Journal of Plant Sciences

ISSN 1816-4951

Academic Journals Inc.

www.academicjournals.com

Journal of Plant Sciences 3 (3): 230-235, 2008
ISSN 1816-4951

Effects of Limited Irrigation on Growth and Grain Yield of Common Bean

K. Ghassemi-Golezani and R.A. Mardfar
Department of Agronomy and Plant Breeding, Faculty of Agriculture,
University of Tabriz, Iran

Abstract: Water resources are limited in many agricultural areas of West Asia. So, effective use of this scarce resource is very important in this region. Therefore, this research was conducted in 2004 at the Research Farm of the Faculty of Agriculture, University of Tabriz, Iran, to investigate the effects of different irrigation regimes (I_1, I_2 and I_3: irrigation after 60, 80 and 100 mm evaporation from class A pan, respectively) on growth, yield and yield components of three common bean cultivars (COS16, Talash and Khomain). A split-plot experiment based on randomized complete block design in three replications was used, with the irrigation levels in main plots and common bean cultivars in subplots. The results of plant growth analysis on the basis of Growth Degree Days (GDD) showed that Percentage Ground Cover (PGC), Dry Matter Accumulation (DMA), Crop Growth Rate (CGR) and Relative Growth Rate (RGR) were considerably reduced, due to water deficit. In all cultivars, the highest PGC, DMA, CGR and RGR were obtained under I_1. PGC at different stages of growth under I_3 was much less than that under I_1. PGC for Talash was more than that for other cultivars under I_3. CGR of COS16 under well-irrigation (I_1) was more than that of other cultivars, but CGR of Talash and COS16 under I_3 was almost similar at different stages of growth. All three cultivars had higher RGR at early stages of growth under I_1, compared to I_2 and I_3. However, this difference gradually decreased with increasing degree days. PGC had the practical advantage of easy, quick and non- destructive measurement. Therefore, it can be used as the best growth index for estimating crop performance in the field. Although, mean grain weight of Khomain was more than that of two other cultivars, but Talash and COS16 produced more pods and grains per plant, leading to higher yield per unit area, compared to Khomain. Drought stress led to the reduction of number of pods per plant, grains per plant and grain yield per unit area. However, differences in 1000 grains weight among I_1, I_2 and I_3 were not significant. Yield reduction under limited irrigations was only 9.45-16.5%. These results indicate that limited irrigation can considerably overcome the deleterious effects of drought stress on field performance of common bean.

Key words: Common bean, limited irrigation, growth analysis, grain yield

INTRODUCTION

Common bean (*Phaseolus vulgaris* L.) is the centerpiece of the daily diet for more than 300 million of the world's people. This crop is the world's most important food legume, far more than chickpeas, faba beans, lentils and cowpea. Nutritionist characterizes the common bean as a nearly perfect food because of its high protein content and generous amount of fiber, complex carbohydrates and other dietary necessities (Anonymous, 2001).

Drought stress is a worldwide production constraint of bean crop (Wortmann *et al*., 1998). The effect of drought can vary when it occurs during different stages of plant development. In general,

Corresponding Author: Kazem Ghassemi-Golezani, Department of Agronomy and Plant Breeding, Faculty of Agriculture, University of Tabriz, Tabriz, Iran Tel: 098411-3392028

drought has the greatest impact on bean seed yield when it occurs during reproductive development. Morphological and phenological traits such as plant type, root systems and early flowering play a major role in adaptation of plants to specific drought conditions.

Moderate to high drought stress can reduce biomass, number of pods and seeds, days to maturity, harvest index, seed yield and seed weight in common bean (Acosta-Gallegos and Adams, 1991; Ramirez-Vallejo and Kelly, 1998). A moderate drought stress has reduced yield by 41% (Foster *et al*., 1995). However, severe drought stress has reduced yield by 92% (Castellanos *et al*., 1996). In general, the lack of water interferes with the normal metabolism of the plant during flowering and grain filling, as these are stages when drought causes the greatest yield reduction.

Although common bean is considered a sensitive crop to water deficit (Molina *et al*., 2001; Szilagyi, 2003; Nunez-Barrios *et al*., 2005; Munoz-Perea *et al*., 2006), but limited irrigation, particularly at reproductive stages, may prevent substantial yield loss under drought stress (Singh, 1995; Pimentel *et al*., 1999; Costa-Franca *et al*., 2000). Also, regulation of limited irrigation to adequately meet the crop needs at the critical stages of growth and development is crucial for realization of yield potential of common bean cultivars in the field. Therefore, the objective of this investigation is to evaluate field performance of common bean cultivars under well and limited irrigation conditions.

