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Water deficit on three common bean cultivars

Daniel Soares Alves[1], Jefferson Vieira José[2], Patrícia Angélica Alves Marques[2],
Vânia Moda-Cirino[1], Pablo Ricardo Nitsche[1], Bruno Patias Lena[2], Marcos Vinícius Folegatti[2]

[1] Paraná Agronomic Institute, Plant Breeding Department, Curitiba - PR, Brazil. E-mail: danielsoares31@yahoo.com.br; vamoci@iapar.br; pablo@iapar.br
[2] "Luiz de Queiroz" College of Agriculture, Biosystems Engineering Department, Piracicaba-SP, Brazil. E-mail: jfvieira@usp.br; paamarques@usp.br; brunoplena@usp.br; mcfolega@usp.br

Abstract: This study had the objective of evaluate the effect of different irrigation depth on yield for three different common bean (*Phaseolus vulgaris* L.) cultivars. The experiment performed in greenhouse using PVC pots with 70 dm^3. The cultivars analyzed was IAPAR 81, IPR Tangará and IPR Curió and the irrigations occurred when the soil water tension showed 30 kPa considering tensiometers installed at 0.15 m of depth (T1), 0.20 m (T2) and 0.30 m (T3) defining three levels of water in the soil. The plant variable such as dry leaves mass, dry stem mass, dry pods mass, dry roots mass, as well as grain yield and the yield index were determined and analyzed statistically. IAPAR 81 cultivar presented higher grain yield for T2, and IPR Tangará and IPR Curió were not statistically different for T2 and T3. The dry root mass results were different only between cultivars, with similar grain yield between IAPAR 81 and IPR Tangará, and IPAR Curió presented mean yield reduction of 52% for all three water management. For all cultivars analyzed, IAPAR 81 had less plant development interference due the different soil water management, considering a good genotype for regions with high water deficit risk.

Keywords: *Phaseolus vulgaris*, soil water availability, deficit irrigation.

Análise da deficiência hídrica em três cultivares de feijão

Resumo: Este trabalho teve como objetivo avaliar a resposta produtiva de três cultivares de feijão (*Phaseolus vulgaris* L.) sob diferentes lâminas de irrigação. O experimento foi conduzido em casa de vegetação usando vasos de 70 dm^3. As cultivares estudadas foram IAPAR 81, IPR Tangará e IPR Curió e as irrigações foram realizadas quando a tensão de 30 kPa foi atingida nos tensiômetros instalados a 0,15 m de profundidade (T1), 0,20 m (T2) e 0,30 m (T3), definindo assim três níveis de disponibilidade hídrica no solo. Foram avaliados e analisados estatisticamente a fitomassa seca das folhas, do caule, das vagens, das raízes, assim como rendimento de grãos e o índice de colheita. A cultivar IAPAR 81 apresentou maior produção de grãos no regime hídrico T2, enquanto a IPR Tangará e IPR Curió não diferiram estatisticamente para os regimes T2 e T3. A matéria seca de raízes foi diferenciada apenas entre cultivares, com produção semelhante entre IAPAR 81 e IPR Tangará, enquanto a IPR Curió apresentou redução de 52% na média dos três tratamentos hídricos. Para todas as cultivares analisadas, a cultivar IAPAR 81 teve menor interferência à baixa disponibilidade hídrica, constituindo-se num genótipo interessante para regiões com elevado risco de deficiência hídrica.

Palavras-chave: *Phaseolus vulgaris*, disponibilidade hídrica, melhoramento vegetal.

Introduction

The irrigated agriculture is the most water consumptive worldwide, representing around 70% of total fresh water demand (FAO, 2011). In addition, irrigation in some parts of the world has been performed with no concern to the irrigation efficiency (Chai et al., 2014), and, in arid and semi-arid region, the fresh water is limited (Forouzani and Karami, 2011). Consequently, water resources for irrigated agriculture will be rationalized in order to provide water for others sectors such as urban areas and industry (Wasson et al., 2012).

Agriculture and livestock use together 13.2 bi h worldwide with 12% for agricultural crops (1.6 bi ha) (FAO, 2011). Considering only the agricultural crops land use, 0.3 bi ha are under irrigation (only 17%). Despite the small participation of irrigation in acreage, it represents about 44% of the world food production. In the last 50 years the irrigated agriculture more than doubled in acreage. In addition, the irrigated practice improve yield around 2.5 times higher in comparison with rainfed areas (Paulino et al., 2011).

