cultivars led to increase of harvest index in this cultivar.

*Leaf Area Index*

Leaf area index of faba bean was significantly influenced by the varieties at 1% probability level as well as planting density at 1% probability level. The interaction of varieties and planting density was not significant (Table 1). Mean comparison of data analysis showed that as density increased in this research, leaf area index increased too and the highest leaf area index was related to density of 16 plants/m² by 5.117 g/m² and the lowest harvest index belonged to density of 8 plants/m² by 3.869 g/m² (Table 2). It seems like that as Chaieb *et al.,* (2011)has reported in high densities due to greater number of plants per area unit, the plant population has produced larger leaf area. In general, increase of plant density is followed by increase of leaf area, light absorption, and ultimately crop growth rate. The results were consistent with findings of this research. Low leaf area index in density of 8 plants/m² was due to fewer number of plants and less leaf area. The results were consistent with findings of Torabi Jafroudi *et al.,* (2012). The ANOVA results showed that the highest leaf area index in the research belonged to Barekat cultivar by 4.983 and the lowest leaf area index belonged to local cultivar by 4.010(Table 2).Barekat cultivar had the highest leaf area index which indicates further production of sub branches, more number of plants per area unit, and larger leaf area in this cultivar compared with other cultivars. The results were consistent with findings of Dordas *et al.,* (2011).

*Optical Extinction Coefficient*

Optical Extinction coefficient of faba bean was significantly influenced by the varieties at 1% probability level as well as planting density at 1% probability level. The interaction of varieties and planting density was not significant (Table 1). Mean comparison of the effect of different plant densities showed that as density increased, optical extinction coefficient significantly decreased, so that the highest extinction coefficient belonged to density of 8 plants/m² by 0.6698% and the lowest extinction coefficient belonged to density of 16 plants/m² by 0.4527% (Table 2). In this experiment optical extinction coefficient was affected by different plant densities. As plant density increased, optical extinction coefficient decreased due to the increase of leaf area index. Kiniry *et al.,* (2009) stated that due to larger leaf area index and smaller optical extinction coefficient and or due to higher density of leaf area in top layers of canopy the plant will be able to absorb more light and will have more competition capability. Awal *et al.,* (2006) stated that there is an inverse relationship between two parameters of leaf area index and optical extinction coefficient, so that as leaf area index in area unit increases, which is naturally due to increase of plant density, extinction coefficient will decrease. The results of this research were consistent with the findings of Yahuza (2011) and he stated that as the plant density increased, the number of leaves in area unit increased, too and optical extinction coefficient was lower than that of other densities until the end of growth stage. Mean comparison of different cultivars showed that the highest coefficient of optical extinction belonged to local cultivar by 0.5931% and the lowest extinction coefficient belonged to Barekat cultivar by 0.5567% and Ramp cultivar by 0.5770%, even though there was not a significant difference between these two cultivars (Table 2). The difference in optical extinction coefficients in above cultivars seems to be due to difference in engineering structure of plant population particularly leaves arrangement and leaf area index. Awal *et al.,* (2006) has stated that optical extinction coefficient is determined by the average of leaf area to horizontal surface of ground and factors such as leaf area, leaf angle, and the rate of solar radiation will influence it. Zhang *et al.,* (2008) stated that leaf area index increases as the number of plants per area unit increased. However, the number and leaf area of each plant depended on the rate of light absorption. Moreover, leaf angle and leaf area index affected light penetration into plant canopy and the important role of optical extinction coefficient would be identified in this state. The results of the findings of these researchers were quite consistent with the result of present research.

**Conclusion**

The results of the research showed that grain yield, leaf area index and harvest index were affected by density and cultivar. As density increased, the grain yield increased, too so that the density of 12 plants per square meter due to optimum condition and appropriate light had more grain yield than other cultivars. The highest grain yield belonged to Barekat cultivar. High yield of Barekat cultivar is due to more accumulation of dry matter and greater number of pods and grains per pod in this cultivar rather than other cultivars. Harvest index was also affected by plant density and cultivar and the highest harvest index belonged to density of 12 plants/m² and Barekat cultivar. In this research, different plant densities and various cultivars of broad bean had significant effects on optical extinction coefficient, so that as plant density increased, optical extinction coefficient decreased. The increase of leaf area index which naturally results from the increase of plant density leads to decrease of optical extinction coefficient. Moreover, among the studied cultivars, Barekat cultivar had the lowest opticale xtinction coefficient.

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