INTERNATIONAL JOURNAL OF PLANT, ANIMAL AND ENVIRONMENTAL SCIENCES

IJPAES

VOLUME-2, ISSUE-2 APRIL-JUNE-2012 ISSN 2231-4490

Coden : IJPAES www.ijpaes.com

Received: 23rd Feb-2012 *Revised: 26th Feb-2012* *Accepted: 01st Mar-2012*

Research Article

APPLICATION OF A RECIPROCAL MODEL TO ESTIMATE OPTIMUM ECONOMIC DENSITY IN BEAN CULTIVARS

Kazem Ghassemi-Golezani*, Hamed Akbari

Department of Plant Eco-physiology, Faculty of Agriculture, University of Tabriz, Iran

*Corresponding author, e-mail; golezani@gmail.com

ABSTRACT : A factorial experiment based on RCB design with three replications was conducted in 2010 to study the effect of plant density and cultivars on grain yield and yield components of bean. Factors were cultivars (‘Akhtar’, ‘Derakhshan’, and ‘Sayad’) and plant densities (30, 40, 50 and 55 plants/m^2). The number of pods per plant, grains per plant and 1000 grain weight were significantly reduced by increasing plant density. Sayyad had the highest pods per plant, but the lowest grains per pod, grains per plant and 1000 grains weight, compared with Derakhshan and Akhtar. The highest grains per plant and 1000 grains weight were produced by akhtar. Relationship between plant density and grain yield of bean cultivars was well described by the equations ***1/w = a + bp*** and ***Y = p/(a + bp)***, where *w* is grain yield per plant, *p* is plant density and *Y* is grain yield per unit area. Biological and grain yields of all bean cultivars increased with increasing plant density. Optimum economic density was estimated 50 plants m^{-2} for Akhtar and Derakhshan and 55 plants m^{-2} for Sayyad. Biological and grain yields per unit area for Sayyad were considerably lower than those for Akhtar and Derakhshan, particularly at high plant densities. The highest plant biomass and grain yield per unit area at different densities were produced by Akhtar, followed by Derakhshan. The superiority of these cultivars in grain yield were attributed to production of more grains per pod, grains per plant and 1000 grains weight, compared with Sayyad.

Keywords: Bean, Grain yield, plant biomass, plant density, reciprocal model

INTRODUCTION

As one of the oldest groups of agricultural plants, food legumes are the second most important human’s food supply after the cereal grains, since their grain contain 38 to 59% carbohydrate, 4.8 to 5.9% oil, 3% ash, 3% fiber, 0.2% calcium, and 0.3% phosphorus [1]. Bean (*Phaseoulos Vulgari*s) is the most important food legume, far more than chickpeas, faba beans, lentils, and cowpea. This crop is the centerpiece of the daily diet for more than 300 million of the world population. Nutritionists characterize the bean as a nearly perfect food because of its high protein content and generous amount of fiber, complex carbohydrates and other dietary necessities [2].

The maximum yield of a legume crop depends upon its yield components, such as the pods per plant, seeds per pod and seed weight. kakuichi and kobata [3] found that pod number per plant decreased as plant density increased. Shahein et al [4], Hussein et al [5] and Mokhtar [6] reported that increasing plant density negatively influences the number of pods per plant in bean varieties.

Plant density is not stable for a variety at different climatic conditions. In a plant community, after a saturation threshold, adding more plants will not increase yield per unit area. On an individual plant basis, as density increases, individual plant yield decreases non-linearly [7]. Yield-density relationship can be literally defined as a mathematical quantification of crop response to increase in plant population density [8, 9]. The use of equations in density trials for determining optimal density is more efficient than analysis of variance procedures alone [10]. This is because establishing the quantitative relationships between two or more variables using mathematical equations helps to reduce the need for multi-location density trials and it is possible to extrapolate beyond actual data [11, 12; 13].

The most common model that relate individual plant yield to population density is a reciprocal equation proposed by Holliday [14]:

1/w = a + bp **(1)**

Where w is individual plant weight or yield, p is plant density, and a and b are constants.This linear form of the equation describes an asymptotic response of area yield to plant density, whereas expansion to a quadratic equation describes a parabolic response. Biological meaning is ascribed to the parameters: 1/a is the plant yield at low density representing genetic potential and 1/b is the area yield at high density representing environmental potential. These attributes of the reciprocal form were cited as reasons for preference by Wiley and Heath [11]. The values of *a*and*b* (estimated by equation 1) can be used in equation 2 to determine crop yield per unit area (*Y*) at different plant population densities:

Y = p/(a + bp) **(2)**

Thus, this research was carried out to test the validity of equations 1 and 2 in quantifying the relationship between grain yield and plant density of bean cultivars.