Deficit irrigation is one of the most water saving technic within irrigated agriculture. The partial irrigation on the root zone is the second most technic used in the deficit irrigation, which is characterized by providing water only for part of the plant root, where the other part is maintained exposed to the water deficit condition (Chai et al., 2016). However, this method has not been stablished yet and it is necessary to understand its dynamic in order to determine its efficiency on crops.

The effect of different water management on common bean (*Phaseolus vulgaris* L.) can provide information to help the breeding programs to identify varieties that are water deficit tolerant and, at the same time, with high yield, which will reduce the agricultural risks. The water deficit influences on the initial plant development, resulting in yield reduction (Bougault et al., 2010). However, depending on the genetics characteristic, the plant may be induced to adapt to this condition. For example, in drought condition the plant increases the root development (Subbarao et al., 1995), improving the plant ability to adapt to water deficit.

The objective of this study was to determine the influence of three soil water availability in three common bean cultivar on plant growth parameters and grain yield.

Material and Methods

Experimental area

The experiment was performed in greenhouse condition at Agronomic Institute of Paraná State (IAPAR) experimental area (23°23'S e 51°11'W). The greenhouse had 6.4 m width and 22.5 m length, totalizing 144 m^2, with laterals covered with treated polycarbonate to reduce direct ultraviolet light and the roof covered with low density plastic film. The inside air was constantly renewed by an automatic system. The experiment was performed from January to September 2013. The inside air temperature during experiment varied from 18 to 27 °C, with average of 23 °C, Figure 1.

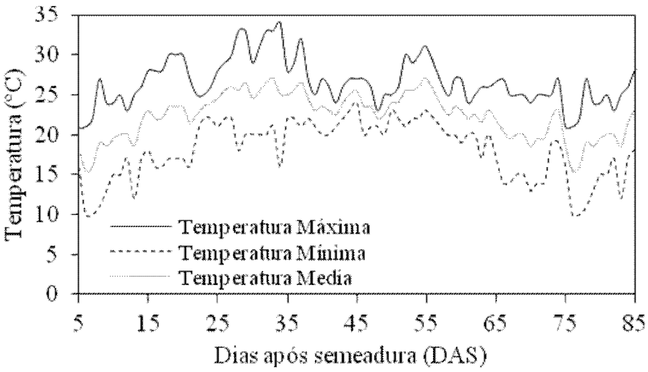

Figure 1. Maximum, minimum and average temperature of air registered at the greenhouse during experiment period.

Experimental design

The experimental design was the factorial composed by three common bean cultivar (IAPAR81, IPR Tangará, and IPR Curió), three soil water availability (considering T1, T2, and T3 was 256, 463, and 547 mm, respectively for both IAPAR 81 and IPR Tangará cultivars, and T1, T2, and T3 was 256, 329, and 404 mm, respectively for IPR Curió), and with five replications. In each experimental plot, it was represented by a circular pot with 1 m height, in which was composed by 5 rings of 0.2 m height and 0.3 m diameter. The pots were filled with soil and kept with high soil moisture for 30 days to guarantee that the nutrients availability to the plants. Then, it was cultivated 5 common bean seeds per pot, respecting the experimental design for each cultivar. We assessed dry leaves mass (DLM), dry stem mass (DSM), dry pods mass (DPM), dry root mass (DRM), dry total mass (DTM), grain yield (GY) and harvest index (HI).

Soil and crop management

The soil was composed by a substrate with a Red Latosol (EMBRAPA, 2013), in which was incorporated dolomite lime (PRNT = 91%) adjusting V for 70%. For 180 L of soil (Red Latosol), it was added 60 L of sand, 60 L of organic matter (composted cow manure) and 1 kg of 04-30-10 NPK concentration. The final soil chemic-physic characteristic used in the experiment was: pH ($CaCl_2$) = 5.40; Ca^{+2} = 4.05 $cmol_c$ dm^{-3}; Mg^{+2} = 1.97 $cmol_c$ dm^{-3}; Al = 0.00 $cmol_c$ dm^{-3}; P = 469.9 mg dm^{-3}; K = 2.35 $cmol_c$ dm^{-3}; C = 14.45 mg dm^{-3}; silt = 90 g kg^{-1}; sand = 460 g kg^{-1}; clay = 450 g kg^{-1}, determined by the methodology presented by EMBRAPA (1997) and Raij et al. (2001).

