Drought stability in different common bean (*Phaseolus vulgaris L.*) genotypes

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ABSTRACT

The objective of this paper was to evaluate the possible use of the biological stability concept as selection criteria for drought stress in common bean breeding program. Three commercial cultivars (Aporé, Jalo EEP 558, and Jalo Precoce) and the landrace Guarumbé were cultivated in organic substrate under greenhouse conditions. Irrigation was suspended for 10 days period in a half of plants. To evaluate the recovery capacity, plants were irrigated after the drought period. Variables measured were CO_2 assimilation (A); transpiration (E); stomatal conductance (gs); water potential (y_w); dry matter (MS), and leaf area (Af). The cultivar Jalo Precoce showed the lowest values of ψ_w , E, and gs under drought, and after re-irrigation, no complete recovery was observed. The other genotypes showed similar behavior and good stability for these parameters. The smallest reduction values for MS and Af were observed in the landrace, while Jalo Precoce showed the most important decreases. Our results indicate that stability could be considered a good indicator of genotypic behavior and its concept could be incorporated in plant breeding programs.

KEY WORDS: Biological stability, common bean, drought, gas exchange.

INTRODUCTION

The common bean (*Phaseolus vulgaris* L.) is considered the most important legume for human nutrition in Latin America and Africa. According to Jungmann et al. (1999), common bean is cultivated in approximately 12 million hectares around the world, and Brazil is the main producer. However, this crop can be affected by several environmental stresses, and the drought is considered one of the most important causes of yield reductions. Common beans have low tolerance to water stress. This condition is very important considering that approximately 60 percent of the world production is carried out under drought conditions (Molina et al., 1999).

The presence of large amounts of genetic variability for drought tolerance is fundamental since it allows the selection of the best varieties for breeding programs and for farming production, depending on the technical and climatic conditions of the region (Neto and Fancelli, 2000).

In a broad sense, genetically improved genotypes demand more crop technology, specially irrigation. The release in 1969 of the Carioca common bean cultivar by the Agronomic Institute of Campinas (IAC) started an important modernization process of the bean crop in Brazil, by reversing the declining productivity level. The great rusticity showed by Carioca bean conferred by the drought, the acid soil, and its disease tolerance allows great yield stability (Vicente et al., 2000).

In this context, the availability of stable genotypes could represent an important source of genetic resources for plant breeding programs. In this paper, biological stability (homeostasis) is defined as the capacity of an organism to maintain a relative constant behavior in the presence of external perturbation, and to return to the normal level after the disappearance of the stress factor (Kauffman, 1993).

The objective of this study was to evaluate differences of drought stability among common bean genotypes and to demonstrate the possible use of stability analysis as a selection criteria in plant breeding programs.

MATERIAL AND METHODS

Three commercial varieties of common bean (*Phaseolus vulgaris* L.): Jalo Precoce (Type II), Aproré (Type III) and Jalo EEP 558 (Type III) were used. The two first genotypes were obtained by EMBRAPA-CNPAeF and the third by IPEACO/EEP (Neto and Fancelli, 2000), and the landrace Guarumbé native of the Foz do Iguaçu-PR natural reserve. All the seeds were supplied by the of UNOESTE's Seeds laboratory germoplasm collection.

The study was carried out in the Laboratory of Plants Cultivated Under Stress at ESALQ-USP Biological Science Department under greenhouse conditions from March to April of 2002. Plastic cups (5 L) filled with 4 Kg of substrate Plantmax (Eucatex-Agro, Brazil) were used, and irrigated with tap water until saturation. Three seeds of each genotype were sowed in each cup, and only one plant was maintained after complete seedling development.

All the cups were irrigated with 600 ml of nutrient solution (McCree, 1986) 8 and 16 days after germination. The experiment was started at the 16th day with the submission of half of the plants to drought treatment by suppression of the irrigation by a period of ten days. The control group was maintained under daily irrigation (400 mL of water/ plant). After the drought treatment, plants were re-irrigated, when the first signals of leaf wilting started.

Leaf water potential (ψ_w) of plants under drought treatment was measured in periods of 3 days by the dew point method, using a microvoltimeter (HR-33T, Wescor, Logan, USA) coupled to the sampling chamber (C-52, Wescor, Logan, USA). For this quantification, leaf discs of 0.2 cm^2 were used. The discs were obtained in fully illuminated and expanded leaves, located in the central third portion of the plant.