MATERIALS AND METHODS

A factorial experiment based on RCB design with three replications was conducted in 2010 at the Research Farm of the Faculty of Agriculture, University of Tabriz, Iran (latitude 38.05° N, longitude 46.17° E, altitude 1360 m). The climate is characterized by mean annual precipitation of 245.75 mm, mean annual temperature of 10°C and mean annual maximum and minimum temperatures of 16.6°C and 4.2°C, respectively. Factors were cultivars (‘Akhtar’, ‘Derakhshan’, and ‘Sayad’) and plant densities (30, 40, 50, 55 plants/m^2).

Seeds of bean were treated with 2 g/kg Benomyl and then were sown by hand on 10 May 2010 in 3 cm depth of a sandy loam soil. Sowing densities were 40, 60, 80 and 100 seeds/m^2 to achieve proposed plant population densities. At the same time, plots were fertilized with 100 kg/ha urea (46%N). Each plot consisted of 6 rows of 6 m length, spaced 25 cm apart. All plots were irrigated immediately after sowing. Subsequent irrigations and hand weeding of the experimental area was carried out as required.

At maturity, the plants at 1 m^2 of the middle part of each plot were separately harvested and pods per plant, grains per pod and grains per plant were determined. Plants of another 1 m^2 from each plot were dried in an oven with 80°C for 48 hours. Subsequently, biological yield, 1000 grains weight and grain yield per unit area were recorded.

All the data were analyzed on the basis of experimental design, using MSTATC software. Excel software was used to draw figures.

RESULTS AND DISCUSSION

Analysis of variance of the data for yield components (Table 1), showed that pods per plant, grain per plant and 1000 grain weight were significantly affected by plant density and cultivar, but grains per pod only affected by cultivar. No significant density × cultivar interaction was observed on yield components (Table 1).

Table 1. Analysis of variance of the data for yield components of bean cultivars at different densities

Source	df	Pods per plant	Grains per pod	Grains per plant	1000- grains weight
Replication	2	7.043^{ns}	.017^{ns}	.026^{ns}	20.31^{ns}
Cultivar(c)	2	94.81**	1.382**	3.26**	3216.480*
Density	3	54.41**	.084^{ns}	2.36**	157.12*
D*C	6	.582^{ns}	.165^{ns}	.036^{ns}	35.77^{ns}
Eror	22	4.064	.026	.034	37.034
CV (%)		18.47	8.60	4.25	17.68

ns, *, **: No significant and significant at $p \leq 0.05$ and $p \leq 0.01$, respectively

The number of pods per plant, grains per plant and 1000 grain weight were significantly reduced by increasing plant density. However, differences in these traits between 30 and 40 plants m^{-2} and also between 50 and 55 plants m^{-2} were not significant (Table 2). Higher yield components at low densities related with the decreased inter-plant competition that leads to increased plant capacity for utilizing the environmental inputs in building great amount of metabolites to be used in developing new tissues [15]. These results are in agreement with those obtained by Mokhtar [6].

Table 2. Means of the yield components of bean for plant densities and cultivars

Treatment	Pods per plant	Grains per plant	Grains per pod	1000 grains weight (g)
Density D1	14.7^a	36.4^a	4.51^b	384.4^b
D2	14.3^a	35.1^a	4.33^b	376.2^b
D3	12.1^b	31.2^b	4.21^b	320.1^a
D4	11.3^b	30.4^b	4.23^b	310.52^a
Cultivar Akhtar	11.8^b	42.6^a	6.2^a	410^a
Derakhshan	10.4^b	34.2^b	5.8^a	395^a
Sayyad	13.1^a	32.2^b	4.1^b	220^c

Different letters in each column indicating significant difference at $p \leq 0.05$

D_1, D_2, D_3, D_4: 30, 40, 50, 55 plants/m^2 respectively.

Sayyad had the highest pods per plant, but the lowest number of grains per pod, grains per plant and 1000 grains weight, compared with Derakhshan and Akhtar. The highest grains per plant and 1000 grains weight were produced by akhtar (Table 2). These variations in yield components can be attributed to differences in genetic constitution of bean cultivars [16]. No significant effect of plant density, but significant effect of cultivar on number of grains per pod (Table 1) clearly suggests that this trait is controlled by genetics rather than by environmental factors.

The mean reciprocal data for biological and grain yields per plant are well described by equation 1 (Figures 1 & 2) (R^2 = 0.94-0.98). Thus, Regression coefficients obtained from equation (1) were used in equation 2 and the relations of plant density with biological and grain yields per unit area were determined (Figures 3 & 4).