MATERIALS AND METHODS

This research was conducted in 2004 at the Research Farm of Tabriz University, Tabriz, Iran (Lat. 38°05′ N, 46°17′ E, Altitude 1360 m above sea level). Tabriz is located in the North-west of Iran and has a mean annual temperature of 10°C and mean annual precipitation of 245.75 mm. The soil of research area was sandy-loam with EC of 0.68 dS m^{-1}, pH of 8.1 and field capacity of 28.8%.

This experiment was split-plot, based on randomized complete block design in 3 replications with the irrigation treatments (I_1, I_2, I_3: Irrigation after 60, 80 and 100 mm evaporation from class A pan, respectively) in main plots and cultivars (COS16, Talash and Khomain) in sub plots. The seeds were treated with 2 g kg^{-1} Mancozeb and then were sown by hand on 24 May 2004 in 5 cm depth of soil. At the same time, plots were fertilized with 100 kg ha^{-1} Ammonium Phosphate. Each plot size was 24 m^2 and consisted of 12 rows of 6 m length, spaced 30 cm apart. All plots were irrigated immediately after sowing, but subsequent irrigations were carried out according to the treatments. Hand weeding of the experimental area was done as and when required.

Ground cover was measured every week by viewing the canopy through a wooden frame (60×100 cm dimensions) divided into 100 equal sections. The sections were counted when more than half filled with crop green area. After seedling establishment, 3 plants were harvested from each plot in weekly intervals, up to crop maturity. Harvested plants were dried in an oven adjusted on 75°C for 48 h.

Excel software was used to find the best mathematical model, to describe the relationship between Dry Matter Accumulation (DMA) and Growing Degree Days (GDD). The best fit was obtained, using the following equation:

$$DMA = a+bH+cH^2+dH^3 \tag{1}$$

Where:

H	=	Accumulated growth degree days
a, b, c and d	=	Constants

Following equations were used to calculate CGR and RGR:

$$CGR = b+2cH+3dH^2 \tag{2}$$

$$RGR = (b+2cH+3dH^2)/(a+bH+cH^2+dH^3) \quad (3)$$

At maturity, three plants from each plot were harvested to determine pod length, pods per plant, grains per plant, grains per pod and 1000 grains weight. Finally, plants in 2 m^2 of each plot were harvested and grains detached from the pods and then grain yield per unit area was recorded.

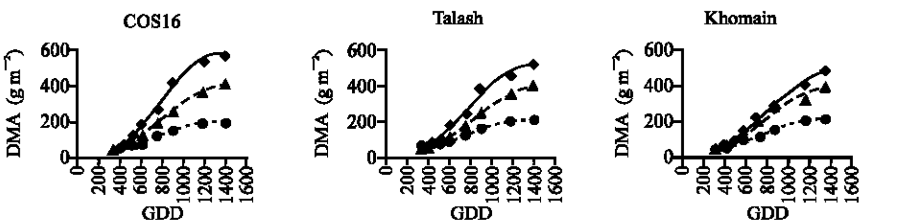
Analysis of variance of the data was carried out, using SAS (1996). Duncan test was applied to compare means of each trait at 5% probability. Excel software was used to draw figures.

RESULTS

Dry Matter Accumulation (DMA) of the common bean cultivars under different irrigation regimes at the early stages of growth was slow, but then showed a linear increase between 500 to 1150 GDD and then at later stages of growth again slowed down (Fig. 1). DMA of COS16 under I_1 was better than that of Talash and Khomain, but DMA of all cultivars under I_2 and I_3 was almost similar. In general, the highest and the lowest DMA obtained form plants under I_1 and I_3, respectively (Fig. 1).

CGR of the cultivars under all irrigation treatments primarily increased, until maximum value was attained and then gradually decreased, with increasing GDD (Fig. 2). Maximum CGR of each cultivar under I_3 was obtained earlier than that under I_1 and I_2. CGR of plants substantially reduced, due to water deficit (I_3), compared to well-watering (Fig. 2).

RGR of the common bean cultivars under all watering conditions decreased with increasing GDD (Fig. 3). This reduction was very rapid at the early stages of growth and slowed down at the later stages of growth. RGR reduction at the early stages of growth was much faster for I_1 and I_2 treatments, compared to I_3 treatment (Fig. 3).