Gas exchange measurements such as CO_2 assimilation (**A**), transpiration (**E**) and stomatal conductance (**gs**) were carried out in both control and stressed plants in two moments: under moderate and severe stress, measured at 7 and at 10 days without irrigation, respectively. The recovery capacity was quantified using the same parameters of gas exchange ,48 hours after re-irrigation. All measurements were performed with a gas exchange meter in a open system (LI-6400, Li-Cor, Lincoln, USA) in the morning (10:00 AM) under environmental conditions of air temperature and PAR (photosynthetic active radiation) around 36 ^oC and 1000 $\mu mol\ m^{-2}\ s^{-1}$, respectively.

At the end of the experiment, the leaf area (**AF**) was measured using a leaf area meter (LI-3100, Li-Cor, Lincoln, USA) and dry mater production (**MS**) was quantified by the weight of the whole plants dried in stove at 60 ^oC.

Trial was conducted using a complete randomized design with 5 replications (plants) for gas exchanges measurements and 10 replications for MS and AF measurements. Data were analyzed using ANOVA ($p<0.05$) and standard deviations.

RESULTS

Gas exchange measurements taken at the end of the drought period (10 days) were ignored due to the detection of measurement problems caused by stomatal closure in response to water stress (Kaiser, 1987; Taiz and Zeiger, 1998).

For water potential ($\boldsymbol{\psi_w}$) measurements under control conditions, all the genotypes showed similar behavior (-0.5 MPa). However, important differences were observed under drought stress. The cultivar Jalo Precoce showed the lowest value of $\boldsymbol{\psi_w}$ observed among the tested genotypes (-0.95 MPa). After the recovery period, this genotype presented the lowest value (-0.75 MPa) and showed no capacity to return to the values observed in the control. The Aporé genotype showed under control conditions, an average value of -0.4 MPa. After the drought treatment, this genotype showed -0.65 and -0.5 MPa, at recovery treatment. Control plants of Jalo 558 and Guarumbé showed values of -0.55 and -0.5 MPa, and -0.75 and –0.65 MPa under drought conditions, respectively. After the recovery period, values of -0.5 and -0.6 MPa were observed for these genotypes (Figure 1a).

For CO_2 assimilation (**A**) (Figure 1b), Jalo Precoce showed an important decrease when the control mean (18 $\mu mol\ m^{-2}\ s^{-1}$) was compared with the moderate stress (10 $\mu mol\ m^{-2}\ s^{-1}$). After the recovery process, Jalo Precoce showed 12 $\mu mol\ m^{-2}\ s^{-1}$, resulting in the lowest value for **A** among genotypes. Plants of Aporé cultivated under control conditions presented values higher than 22 $\mu mol\ m^{-2}\ s^{-1}$. After the drought treatment, this genotype showed an important decrease of 13 $\mu mol\ m^{-2}\ s^{-1}$, and an intense recovery to 27 $\mu mol\ m^{-2}\ s^{-1}$ with the return of irrigation. This cultivar, together with Jalo 558, presented the best recovery values for A.

When cultivated under complete irrigation, plants from Jalo 558 showed values higher than 23 $\mu mol\ m^{-2}\ s^{-1}$, in contrast with the 17 $\mu mol\ m^{-2}\ s^{-1}$ values observed at the end of the drought period. After the recovery process, this genotype showed values of 24 $\mu mol\ m^{-2}\ s^{-1}$.

Values of 21 $\mu mol\ m^{-2}\ s^{-1}$ were observed in plants from the landrace Guarumbé under control conditions. This genotype reached values of 15μmol