It was also performed a nitrogen fertilizing during planting and 30 days after planting (DAP) with 0.3 g of ammonium sulfate following the recommendations of Polanía et al. (2012) for common bean. At 10 DAP was performed the thinning to maintain only one plant per experimental plot.

The preventive control from anthracnose (*Colletotrichum lindemuthianum*) and root rot (*Rhizoctonia solani*) disease was realized in the seeds (before planting) using Thiram (150 mL (100 kg)$^{-1}$ seeds).

Irrigation system and water management

It was used a drip irrgation system with pressure compensating drip emitters, at 10 mca pressure service and 7.5 L h^{-1} nominal flow rate. The emitters were connected to the main line (polyethylene pipes of 16 mm), in which four derivation of microtubes per pot was installed (Figure 2). The emitters had high distribuition uniformity, presenting 99,95%, and flow rate for all emmiters evaluated varying from 7.14 to 7.73 L h^{-1}.

The soil water continent was measured by tensimeters installed at 0.15, 0.2, and 0.3 m depth (one per treatment). The irrigation was performed when soil water tension was between 30 and 35 kPa (registered by the tensimeters), providing water until soil water tension decrease to 5 kPa (field capacity for the pots used) (Figure 3). Soil water tension readings were performed early in the morning, and amount of irrigation was calculated according to the water retention curve determined for soil used in the experiment according to equation:

$$\theta = 0.6151 \times SWT^{-0.114} \quad R^2 = 0.998^{**}$$

on what, θ - soil moisture (cm cm^{-3}); SWT - soil water tension evaluated by tensimeter (kPa).

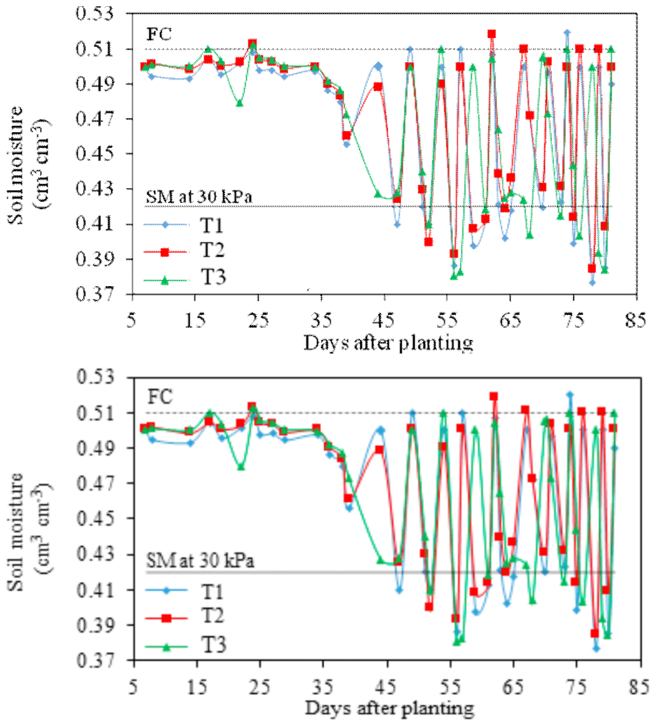

Figure 3. Soil water available for tensimeters installed at 0.15 (T1), 0.20 (T2), and 0.30 m (T3) depth. FC – field capacity; SM – soil moisture; θ – Soil moisture; SWT – Soil water tension.

Biomass and yield

At the end of season, it was determined the dry leaves mass (DLM), dry stem mass (DSM), dry pods mass (DPM), and dry roots mass (DRM) by a kiln at 60 °C until constant mass, presenting results in grams per plant (g p^{-1}). For roots, the dry mass was divided by five soil levels at 0-0.2, 0.2-0.4, 0.4-0.6, 0.6-0.8, and 0.8-1 m. It was also determined the dry total mass (DTM) by the sum of DLM, DSM, DPM, and DRM, the grain

Figure 2. Experimental detail with five rigs per pot (A), lateral view (B) and tensimeter installed in the pot with reading example (C).

yield and the yield index (YI) by the ration between grain yield and DTM (Muños-Perea et al., 2007). These parameters were evaluated at 77 DAP for IPR Curió and at 92 DAP for IAPAR 81 and IPR Tangará.

