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Effects of drought on stomatal resistance, surface resistance and leaf temperature in four common bean genotypes (*Phaseolus vulgaris* L.) [1]

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ABSTRACT

Stomatal resistance (r_L), surface resistance (r_s) and leaf temperature (T_L) are important physiological variables for the understanding of the interaction between the soil, plant, and atmosphere. These variables are used to study the response of plants to abiotic stress conditions, such as drought and high temperature, in addition to micrometeorological variables such as evapotranspiration (ET). The goal of this research was to measure the r_L, r_s and T_L of four genotypes of common bean (*Phaseolus vulgaris* L.) under drought and non-drought conditions in a greenhouse environment. Three drought-tolerant genotypes were studied, BAT 477, SER 16 and SER 21, and one drought susceptible genotype, Morales. Three water regimes were used: full water supply (FWS) using 80% of the water required for soil saturation (WS) during the complete growing season; Stress 1 (S1) with 50% of WS before flowering and 60% of WS after flowering; and Stress 2 (S2) with 20% of WS before flowering and 40% of WS after flowering. Measurements were taken throughout the day at different stages of growth. The results show that there were differences in the r_L, r_s and T_L between genotypes and between water levels, especially during the afternoon. The major differences were found between treatments S1 and S2 during reproductive development. The r_L, r_s and T_L responded directly to the substrate water status and the rate of change was influenced by hour of the day. T_L showed a linear relationship with air temperature, and the slope increased with water stress and had a polynomial relationship with r_L.

Key words: Common bean, Drought, Stomatal resistance, Surface resistance, Leaf temperature

RESUMEN

La resistencia estomática (r_L), la resistencia superficial (r_s) y la temperatura de la hoja (T_L) son variables fisiológicas importantes en el estudio de la relación entre el suelo, la planta y la atmósfera. Estas variables se han empleado para caracterizar la respuesta de la planta a condiciones de estrés abiótico tales como sequía y altas temperaturas, en adición a otras variables micrometeorológicas como la evapotranspiración (ET). El objetivo de esta investigación fue medir la r_L, r_s and T_L en cuatro genotipos de habichuela (*Phaseolus vulgaris* L.) bajo condiciones de sequía y

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[1]Abbreviations: r_L, stomatal resistance; T_L, leaf temperature; r_s, surface resistance; SFC, substrate field capacity; Ta, air temperature.

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sin sequía, en condiciones de invernadero. Se evaluaron tres genotipos de habichuela con tolerancia a sequía, BAT 477, SER 16 y SER 21, y uno susceptible, Morales. Se usaron tres niveles de agua: aplicación completa sin estrés, aplicando el 80% de la cantidad máxima de retención (MCR) durante toda la etapa de crecimiento; estrés 1, con 50% de MCR antes de floración y 60% después de floración; y estrés 2, con el 20% de MCR antes de floración y 40% después de floración. A lo largo del día y en diferentes fases de crecimiento se tomaron medidas de r_L, T_L, índice de área foliar (IAF) y humedad volumétrica del sustrato. Las mayores diferencias se encontraron entre los tratamientos de estrés 1 y 2 durante la fase reproductiva. La r_L, r_s y T_L mostraron altas tasas de cambio durante el día al igual que con el nivel del agua en el suelo. La resistencia estomática, la temperatura de la hoja y la temperatura del aire se correlacionaron positivamente.

Palabras clave: Habichuelas, Sequía, Resistencia estomática, Resistencia superficial, Temperatura de la hoja

INTRODUCTION

Common bean (*P. vulgaris* L.) is the most important food legume (Broughton et al., 2003) and is an important source of calories, proteins, dietary fiber and minerals (Singh et al., 1999). The majority of common bean production is under drought conditions, and thus yield reductions due to drought are very common (Terán and Singh, 2002).

Drought stress reduces the transpiration rate, stomatal conductance ($1/r_L$), and turgor (Yang, 1995; Mayek et al., 2002; Brevedan and Egli, 2003). De Oliveira et al. (2005) found that high levels of drought stress reduced substantially the stomatal conductance ($1/r_L$) and transpiration rates, and increased the leaf temperature in bean, the major effect being observed during the afternoon. Different cultivars of beans cultivated in the same geographic area display distinct responses to prolonged drought stress (Markhart, 1985; Carvalho et al., 1998; Costa Franca et al., 2000). The aim of this research was to evaluate how four common bean genotypes, with and without drought tolerance, respond to water deficits, reducing the transpiration through stomatal regulation, and to use r_L, r_s and T_L as indices to characterize the water relationship in previously unstudied common beans genotypes.

