American-Eurasian J. Agric. & Environ. Sci., 9 (5): 495-499, 2010
ISSN 1818-6769

Water Stress Effects on Two Common Bean Cultivars with Contrasting Growth Habits

Y. Emam, A. Shekoofa, F. Salehi and A.H. Jalali

College of Agriculture, Shiraz University, Shiraz, Iran

Abstract: In most rainfed production areas in Iran, where wheat fallow is common, crop yield and resource sustainability could be improved by changing to more diverse crop rotation. It seems necessary to identify crop cultivars suitable for such diversification. This study was aimed to determine responses of two common bean *(Phaseolus vulgaris* L.*)* cultivars with different growth habits (Sayyad as an indeterminate and D81083 as a determinate cultivar) to water stress conditions. The study was conducted in controlled conditions (the greenhouse of Department of Crop Production and Plant Breeding, College of Agriculture Shiraz University, Shiraz, Iran) during 2008 growing season. There were four water stress levels (100, 75, 50 and 25% of field capacity by weight). The results showed that plant height, number of leaves, leaf area, number of pods, pod dry weight and total dry weight of both cultivars responded significantly to water stress conditions. Water stress also reduced stem height and reduced leaf area. Furthermore, it reduced pod dry weight in both cultivars and in 50 and 25% water stress levels, all plant pods of both cultivars were aborted. Common bean cultivar with determinate growth habit (D81083) appeared to have potential as a dryland rotation crop for arid areas with dryland farming. Further field research might shed more light on sensitivity of bean cultivars to water stress levels with the aim of crop diversification for dryland areas in Iran, where adequate moisture supply is limiting.

Key words: Sayyad and D81083 bean cultivars · Rainfed · Determinate and indeterminate growth habits

INTRODUCTION

Crop rotations can increase crop yield (compared with monoculture) by employing diversity in plant water use, rooting pattern and crop type (broad leaf vs. grass) [1]. The beneficial effects of rotation may arise from better soil moisture use and nutrients uptake and reduced disease, insects, weeds and phytotoxic compounds [2]. Drought stress is one of the limiting factors in crop growth and yield which reduces dry matter production, yield and yield components through decreasing leaf area and accelerating leaf senescence [3].

Common bean (*Phaseolus vulgaris* L.) is considered one of the most important grains for human alimentation and is worldwide planted on approximately 26 million hectares (www.faostat.fao.org). Common bean could be grown as a seed legume in dryland rotations with winter wheat to increase production diversity [1]. Although there are reports that common bean is susceptible to drought stress or water deficit, the production of this crop in many places of the world is carried out under drought stress conditions, due to insufficient water supply by rainfall and/or irrigation [4-6].

As much as 60% of common bean production in the developing world occurs under conditions of significant drought stress [7]. This is probably the reason why the average global yield of beans remains low (<900 kg ha^{-1}) [8]. Therefore, it appears that drought stress is a worldwide production constraint for common bean [9-12].

Some management practices, like irrigation, can contribute to the increase of grain yield under water stress conditions, thus the development of tolerant cultivars becomes an efficient and economical production strategy [6, 13]. Indeed, drought tolerance implies the ability to sustain reasonable yields under moderate water stress and not the ability to survive over prolonged and severe water stress periods [13, 14]. Water stress has been reported to reduce the expression of many characteristics in faba beans except days to flowering and moisture retention in the leaf [14]. In common beans, accelerated maturity of crop along with reducing grain yield and mean weight of hundred seeds following water stress, have been reported [1, 13, 15].

Periods of water stress during the reproductive phase of the common bean, has been associated with a significant reduction in grain yield [3, 15] and nodulation [15]. Decrease in grain yield has been resulted from a

Corresponding Author: Y. Emam, College of Agriculture, Shiraz University, Shiraz, Iran
Tel: +98 711 2286134; Fax: +98 711 2286134 E mail: yaemam@shirazu.ac.ir

lower percentage of pod production, when drought occurred during flowering [15] and from embryos abortion, when it occurred in the pod-forming stage [16].

In general, grain yield was decreased as the number of days under drought stress was increased [1, 3, 6, 13,]. Furthermore, common bean cultivars and lines has reported to respond differently to soil moisture stress during the flowering period, depending on the severity of water stress [9, 13]. Water stress during the flowering and grain filling periods reduced seed yield and seed weight and accelerated maturity of dry bean [6, 10].