Data analysis

The variables used to describe yield components were statistically analyzed by variance analysis. When was verified significant interaction, it was applied the mean test using Tukey test at 5% probability level, using the Assistat 7.7 Beta software (Silva, 2013).

Results and Discussion

Considerando as características avaliadas os resultados indicam diferença estatística em função das cultivares e dos níveis de disponibilidade hídrica (Tabelas 1 e 2).

It was observed a difference in irrigation depth between both IAPAR 81 and IPR Tangará (256, 463, and 547 mm for T1, T2, and T3, respectively) and IPR Curió (256, 329, and 404 mm for T1, T2, and T3, respectively), which was explained by the IPR Curió early-season cultivar characteristic. IPR Curió season was in 77 days, 15 days early than the other two cultivars, which required less total water in comparison.

The DLM presented statistical difference in comparison to the cultivars and irrigation depths (Table 2), ranging from 35.69 to 67.52 g p^{-1}. It was observed that IAPAR 81 did not presented significant increments for DLM when the irrigation depth varied from 463 (T2) to 547 mm (T3), indicating that this cultivar is able to develop adequately even with some restriction on soil water availability. For IPR Tangará, it was observed statistically difference for DLM from T3 to T2, in which T3 presented around 17% higher values than T2, showing that this cultivar is more sensitive to water deficit in comparison to IAPAR 81.

Table 2. Mean results for dry leaf mass, dry stem mass, dry pods mass, total above grown mass, yield and index yield for the three commom bean cultivars under three water management.

Cultivar	Tensiometer depth (T)		
	T1	T2	T3
	Dry leaves mass (g p^{-1})		
IAPAR 81	46.58 aB	55.34 aA	55.73 bA
IPR Tangará	48.56 aB	55.78 aB	67.52 aA
IPR Curió	36.04 bA	35.69 bA	39.20 cA
	Dry stem mass (g p^{-1})		
IAPAR 81	39.83 aA	44.91 aA	43.98 bA
IPR Tangará	40.43 aB	45.21 aAB	50.45 aA
IPR Curió	29.50 bA	31.01 bA	32.84 cA
	Dry pods mass (g p^{-1})		
IAPAR 81	29.98 aA	34.91 aA	31.30 aA
IPR Tangará	24.44 aB	31.26 aA	32.45 aA
IPR Curió	15.79 bA	19.26 bA	20.17 bA
	Dry root mass (g p^{-1})		
IAPAR 81	6.21 aA	7.49 aA	7.83 aA
IPR Tangará	6.16 aA	6.07 aA	6.74 aA
IPR Curió	3.13 bB	3.24 bB	4.38 bB
	Dry total mass (g p^{-1})		
IAPAR 81	201.79 aB	251.31 aA	224.97 bAB
IPR Tangará	194.01 aB	240.58 aA	257.34 aA
IPR Curió	136.41 bB	153.85 bAB	169.12 cA
	Grain yield (g p^{-1})		
IAPAR 81	79.23 aB	108.66 aA	86.83 bB
IPR Tangará	74.36 aB	102.26 aA	100.18 aA
IPR Curió	51.95 bB	64.64 bA	72.55 cA
	Harvest index		
IAPAR 81	0.39 aB	0.43 aA	0.39 bB
IPR Tangará	0.38 aB	0.42 aA	0.39 bB
IPR Curió	0.38 aB	0.42 aA	0.43 aA

Means followed by the same latter in the same column and line do not differ statistically by Tukey test at 5% probability level.

The IPR Curió cultivar did not present statistical difference for DLM for all soil water available, showing the most adaptive cultivar for the water deficit. Larcher (2000) inform that DLM differences in common bean

Table 1. Test F results for dry mass leaves, stem, pods, aerial part, roots, total, grain yield and harvest index for three cultivar of bean under different levels of water availability.