COS16:
(1) $y = -8E\text{-}07x^3+0.0019x^2-0.7061x+85.29$ $R^2 = 0.9987$
(2) $y = -4E\text{-}07x^3+0.001x^2-0.2733x+29.004$ $R^2 = 0.9978$
(3) $y = -2E\text{-}07x^3+0.0004x^2-0.0616x+5.8596$ $R^2 = 0.9952$

Talash:
(1) $y = -5E\text{-}07x^3+0.0012x^2-0.2592x+0.3888$ $R^2 = 0.9951$
(2) $y = -3E\text{-}07x^3+0.0009x^2-0.271x+33.461$ $R^2 = 0.999$
(3) $y = -2E\text{-}07x^3+0.0004x^2-0.0364x+8.8415$ $R^2 = 0.9986$

Khomain:
(1) $y = -3E\text{-}07x^3+0.0008x^2-0.0818x-17.249$ $R^2 = 0.9986$
(2) $y = -4E\text{-}07x^3+0.001x^2-0.2957x+33.801$ $R^2 = 0.9855$
(3) $y = -2E\text{-}07x^3+0.0005x^2-0.1022x+25.061$ $R^2 = 0.9943$

Fig. 1: Dry Matter Accumulation (DMA) of COS16, Talash and Khomain under I_1 (-◆-), I_2 (-▲-) and I_3 (··●··) (Irrigation after 60, 80 and 100 mm evaporation from class A pan, respectively)

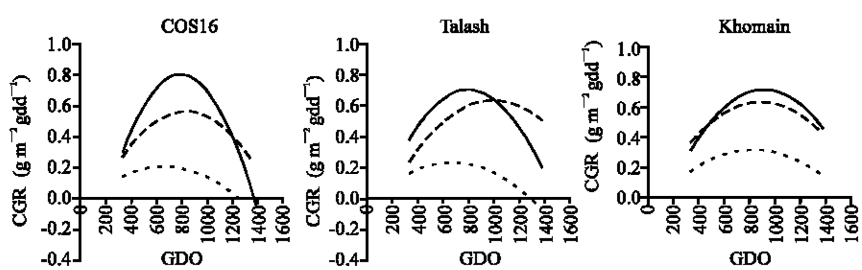


Fig. 2: Crop growth rate of COS16, Talash and Khomain under I_1 (__), I_2 (- - -) and I_3 (...)

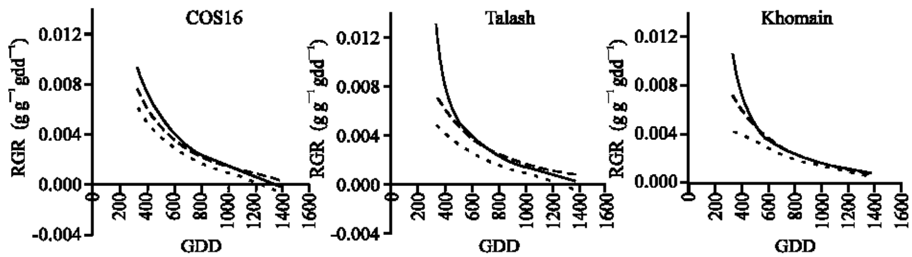


Fig. 3: Relative growth rate of COS16, Talash and Khomain under I_1 (—), I_2 (---) and I_3 (...)

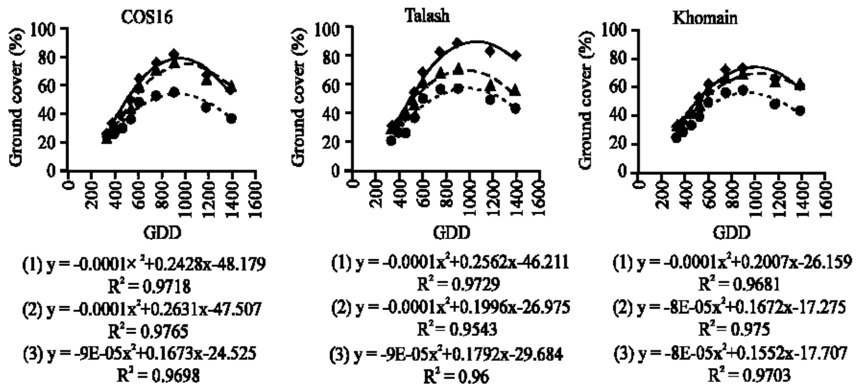


Fig. 4: Average percentage ground cover of COS16, Talash and Khomain under I_1 (-◆-), I_2 (-▲-) and I_3 (-●-)

Table 1: Analysis of variance of the data for yield and yield components of common bean cultivars, affected by irrigation regimes

Source	df	Pods per plant	Grains per plant	Grains per pod	1000 grains weight	Grain yield
Rep.	2	20.9**	246.22*	0.730	170.96	7701.3**
Irrigation(I)	2	15.79*	191.22*	0.240	32.62	3417.88*
Ea	4	4.50	142.99	0.190	305.01	1040.68
Cultivar(C)	2	23.16**	289.14*	0.430	2862.55**	3948.97*
I*C	4	1.31	10.46	0.057	457.21	1326.77
Eb	12	2.47	44.45	0.243	165.00	764.65
Total	26	----	----	----	----	----
CV	----	17.50	23.36	15.250	3.74	12.84

*, **: Significant at $p \leq 0.01$ and $p \leq 0.05$, respectively

stages of growth. RGR reduction at the early stages of growth was much faster for I_1 and I_2 treatments, compared to I_3 treatment (Fig. 3).