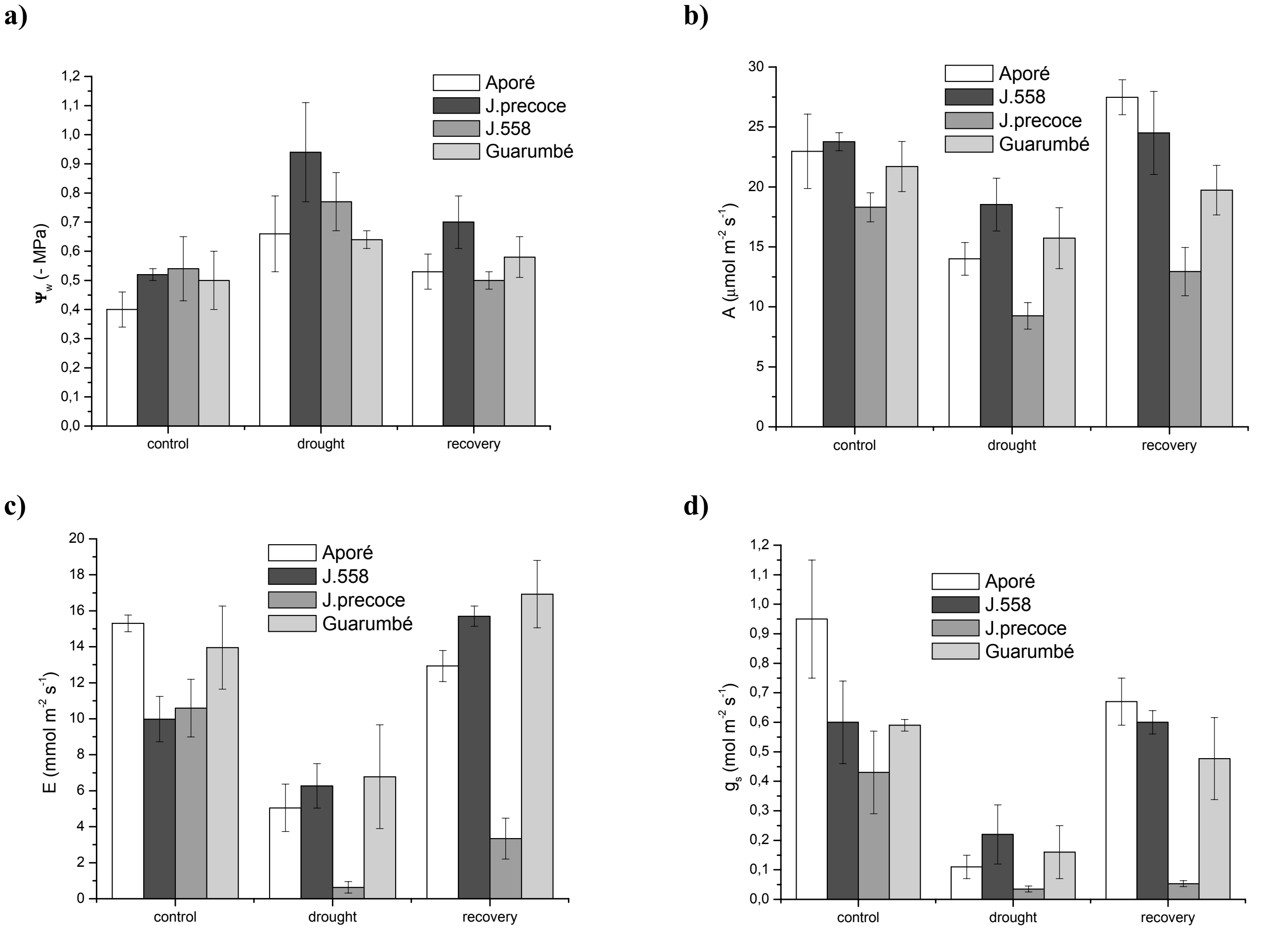

Figure 1: Physiological parameters used in the comparison among the different common bean genotypes. a) water potential $\mathbf{\Psi_w}$ (MPa), b) CO_2 assimilation **A** (CO_2 ìmol m^{-2} s^{-1}), c) transpiration **E** (μmol m^{-2} s^{-1} H_2O), d) stomatal conductance **gs** (mol m^{-2} s^{-1}).

m^{-2} s^{-1} and 20μmol m^{-2} s^{-1} under moderate drought and at the end of the recovery process (Figure 1b).