Variation factor	Cultivar	Tensiometer depth	Interaction	C.V. (%)
Dry leaves mass	64,17**	15,44**	3,84**	10,50
Dry stem mass	51,50**	7,77**	1,32 n.s.	10,33
Dry pods mass	53,84**	8,03**	1,21 n.s.	14,35
Dry aerial part mass	82,32**	22,92**	3,46*	9,01
Dry root mass	15,99**	1,02 n.s.	0,36 n.s.	17,87
Dry total mass	78,75**	20,93**	3,13*	9,34
Grain yield	70,66**	38,02**	5,69**	9,34
Harvest index	0,75**	14,32**	3,11*	5,20

* Significant at 5% of probability, **Significant at 1% of probability, n.s. not significant and C.V. Coefficient of variation, tensiometers installed at 0.15 (T1), 0.20 (T2) and o.30 m (T3) depth

may occur due the different soil water availability for the culture. In the study with common bean by Oliveira et al. (2008), DLM was reduced when plants were under water availability of 20% total pores volume (TPV) when plants were during flowering and grain filling. However, when soil water available was at 60% of TPV, DLM was seven times higher in comparison to 60% of TPV results. The results presented for the three cultivars show that the breeding programs focused in finding cultivars with resistance to a low soil water availability, especially for IAPAR 81 and IPR Curió cultivars.

The DSM did not present statistically difference for IAPAR 81 in relationship to the water management (Table 2), with mean values of 42.91 g p^{-1}. However, IPR Tangará was more sensitive to the water management, showing increment of DSM for T3, representing around 15% higher values in comparison to T1. For IPR Curió, DSM was not affected by the different soil water availability, with average of 31,12 g p^{-1} for all treatments.

According to Molina et al. (2001), evaluated bean genotypes in field condition at Londrina - PR during the dry season in the years 2000 and 2001 the DPM for common bean is a characteristic that may be used to identify the genotypes that has tolerance for lower soil water availability, and Do Vale et al. (2012) describes that genotypes that has good results on DPM usually are more drought tolerance. This results was obtained using pots with 10 liters of Humic cambissoil organized at greenhouse conditions.. In this context, the results presented by IAPAR 81 and IPR Curió for DPM identify both cultivars as more drought tolerant in comparison to IPR Tangará cultivar. The IPR Curió cultivar had DPM reduction of 23% for lower soil water availability, showing that this cultivar is more responsive to water deficit.

The higher values of DT were observed by IPR Tangará cultivar for T3 (Table 2). For all treatments studied, for T1 and T2 (lass water availability) only IPR Curió was statistically different from the other cultivars. In addition, it was not observed statistical difference between both treatments (T1 and T2) for this cultivar.

These results are similar to those observed by Oliveira et al. (2008), in which Capixaba early-season cultivar did not presented statistical difference for DTM at 60% of soil water availability, with mean values of 24 g p^{-1}. The effect of water deficit was only observed when soil water availability was around 20% with mean values of 17 g p^{-1}. Emam et al. (2010), evaluating the water deficit tolerance of two common bean cultivars (Sayyad and D81083), reported positive effect on plant growth when soil water availability was under 50%. In this case, the DTM was slightly superior (4 and 3 g p^{-1}) for Sayyad e D81083, respectively. This results were obtained under similar conditions to the present study, i.e. they conducted in greenhouse and in pots.

The grain yield results indicate that IAPAR 81 cultivar presented higher values for T2, reducing the grain yield with the increase of water availability (around 24%, Table 2). For IPR Tangará, the results showed higher values for T2, slightly smaller for T3 and, for T1, presenting the lowest values. Within T3, it was observed statistically difference between cultivars, in which IPR Tangará presented higher grain yield, intermediate for IAPAR 81 and lower for IPR Curió.

The results presented in this study indicates that different genotypes may present different yield in relationship to the water availability. In the same genotype, it is possible to observe changes on yield when plants are under different soil water availability. IAPAR 81 presented higher yield for total irrigation depth of 463 mm, in lower yield for total irrigation depths of 347 and 567 mm, indicating that it is possible to reduce water consumption in around 15% and keep a high level yield. However, IPR Tangará had a yield increase with the increase of total irrigation depth, in which the treatment with 347 mm had lowest values and the treatments with 463 and 547 mm presented higher values. IPR Curió had similar behavior in comparison to IPR Tangará, increasing yield with the increase of total irrigation depths. Thus, it is possible to reduce water use in common bean without reducing the drastically yield for this culture.