At the most stages of growth, the highest PGC was obtained under I_1, followed by I_2 and I_3, respectively (Fig. 4). These differences were more evident for Talash than for other cultivars. PGC increased with increasing GDD up to about 920-1050, depending on cultivar and irrigation regime. After that, PGC of cultivars decreased. This reduction for plants under I_3 started earlier, compared to those under I_1 and I_2 (Fig. 4).

Analysis of variance of the data for yield and yield components (Table 1) showed that pods per plant, grains per plant and grain yield per unit area were significantly affected by irrigation and cultivar, but 1000 grains weight only affected by cultivar. Neither irrigation nor cultivar had significant effect on grains per pod. No significant irrigation×cultivar interaction was observed on yield and yield components (Table 1).

Although, pods and grains per plant were comparatively higher for COS16, but the largest grains produced by Khomain. The highest and the lowest grain yield per unit area were obtained from

Table 2: Comparison of means of the yield and yield components of common bean for three irrigation regimes and three cultivars

Treatment	Pods per plant	Grains per plant	1000 grains weight (g)	Grain yield (g m^{-2})
Irrigation				
I_1	10.33^a	33.70^a	341^a	235.620^a
I_2	8.92^{ab}	26.70^b	345^a	196.790^b
I_3	7.68^b	25.01^b	337^a	213.340^b
Cultivar				
COS16	9.96^a	34.30^a	335^b	230.270^a
Talash	9.85^a	28.33^b	331^b	224.150^a
Khmain	7.13^b	22.79^b	358^a	191.321^b

Different letter(s) indicating significant difference at $p \leq 0.05$, I_1, I_2 and I_3: irrigation after 60, 80 and 100 mm evaporation from class A pan, respectively

COS16 and Khomain, respectively. However, difference in grain yield between COS16 and Talash was not statistically significant (Table 2). Mean number of pods per plant, grains per plant and grain yield per unit area under well-watered condition (I_1) were higher than those under limited irrigations (I_2 and I_3). These traits were almost similar for I_2 and I_3 treatments (Table 2).

DISCUSSION

Limitation in water resources and increasing demands to water supply, leading to rational use of these valuable resources in agriculture, without adverse effect on crop production. Common bean has a shallow rooting system and require frequent irrigations (Weaver *et al*., 1984). Therefore, this crop may respond strongly to water deficit (White and Singh, 1991; Nielsen and Nelson, 1998; Ramirez-Vallejo and Kelly, 1998; Teran and Singh, 2002; Nunez-Barrios *et al*., 2005; Munoz-Perea *et al*., 2006). In this research, limited irrigation led to reductions in DMA, CGR, RGR and consequently PGC of common bean cultivars (Fig. 1-4). Since, there is a linear relationship between PGC and light interception (Burstall and Harris, 1983), it is reliable to use this growth index to estimate yield potential of the crops under favorable or unfavorable conditions. It has, also, the practical advantage of quick, simple and non-destructive measurements, which makes frequent sampling available.

Although mean grain weight of COS 16 and Talash was lower than that of Khomain, but they produced more pods and grains per plant, leading to higher grain yield (Table 2). Nielsen and Nelson (1998) also showed that the yield component with the highest correlation to grain yield of black bean is number of pods per plant. Szilagyi (2003) reported that reduction of grain yield for common bean under drought stress was mainly due to reduction in number of pods per plant. Therefore, number of pods or grains per plant is the main component in determining yield potential of common bean cultivars in the field. No significant cultivar × irrigation interaction (Table 1) indicates that COS 16 and Talash were superior both under well and limited irrigation conditions.

Superiorities of well-watered (I_1) plants in growth indices and PGC resulted in production of more pods and grains per plant and finally higher grain yield per unit area, compared to limited irrigations (I_2 and I_3). These traits significantly reduced, due to water deficit. However, 1000 grains weight was similar for well and limited irrigations. Yield reduction under limited irrigations was only 9.45-16.5% (Table 2). These reductions were much less than those reported by Foster *et al*. (1995) and Castellanos *et al*. (1996) for common bean. Reductions in grain yield and yield components of common bean under mild water stress are also reported by other authors (Acosta-Gallegos and Kohashi Shibata, 1989; Acosta-Gallegos and Adams, 1991; Ramirez-Vallejo and Kelly, 1998).