Molina *et al*., [13] reported that water stress reduced grain yield of common bean cultivars, by approximately, 50%, however, the IPR88 Uirapuru cultivar, from the black commercial group and the LP 97-13 and LP 97-4 lines from the carioca commercial group, stood out as "drought tolerant" and showed high yield potential.

Shoot biomass accumulation is considered an important trait to attain high seed yield in grain legumes. Significant differences have been observed for shoot biomass accumulation among dry bean cultivars grown under severe drought stress conditions. Furthermore, differences in biomass accumulation and allocation have been detected among bean cultivars with different growth habits [17].

This work aimed to study the effect of some water stress treatments (25, 50, 75 and 100% of field capacity) on growth and development of two common bean cultivars (D81083 and Sayyad) with contrasting growth habits, under controlled conditions.

MATERIALS AND METHODS

A greenhouse study was carried out from November 2008 to January 2009 to investigate the impact of different levels of water stress as a percentage of field capacity (by weight) on growth and development of two bean cultivars of D81083 and Sayyad. Sayyad was an indeterminate upright cultivar (type II), however, D81083 was a bushy determinate upright cultivar (type I) [7].

Each pot was filled with 5 Kg of air-dried soil. The experimental soil characteristics of Daneshkadeh soil series (Fine, mixed, mesic, Calcixerollic, Xerochrepts), are given in Table 1. Plants were given routine fertilizers throughout the experiment. Other normal agronomic practices for bean production were followed.

Soil field capacity was calculated on soil dry weight basis. Four uniform seeds were sown 5 cm deep in each pot and then thinned to one at two leaf stage. Water-stress treatments were (100, 75, 50 and 25% of field capacity by weight), imposed when the plants were established (with two true leaves).

The pots were weighed in two days intervals to compensate the water loss by evapotranspiration and therefore, the pot soil moisture was kept at 100, 75, 50 and 25% of field capacity according to treatments. The experiment was designed as a randomized complete block with four replications.

The following plant growth parameters were measured at 76 days after planting: plant height, leaf area per plant, leaf dry weight, pod dry weight per plant and total dry weight per plant. The leaf area was measured using a digital leaf area meter, Delta T Device model. Dry weights were measured after the samples were oven-dried (48 h in 75°C). All collected data were statistically elaborated using analysis of variance (ANOVA), followed by means separation using Duncan's multiple range test at $P<0.05$. All calculations were performed using SAS 9.0 software package.

RESULTS AND DISCUSSION

Plant Height: Plant height was significantly affected by soil moisture treatments (Table 2). The interaction among soil moisture and cultivar was also significant. Sayyad cultivar produced the tallest plants at all water stress levels (Table 2). This was related to the growth habit of this cultivar, however, water stress depressed plant height of both cultivars and the shortest plants were produced at higher water stress levels (Table 2).

Table 1: Some physical and chemical properties of experimental soil

pH	EC (µmos/s)	N (%)	P	Fe	Zn	Mn	Cu	OM (%)	Sand (%)	Silt (%)	Clay (%)
			(ppm)								
7.83	2.61	0.091	21.8	6.4	2.31	6.75	2.48	2.85	21.28	60.72	18

Table 2: Effect of water stress levels on plant height (cm) of two common bean cultevars

Treatments	Water stress levels (% of FC)				
Common bean cultivars	100	75	50	25	Mean
D81083	35.250c	29.500d	24.750e	22.750e	28.0625B
Sayyad	51.000a	43.250b	36.000c	30.000d	40.0625A
Mean	43.125A	36.375B	30.375C	26.375D	

Values followed by different letters are significant at P<0.05 (Duncan Multiple Range Test). Small letters for nteraction effeccts and capital letters for the main effects were used

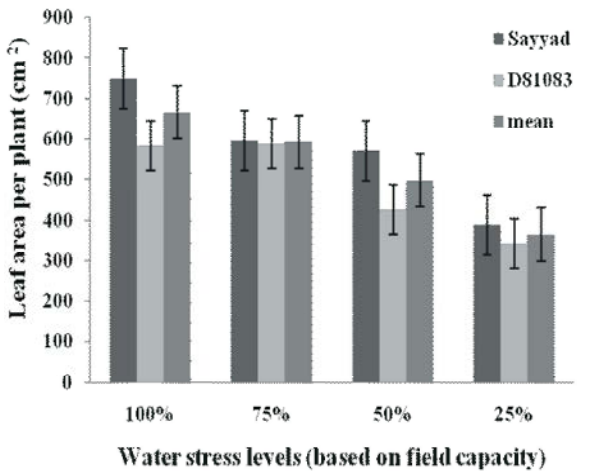

Fig. 1: Effect of water-stress levels on common bean leaf area. Vertical bars are standard error of the means