For transpiration (**E**) measurements (Figure 1c), under control conditions, the genotypes Aporé and Guarumbé showed the highest mean values of 15 and 14 μmol m^{-2} s^{-1} , respectively. These genotypes presented values between 10 and 11 μmol m^{-2} s^{-1} when cultivated under drought. Under this condition, Jalo Precoce showed a strong limitation of E and values lower than 1 μmol m^{-2} s^{-1} were observed , allowing to establish statistic differences among genotypes. A similar situation was observed after the recovery process. Jalo Precoce showed a very limited capacity, attempting values lower than 4 μmol m^{-2} s^{-1} (Table 1).In contrast, plants from Aporé, Jalo 558, and Guarumbé showed mean values of 13, 16, and 17 μmol m^{-2} s^{-1} , respectively. Genotypes Jalo 558 and Guarumbé showed **E** values higher than those observed in the control (Table 1).

Under control conditions, the values of stomatal conductance (**gs**), for genotype Aporé were the highest (0.95 mol m^{-2} s^{-1}) while for Jalo these values were the lowest (0.45 mol m^{-2} s^{-1}). Under drought, the observed values of **gs** for Aporé, Jalo 558 and Guarumbé were very close. These genotypes showed 0.1, 0.2, and 0.15 mol m^{-2} s^{-1}, respectively. Jalo Precoce was more affected by water deficit and showed values of 0.05 mol m^{-2} s^{-1}. After the recovery period, this genotype showed lower capacity (1 mol m^{-2} s^{-1}). The other genotypes showed a very similar behavior and no significant differences were observed when compared with those measured under control conditions (Table 1). These genotypes presented values of 0.7, 0.6, and 0.5 mol m^{-2} s^{-1} for Aporé, Jalo 558, and Guarumbé, respectively.

Leaf area (AF) and dry matter (MS) measurements showed significant differences ($p<0.05$) both among genotypes and water conditions (Table 2 and 3). The landrace Guarumbé, although showing the lowest ($p<0.05$) mean values of both parameters, presented the lowest decrease under drought, indicating highest stability performance compared with the other genotypes (Table 2 and 3).

DISCUSSION

The values for water potential indicated that plants of Jalo Precoce were unable to recover after the drought treatment. Although Jalo Precoce showed the lowest value of $\boldsymbol{\psi}_w$ under drought, which could be an indication of more tolerance (Pimentel and Herbert, 1999). The evident incapacity to return to control values could indicate the lowest stability of this genotype. The low stability of Jalo Precoce was also observed for **A** . This genotype was the only one that showed incapacity to recover after water stress. On the other hand, plants from Aporé attained values of **A** higher than those observed under control condition. For genotypes Jalo 558 and Guarumbé, an important recovery capacity was observed and no significant differences ($p>0.05$) with the control were established (Table 1).

According to Jones (1998), although the effect of a stomatal conductance changes on transpiration or CO_2 assimilation, it appears to be simple to measure. This analysis was accomplished by many feed-back processes that affect stomatal conductance. However, under moderate stress, the decrease in CO_2 assimilation is related with alterations in the stomata function (Kaiser, 1987). According to Taiz and Zeiger (1998), stomata closure is considered the third line of defense against drought following the leaf area reduction and the increase of root growth. However, this mechanism represents an important short-term strategy due to its speed and flexibility, while the other mechanisms are more adequate for long-term response (Chaves, 1991). According to Cowan (1977) stomatal movements tend to minimize water losses in relation with the CO_2 assimilation. This situation is in correspondence with the enhancement of water use efficiency (Larcher, 1995).

Large differences in the morphology, dimensions, and distribution of the stomata are observed among plant species. However, genetic control of the variability is partial as a result from the effects of the plant development stage and the environmental conditions. According to Chaves (1991), the physiological control of the stomata movement can be more important in the determination of the stomatal conductance under water stress than its dimension or distribution. Stomata closure is considered as a mechanism of protection against water loss and it is responsible for the reduction of the photosyntetic activity as a consequence of the restriction in CO_2 assimilation. For this reason, an increase in water use efficiency is observed in well adapted genotypes (Osmond et al., 1987; Chaves and Rodrigues, 1987). The water use efficiency calculated in this study as the relation between **A**/**E**, for the genotype Jalo Precoce resulted in higher values than the other cultivars under drought. However, this genotype showed an important inefficiency in maintaining

Table 1. Analysis of the recovery responses of the different common bean genotypes for water potential (Ψ_w), CO_2 assimilation (A), transpiration (E) and stomatal conductance (gs). Means followed by the same letter are non-significant by the Tukey's test ($p>0.05$), indicating a suitable recovery response.