CONCLUSION

Common bean is a sensitive crop to water stress and high yield of this crop only can be obtained under sufficient irrigation conditions. Nevertheless, limited irrigation can considerably overcome the deleterious effects of drought stress on field performance of common bean. Percentage ground cover and number of grains per plant are the most important traits for estimating yield potential of common bean cultivars under both well and limited irrigation conditions.

REFERENCES

Acosta-Gallegos, J.A. and J. Kohashi-Shibata, 1989. Effect of water stress on growth and yield of indeterminate dry- bean (*Phaseolus vulgaris*) cultivars. Field Crops Res., 20: 81-93.

Acosta-Gallegos, J.A. and M.W. Adams, 1991. Plant traits and yield stability of dry bean (*Phaseolus vulgaris*) cultivars under drought stress. J. Agric. Sci., 117: 231-219.

Anonymous, 2001. Common bean: The nearly perfect food. CIAT in Focus Crop Commitments.http://www.ciat.cgiar.org/ciatinfocus/bean.htm.

Burstall, L. and P.M. Harris, 1983. The estimation of percentage ground cover in potatoes. J. Agric. Sci., 100: 241-244.

Castellanos, J.Z., J.J. Pena-Cabriales and J.A. Acosta-Gallegos, 1996. N-determined dinitrogen fixation capacity of common bean (*Phaseolus vulgaris*) cultivars under water stress. J. Agric. Sci., 126: 327-333.

Costa-Franca, M.G., A.T. Thi, C. Pimentel, R.O. Pereyra, Y. Zuily-Fodil and D. Laffray, 2000. Differences in growth and water relations among *Phaseolus vulgaris* cultivars in response to induced drought stress. Environ. Exp. Bot., 43: 227-237.

Foster, E.F., A. Pajarito and J. Acosta-Gallegos, 1995. Moisture stress impact on N partitioning, N remobilization and N-use efficiency in beans (*Phaseolus vulgaris*). J. Agric. Sci., 124: 27-37.

Molina, J.C., V. Moda-Cirino, N.S.F. Junior, R.T. Faria and D. Destro, 2001. Response of common bean cultivars and lines to water stress. Crop Breed. Applied Biotechnol., 1: 363-372.

Munoz-Perea, C.G., H. Teran, R.G. Allen, J.L. Wright, D.T. Westermann and S.P. Singh, 2006. Selection for drought resistance in dry bean landraces and cultivars. Crop Sci., 46: 2111-2120.

Nielsen, D.C. and N. Nelson, 1998. Black bean sensitivity to water stress at various growth stages. Crop Sci., 38: 422-427.

Nunez-Barrios, A., G. Hoogenboom and D.S. Nesmith, 2005. Drought stress and the distribution of vegetative and reproductive traits of a bean cultivar. Sci. Agric., 62: 18-22.

Pimentel, C., D. Laffray and P. Louguet, 1999. Intrinsic water use efficiency at the pollination stage as a parameter for drought tolerance selection in *Phaseolus vulgaris*. Physiol. Planta., 106: 184-189.

Ramirez-Vallejo, P. and J.D. Kelly, 1998. Traits related to drought resistance in common bean. Euphytica, 99: 127-136.

SAS, 1996. SAS/STAT User's Guide. SAS Institute Inc., Cary.

Singh, S.P, 1995. Selection for water-stress tolerance in interracial populations of common bean. Crop Sci., 35: 118-124.

Szilagyi, L., 2003. Influence of drought on seed yield components in common bean. Blug. J. Plant Physiol., Special Issue, pp: 320-330.

Teran, H. and S.P. Singh, 2002. Comparison of sources and lines selected for drought resistance in common bean. Crop Sci., 42: 64-70.

Weaver, M.L., Ng. H. Burke, D.W. Silbernagel, N.J. foster and K. Timm, 1984. Effect of soil moisture tension on pos retention and seed yield of bean. HortScience, 19: 567-572.

White, J. and Singh, 1991. Breeding for Adaptation to Drought. In: Common Bean: Research for Crop Improvement, Van Shoonhoven A. and O. Voysest (Eds.). CABI, Walingford, UK and CIAT, Cali, Colombia, pp: 501-560.

Wortmann, C.S., R.A. Kirby, C.A. Eledu and D.J. Allan, 1998. Atlas of common bean (*Phaseolus vulgaris* L.) production in Africa. CIAT, Cali, Colombia.