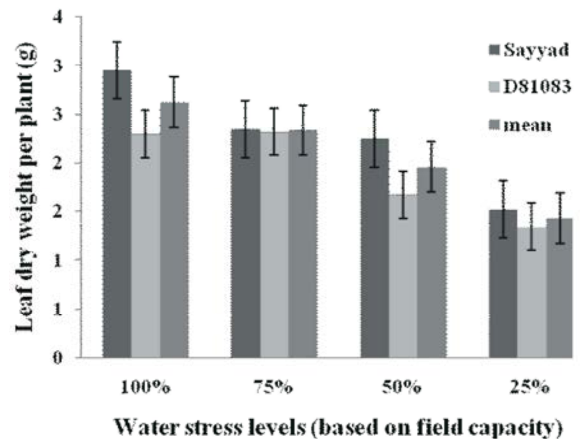

Fig. 2: Effect of water-stress levels on common bean leaf dry weight. Vertical bars are standard error of the means

This finding is in agreement with the results of Nielsen and Nelson, [1] and Shenkut and Brick, [18] who reported on depression of plant height as a result of severe influence from environmental factors such as water stress.

Leaf Area and Leaf Area Dry Weight: Plant leaf area, measured at the end of the stress period differed significantly between the two cultivars (Fig. 1). Sayyad cultivar had a significantly larger leaf area than D81083 and this was associated with its growth habit (i.e. indeterminate). Exposing the plants to drought stress of 50% field capacity resulted in a significant reduction in leaf area (Fig. 1).

Gunton and Everson [19] and Emam [15] reported leaf area of dry beans was reduced when the plants exposed to drought stress during vegetative growth stage. Furthermore, Nielsen and Nelson [1], observed significant LAI reductions in black bean (*P. vulgaris* L) under drought stress in the vegetative phase. Markhart [20] also found significant reductions in the leaf area under drought conditions at 23 days after planting for two bean species (*P. vulgaris and P. acutifolius*). Indeed, loss of leaf area, which could be resulted from reduced size of younger leaves and inhibition of the expansion of developing foliage, is also considered as an adaptation mechanism to moisture deficit [15, 21].

Leaf dry weight was increased significantly by increasing the availability of soil moisture (Fig.2). Sayyad cultivar showed a significantly higher leaf dry weight per plant than D81083 cultivar, especially under the 100% water treatment. This was associated with the growth habit of this cultivar, having more leaves per plant, also noted by Emam, [15]. While the 100 and 75% water treatment did not make any difference in leaf dry weight per plant, there was a significant difference in leaf dry weight between this moisture regimes and the 50% water stress treatment (Fig. 2).

Plant Dry Weight: Plant dry weight was decreased significantly by increasing water stress levels (Fig.3). Again, Sayyad cultivar (i.e. indeterminate growth habit) showed a significantly higher plant dry weight than D81083 cultivar. This difference was greater under 100% water treatment. Other studies Emam, [15] and Rosales-Serna *et al*. [17] have also reported significant differences in shoot biomass accumulation among dry bean cultivars grown under moderate to severe drought stress conditions.

Pod Dry Weight: The weight of the marketable pods produced by bean plants throughout the stress period, was significantly affected by the interaction among water stress treatments and cultivars, (Table 2 and Fig. 4). The poor response of Sayyad to drought stress with respect to pod dry weight in this experiment, could be probably associated with greater vegetative growth in this cultivar, which was also reflected in higher total leaf area (Fig.1). Interestingly, the genotype with the greater reduction in leaf area under drought stress was D81083. This genotype also showed higher pod dry weight values, indicating that genotypes with less vegetative growth might be more efficient in yield per plant, as being noted by Emam, [15].