	$\boldsymbol{\psi}_w$ (MPa)	**A** (μmol m^{-2} s^{-1})	**E** (mmol m^{-2} s^{-1})	**gs** (mol m^{-2} s^{-1})
		Aporé		
Control	-0.4^a	22.4^b	15.3^a	0.95^a
Recovery	-0.5^a	27.3^a	13.4^a	0.68^b
		Jalo 558		
Control	-0.55^a	23.2^a	10.5^b	0.61^a
Recovery	-0.5^a	24.2^a	16.3^a	0.62^a
		Jalo Precoce		
Control	-0.5^b	18.8^a	11.0^a	0.43^a
Recovery	-0.75^a	12.4^b	3.8^b	0.06^b
		Guarumbé		
Control	-0.5^a	21.5^a	14.8^a	0.59^a
Recovery	-0.6^a	20.3^a	17.1^a	0.48^a

photoassimilate productions, quantified by the intense reduction of the dry matter under water stress.

Stomatal conductance measurements in plants before the recovery period showed important differences between Jalo precose compared with the other genotypes. Re-hydrated plants from this cultivar maintain an important stomatal closure, principally when compared with Jalo 558 and Guarumbé (Tabela 1). This finding was fundamental in explaining the reduction in the dry matter production observed in Jalo Precoce.

In a comparative study of the physiological responses to drought of *P. vulgaris* and *Vigna unguiculata*, Carvalho et al. (1998), it was observed that the photosynthetic rate depends strongly on the stomatal opening and on other non-stomatic factors. According to Chaves (1991), the nature and extension of the effects of drought on plant growth depend on the intensity, the length of stress, and on the genetically determined capacity of the species to adequate its metabolism to the environment. Growth reduction and leaf area diminution are important plant strategies to avoid drought effects. Our results for growth parameters showed that Guarumbé, although presenting the lowest values of **Af** under control conditions, showed the lowest reduction of **MS** and **Af** under drought treatment, while Jalo Precoce presented the worst behavior. These results are strong indicators of the larger stability of the landrace when compared with commercial genotypes under drought stress. Generally, landraces or few domesticated genotypes present higher stability values and low yield potential, specially when compared with selected cultivars (Esquinas-Alcazar, 1993).

CONCLUDING REMARKS

Based on the gas exchange data analysis, the Jalo Precoce genotype was considered the most sensible to drought stress, due to its evident incapacity to recover its normal performance after re-irrigation. This condition was confirmed by the fact that this genotype showed a strong decrease in **MS** and **Af**. The susceptibility of Jalo Precoce to water stress could be closely related to the characteristics of the cultivar (Type III) that demands irrigation and middle to high crop technology. On the other hand, the landrace Guarumbé showed high recovery capacity, that allows to return to values very close to the control measurements, and low reduction of **MS** and **Af**.

The landrace Guarumbé showed the best values of stability under drought when compared with the other cultivars, although this genotype presented the lowest mean values for **MS**.

This study showed that biological stability could be considered an important tool to discriminate genotypes under drought stress and that the landrace Guarumbé is a good alternative to increase drought stability in plant breeding programs.

Table 2. Shoot dry matter reduction (g) of the common bean genotypes subjected to water deficit. Small letters indicate differences between control and water deficit treatments at each genotype, whereas capital letters indicate the differences among genotypes at each water condition ($p<0.05$).

	Aporé	J. 558	J. Precoce	Guarumbé
Control	5.83^{aBC}	7.23^{aB}	11.50^{aA}	4.97^{aC}
Water deficit	1.83^{bB}	1.60^{bB}	1.80^{bB}	2.83^{bA}
% of reduction	68.61	77.87	84.35	43.06

Table 3. Leaf area reduction (cm^2) of the common bean genotypes subjected to water deficit. Small letters indicate differences between control and water deficit treatments at each genotype, whereas capital letters indicate the differences among genotypes at each water condition ($p<0.05$).

	Aporé	J. 558	J. Precoce	Guarumbé
Control	1198.75^{aB}	1296.47^{aB}	2522.89^{aA}	1016.68^{aC}
Water deficit	387.05^{bB}	354.79^{bB}	676.49^{bA}	593.06^{bA}
% of reduction	67.71	72.63	73.18	41.67

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