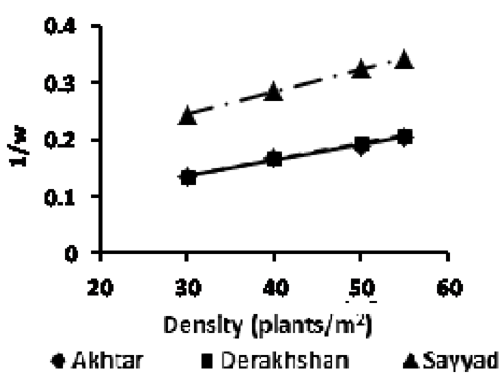

Figure 1. Relations between the reciprocal of bean yield per plant and plant density

Akhtar: 1/w= 0.002x+ 0.054 (R^2=0.94)

Derakhshan: 1/w= 0.002x+ 0.049 (R^2= 0.94).

Sayyad :1/w= 0.004x+ 0.126 (R^2=0.96).

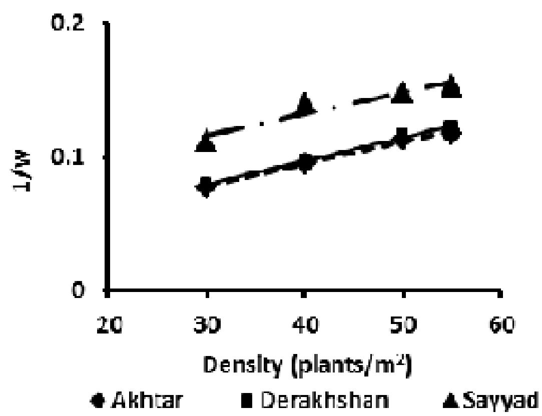

Figure 2. Relations between the reciprocal of biological yield per plant and plant density

Akhtar: 1/w= 0.001x+ 0.027 (R2=0.96).

Derakhshan: 1/w= 0.001x+ 0.028 (R2=0.98).

sayyad: 1/w= 0.001x+ 0.067 (R2= 0.95).

As shown in Figure 3, biological yield of all bean cultivars rapidly increased with increasing plant population density up to 40 plants m^{-2} and thereafter slowed down. Similar trend was shown for grain yield per unit area up to 50 plants m^{-2} (Figure 4). Nevertheless, considering seed cost twofold of grain yield, optimum economic density was estimated 50 plants m^{-2} for Akhtar and Derakhshan and 55 plants m^{-2} for Sayyad. This asymptotic relationship between plant population density and grain yield was also reported for other crops [17; 18]. Therefore, equations 1 and 2 can be successfully applied to predict changes in biological and grain yields of crops at different plant densities, providing that yield – density relationship is asymptotic. This means that crop yield becomes relatively stable at high densities [19, 20, 8, 21].

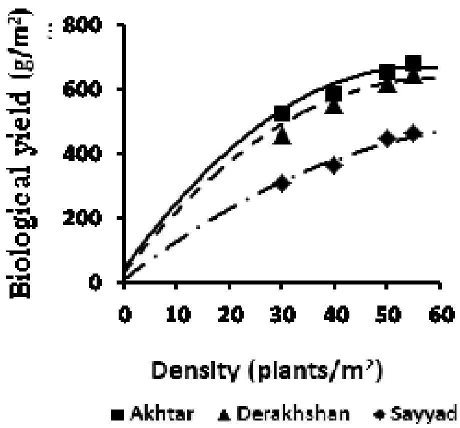

Figure 3. Relations between the biological yield per unit area and plant density in bean cultivars

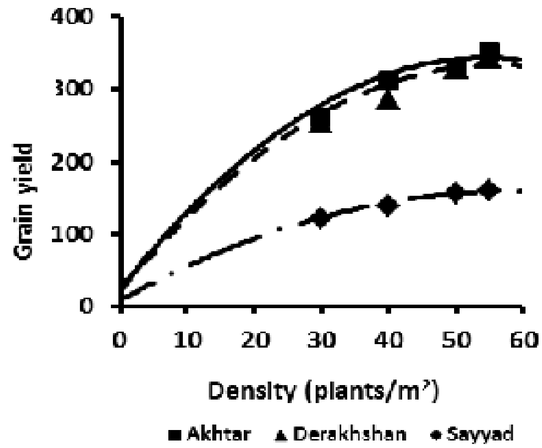

Figure 4. Relations between the grain yield per unit area and plant density in bean cultivars

Biological and grain yields per unit area for Sayyad were considerably lower than those for Akhtar and Derakhshan, particularly at high plant densities. The highest plant biomass and grain yield per unit area at different densities were produced by Akhtar, followed by Derakhshan (Figures 3 & 4). The superiority of the latter cultivars in grain yield is related with production of more grains per pod, grains per plant and 1000 grains weight, compared with Sayyad (Table 2).