Since there was no significant difference between 100 and 75% water stress level with respect to pod dry weight, it appears that 75% of field capacity might be a suitable treatment for achieving efficient bean yield. Drought response difference, between cultivars may arise from:

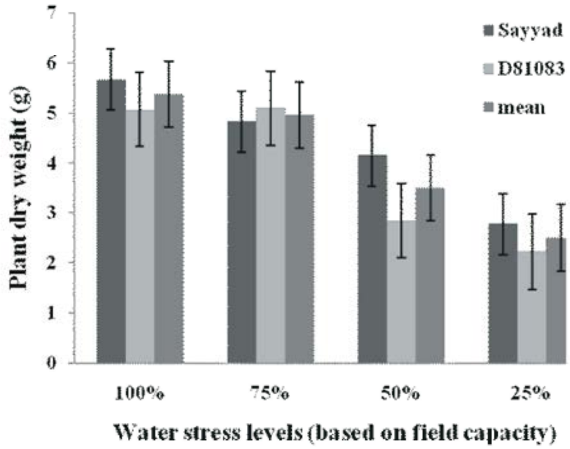

Fig. 3: Effect of water-stress levels on common bean dry weight. Vertical bars are standard error of the means

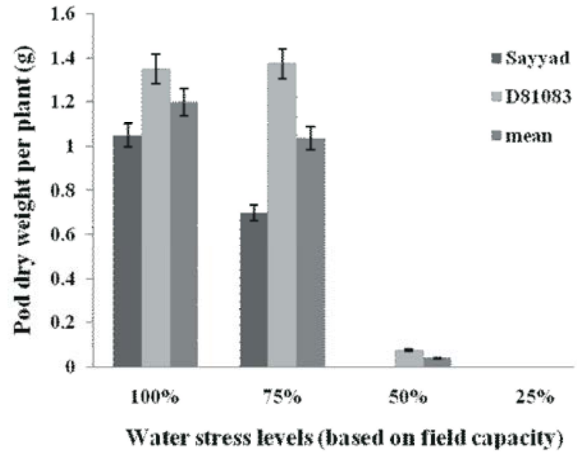

Fig. 4: Effect of water-stress levels on common bean pod dry weight. Vertical bars are standard error of the means

improved water uptake [15], efficient water conduction [3], restriction in transpiration [22] and water storage and desiccation tolerance [23].

Since plant biomass has moderate to high heritability and exhibits low genotype×environment interactions, it has been suggested that this trait could be used as an indirect selection criterion to improve and stabilize seed yield for low moisture areas [18]. According to Chaves *et al*. [24] in addition to dry matter accumulation, the ability of genotypes to partition stored vegetative biomass to reproductive organs to a large extent determines sink establishment and economic yield under drought stress conditions.

Overall, drought stress has considerable impact on common bean growth and seed yield although the ranges of reductions are highly variable due to differences in the timing and intensity of the stress imposed and the genotypes used [15, 18, 25]. Bean seed yield reduction due to drought stress are attributed to adverse effects of the stress on individual yield components (number of pods per plant, number of seeds per pod, seed weight and harvest index). The relative importance of individual components as determinants of seed yield varies from experiment to experiment [9, 15, 18]. Our results showed that although common bean is a sensitive plant to water stress and plant height, leaf area, phytomass production and pod dry weight are reduced with moisture deficit, it appears that cultivars with determinate growth habit, such as D81083, might have potential as a dryland rotation crop for most dryland areas of Iran.

REFERENCES

1. Nielsen, D.C. and N.O. Nelson, 1998. Black bean sensitivity to water stress at various growth stages. Crop Sci., 38: 422-427.
2. Crookston, R.K., J.E. Kurle, P.J. Copland, J.H. Ford and W.E. Lueschen, 1991. Rotational cropping sequence affects yield of corn and soybean. Agron. J., 83: 108-113.
3. Emam, Y. and M.J. Seghatoleslami, 2005. Crop Yield: Physiology and Processes. First edition. Shiraz University Inc., Shiraz. pp: 593. (in Farsi).
4. Machado Neto, N.B. and M.A.B. Durães, 2006. Physiological and biochemical response of common bean varieties treated with salicylic acid under water stress. Crop Breed. Appl. Biotech., 6: 269-277.
5. Souza, M.G., S. De Tarso Aidar, C.D. Giaveno and R.F. De Oliveira, 2003. Drought stability in different common bean (*Phaseolus vulgaris L.*) genotypes. Crop Breed. Appl. Biotech., 3: 203-208.
6. Zlatev, Z. and Z. Stoyanov, 2005. Effects of water stress on leaf water relations of young bean plants. J. Central Eur. Agric., 6: 5-14.
7. Graham, P.H. and P. Ranalli, 1997. Common Bean (*Phaseolus vulgaris* L.). Field Crop. Res., 53: 131-146.
8. Singh, S.P., 2001. Broadening the genetic base of common bean cultivars. Crop Sci., 41: 1659-1675.
9. Boutraa, T. and F.E. Sanders, 2001. Influence of water stress on grain yield and vegetative growth of two cultivars of bean (*Phaseolus vulgaris*, L.). J. Agron. Crop. Sci., 187: 251-257.