According to Allen et al. (2000), the common bean water requirement will vary due the climate and soil condition associated to the cultivar characteristics, with can reach 500 mm during season. Under field conditions in the Pichincha – Equador Calvache et al. (1997) related that common bean total water requirement of 447 mm, in the Idaho – United States Munõz-Perea et al. (2007) observed values of 571 and 661 mm, indicating that this difference is associated to the cultivars characteristics.

The higher YI results was observed in T2 for IAPAR 81 and IPR Tangará, differing statistically to others treatments (Table 2). For IAPAR Curió, it was observed that YI in T2 and T3 were higher and almost the same, with statistical difference in comparison to T1 (Table 2). The comparison within cultivar, only T3 was statistically different between IPR Curió and others, presenting higher values (0.43 against 0.39 of others cultivars).

The YI results was similar to those results observed by Ramirez-Builes et al. (2011). Evaluating six common bean cultivars (BAT 477, Morales, SEN 21, SEN 3, SER 16, SER 21) under the soil water levels, the authors found that the those most water deficit tolerant (and SEN 3 and SER 21) presented YI varying from 0.24 to 0.51, not interfering on plant yield. With this finding, it is possible to affirm that the cultivars evaluated in our study presented the ability of maintaining the yield aspects when cultivated under a specific water deficit level.

Bourgault et al. (2010), studying common bean *Vigna Radiata* (L.) Wilczek, in greenhouse conditions cultivated in PVC pipes with 0.15 m and 0.55 m to diameter and depth, respectively, found that YI did not change with low water availability, differing the results found for common bean *Phaseolus* sp. In the studies performed by Ninou et al. (2012), in climate and soil conditions to Greece, the highest yield was observed for the cultivars with early-season characteristics, as well as for YI values. In this study, the highest values of YI were observed in IPR Curió cultivar, in which is also an early season culture. However, this cultivar did not present the highest yield within those analyzed.

The water deficit tolerance is also related to the best plant root system development and cultivars with this characteristic have genes that prevent against yield reduction during long-term and continuous drought periods (Arunyanark et al., 2009). The DRM was higher for IAPAR 81 and IPR Tangará, with lower values for IPR Curió. However, it was not observed statistically difference between treatments for all cultivars analyzed. Do Vale et al. (2012) found that the best results for DRM in greenhouse conditions for Pérola, IPR Chopim, and IPR Uirapuru, with values of 0.35, 0.31, and 0.29 g p^{-1}, respectively. This values were considered acceptable to characterize these cultivars as water deficit tolerant. The results presented in Table 2 indicate that the cultivars analyzed in this study had higher DRM in comparison to the abovementioned cultivars, characterizing the IAPAR 81, IPR Tangará, and IPR Curió as more drought tolerant.

It was not observed statistical difference between treatments for DRM, indicating that less total irrigation depths does not compromise the plant development, since plant are able to increase root growth in order to find water in lower soil levels, also found in our study (plant root at 1 m depth). In the other hand, it was observed a wide difference between IAPAR 81 and IPR Tangará DRM results (mean of 6.93 and 6.34 g p^{-1}, respectively), and IPR Curió (mean of 3.57 g p^{-1}). It can be associated to the early-season development of IPR Curió cultivar, which had less time to have root growth in comparison to others cultivar.

Oliveira et al. (2008) observed higher DRM when soil water availability was at 60%, resulting in 2.8 g p^{-1}. When soil water availability decreased at 20%, the DRM drastically reduced to 0.5 g p^{-1}, indicating that Capixaba Cultivar did not present water deficit tolerance.

Conclusions

Considering the experimental condition it can be concluded:

IAPAR 81 cultivar presented higher grain yield with total irrigation depth of 463 mm.

IPR Tangará and IPR Curió cultivars were characterized as more responsive to the different soil water availability.

The methodologies used in this study can be adapted on crop breeding programs to characterize water deficit tolerant cultivars for the grain yield and root system growth parameters.

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