CONCLUSIONS

Yield-density relationship for bean cultivars was well described by equations 1 and 2. Optimum economic density was estimated 50 plants m^{-2} for Akhtar and Derakhshan and 55 plants m^{-2} for Sayyad. The highest plant biomass and grain yield per unit area at different densities were produced by Akhtar, followed by Derakhshan. The superiority of these cultivars in grain yield was attributed to the production of more grains per pod, grains per plant and 1000 grains weight, compared with Sayyad.

REFERENCES

[1] Hulse J H. 1991. Nature, composition and utilization of grain legumes. In: Uses of tropical Legumes: Proceedings of a Consultants' Meeting. 27-30 March 1989, ICRISAT Center ICRISAT, Patancheru, A.P. 502324 India, pp. 11-27.

[2] Ghassemi-Golezani K and Mardfar R A. 2008. Effect of limited irrigation on growth and grain yield of common bean. Journal of Plant Science **3:** 230- 235.

[3] Kakiuchi J and Kobata T. 2004. Shading and thinning effects on seed and shoot dry matter increase in determinate soybean during the seed filling period. Agronomy Journal **96:** 398-405.

[4] Shahein A H, Agwah E M R and El-shamma H A. 1995. Effect of plant density as well as nitrogen and phosphorus fertilizer rate on growth, green pods and dry seed yield and quantity of broad bean. Annuals Agriculture of Science **33:** 371-388.

[5] Hussein A H A, El-Deeb M A, Saleib S R and El-Asseily K H. 1999. Response of the new faba bean genotypes to different plant densities in the old and newly reclaimed land in Middle and Upper Egypt Arab univ. Journal of Agriculture Science, Ain Shams Univ. **7:** 467-473.
[6] Mokhtar A. 2001. Response of yield and yield components of faba bean (*Vicia faba* L.) to increasing level of nitrogen and phosphorus under two levels of plant stand density. Annuals Agriculture of Science. Ain ShamsUniv **46:** 143-154.
[7] Roush L M and Radosevich S R. 1985. Relationship between growth and competitiveness of four annual weeds. Journal of Applied Ecology **22:** 895–905.
[8] Bleasdale J K A. 1967. The relationship between the weight of a plant part and total weight as affected by plant density. Journal of Horticultural Science **42:** 51-58.
[9] Li B and Watkinson A R. 2000. Competition along a nutrient gradient: A case study with Daucus carota and Chenopodium album. Ecological Research **15:** 293-306.
[10] Ellis R H and Salahi M. 1997. Optimizing inputs for contrasting cultivars: Quantifying the effects of plant population density and nitrogen fertilizer on the yield of four cultivars of spring wheat. Aspects of Applied Biology **50:** 139-146.
[11] Willey R W and Heath S B. 1969. The quantitative relationship between plant population and crop yield. Advances in Agronomy **21:** 281-321.
[12] Spitters C J T. 1983. An alternative approach to the analysis of mixed cropping experiments. 1. Estimation of competition effects. Netherlands Journal of Agricultural Science **31:** 1-11.
[13] Connolly J. 1987. On the use of response models in mixture experiments. Oecologia **72:** 95-103.
[14] Holliday R. 1960 a. Plant population and crop yield: part I: Field Crop Abstracts **13:** 159-167.
[15] Dahmardeh M, Ramroodi M and Valizadeh J. 2010. Effect of plant density and cultivars on growth, yield and yield components of faba bean (*Vicia faba* L.). African Journal of Biotechnology, pp, **9:** 8643-8647.
[16] Saxena NP. 1984. Chickpea. In: P.R. Gldsworthy and N.M. Fisher (eds.). Physiology of tropical field crops. John Wiley and sons, New York, pp. 419-52.
[17] Ellis R H, Salahi M and Jones SA. 1999. Yield-density equations can be extended to quantify the effect of applied nitrogen and cultivar on wheat grain yield. Annals of Applied Biology **134:** 347-352.
[18] Shirtliffe S J and Johnston A M. 2002. Yield-density relationships and optimum plant populations in two cultivars of solid-seeded dry bean (*Phaseolus vulgaris* L.) grown in Saskatchewan . Canadian Journal of Plant Science **82:** 521-529.
[19] Bleasdale J K A. 1966a. Plant growth and crop yield. Annals of Applied Biology **57:** 173-182.
[20] Bleasdale J K A. 1966b. The effects of plant spacing on the yield of bulb onions (*Allium cepa* L.) grown from seed. Journal of Horticultural Science **41:** 145-153.
[21] Bleasdale J K A. 1984. Plant Physiology in Relation to Horticulture, 2nd edition. London: MacMillan.