10. Szilagyi, L., 2003. Influence of drought on seed yield components in common bean. Bulg. J. Plant Physiol. Special Issue, 320-330.
11. Ramos, M.L.G., A.J. Gordon., F.R. Minchin, J.I. Sprent and R. Parsons, 1999. Effect of water stress on nodule physiology and biochemistry of a drought tolerant cultivar of common bean (*Phaseolus vulgaris* L.). Ann. Bot., 83: 57-63.
12. Singer, S.M., Y.I. Helmy, A.N. Maras and A.F. Abou-Hadid, 1997. Growth and development of bean plants (*Phaseolus vulgaris* L.) grown under water-stress. Cahiers Options Méditerranéennes, 31: 241-250.
13. Molina, J.C., V. Moda-Cirino, N. Da S.F. Júnior, R.T. De Faria and D. Destro, 2001. Response of common bean cultivars and lines to water stress. Crop Breed. Appl. Biotech., 1: 363-372.
14. Husain, M.M., J.B. Reid, H. Othman and J.N. Gallagher, 1990. Growth and water use of faba beans *(Vicia faba*) in a sub-humid climate. I. Root and shoot adaptations to drought stress. Field Crops Res., 23(1): 1-17. [C.f. *Field Crops Abstracts,* 1990, 043-042061].
15. Emam, Y., 1985. Effects of N levels and moisture regimes on agronomic characteristics of four cultivars of dry beans *(Phaseolus vulgaris* L*.)*. M.Sc Thesis. Shiraz University Shiraz, Iran. pp: 41. (in Farsi).
16. Robins, J.S. and C.E. Domingo, 1956. Moisture deficit in relation to the growth and development of dry beans. Agron. J., 48: 67-70.
17. Rosales-Serna, R., J. Kohashi-Shibata, J.A. Acosta-Gallegos, C.T. Lopez, J. Ortiz-Cereceres and J.D. Kelly, 2004. Biomass distribution, maturity acceleration and yield in drought-stressed common bean cultivars. Field Crops. Res. 85: 203-211.
18. Shenkut, A.A. and M.A. Brick, 2003. Traits associated with dry edible bean (*Phaseolus vulgaris* L.) productivity under diverse soil moisture environments. Euphytica, 133: 339-347.
19. Gunton, J.L. and J.P. Evenson, 1980. Moisture stress in navy beans. I. Effect of withholding irrigation at different phonological stages on growth and yield. Irrig. Sci., 2: 49-58.
20. Markhart, H.A., 1985. Comparative water relations of *Phaseolus vulgaris* L. and *Phaseolus acutifolius* Gray. Plant Physiol., 77: 113-117.
21. Acosta-Gallegos, J.A. and J.W. White, 1995. Phenological plasticity as an adaptation by common bean to rainfed environments. Crop Sci., 35: 199-204.
22. Tardieu, F., 2005. Plant tolerance to water deficit: physical limits and possibilities for progress. C. R. Geoscience, 337: 57-67. Www.faostat.fao.org.
23. Larcher, W., 2001. Physiological Plant Ecology: Ecophysiology and Stress Physiology of Functional Groups. 4th edition. Springer, pp: 513.
24. Chaves, M.M., J.S. Pereira, J.P. Maroco, M.L. Rodrigues, C.P.P. Ricardo, M.L. Osŕio, I. Carvalho, T. Faria and C. Pinheiro. 2002. How plants cope with water stress in the field: photosynthesis and growth. Ann. Bot., 89: 907-916.
25. Frahm, M.A., J.C. Rosas, N. Mayek-Pérez, E.L ez-Salinas, J.A. Acosta-Gallegos and J.D. Kelly, 2004. Breeding beans for resistance to terminal drought in the lowland tropics. Euphytica., 136: 223-232.