MATERIALS AND METHODS

Experiment location. The experiment was carried out in the greenhouse, at the USDA-ARS Tropical Agriculture Research Station in Mayaguez, Puerto Rico. Four common beans genotypes (*P. vulgaris* L.) were evaluated. The genotypes included a drought susceptible genotype, Morales (Beaver and Miklas, 1999), and three drought tolerant genotypes, SER 16, SER 21 and BAT 477 (CIAT, Colombia). BAT 477 has a type III growth habit whereas the other genotypes are type II. Forty eight seeds of each genotype were planted in 24 round pots (15 cm x 11 cm) with Sunshine mix #1 (Sun Gro Horticulture, Vancouver, British Colombia) and Osmocote (14-14-14, N-P-K; Marysville, OH) and then thinned to one plant per pot.

Three water regimes were used: full water supply (FWS) using 80% of the water level required to saturate the soil (WS) during the complete growing season; Stress 1 (S1) with 50% of the WS before flowering and 60% of the WS after flowering; and Stress 2 (S2) with 20% of the WS before flowering and 40% of the WS after flowering. The experiment was conducted in a split plot design with four replications.

Stomatal resistance and leaf temperature measurements. The r_L and T_L were measured in different growth stages and during two growing seasons: July-September (experiment 1) and October-December (experiment 2) in 2005. On days of data collection, hourly measurements were obtained. The r_L was measured with a AP4-UM-3 (Delta-T Devices Ltd) Porometer, the T_L was measured using an infrared thermometer (MX4-TD, Raytek), and the substrate volumetric moisture was measured using a Theta Probe soil moisture sensor (model ML2X, Spectrum Technology, Inc.).

Leaf area index and surface resistance. Leaf area (LA) was measured for each genotype using a non-destructive method developed by Ramírez et al. (2006). The r_s was calculated using the equation proposed by Allen et al. (1998). Weather information was collected each minute (air temperature, relative humidity, and absolute humidity) and correlated with leaf temperature and stomatal resistance.

RESULTS AND CONCLUSIONS

Stomatal resistance. The r_L under stress 2 was higher in experiment 1 than in experiment 2 because of higher ambient air temperature during experiment 1. The genotypes which exhibited the greatest increase in r_L were Morales and BAT 477 under strong drought stress conditions (stress 2, experiment 1, see Table 1). The differences in r_L for stress 2 in experiment 1 can be explained by the fact that the volumetric moisture content was always below 0.29 m^3m^{-3}, whereas in the second experiment the volumetric moisture content remained above 0.32 m^3m^{-3}.

Table 1. Mean stomatal resistance (r_L) in four common bean genotypes under three water levels.

Water Level	r_L ms^{-1} Experiment 1†			
	BAT 477	Morales‡	SER 21	SER 16
Non Stress	125.9 (18.9)	151.0 (38.2)	188.3 (51.0)	192.5 (6.3)
Stress 1	168.8 (45.0)	208.4 (65.4)	225.8 (91.4)	215.7 (27.2)
Stress 2	323.7 (39.7)	319.7 (73.2)	262.0 (67.8)	306.1 (40.3)
	r_L ms^{-1} Experiment 2			
Non Stress	108.7 (26.1)	189.8 (81.7)	116.3 (20.1)	174.7 (36.8)
Stress 1	153.7 (17.1)	150.7 (20.3)	94.1 (23.4)	179.3 (53.2)
Stress 2	273.4 (95.3)	228.7 (58.2)	193.8 (103.4)	263.0 (90.0)

† Mean values for r_L

‡ The values in parentheses represent the standard deviation.

Leaf temperature. T_L was affected by drought and showed the opposite tendency during the day as compared to r_L. T_L, however, was more sensitive to changes in plant water status. BAT 477 and Morales showed a stronger response in leaf temperature in the first experiment than in the second experiment because of higher levels of drought stress. As with r_L, T_L revealed the greatest differences between genotypes between the hours of 13:00 and 14:00. The differences between T_L, under strong drought stress (Stress 2) and non-stress conditions, at 13:00 for BAT 477 was 4.2° C; Morales, 4.3° C; SER 16, 3.4° C; and SER 21, 2.4° C.

Surface resistance. The r_s was influenced by drought stress in the four common bean genotypes and reached the highest values at 20 days after planting (V3-V4), while lower r_s values were found at the beginning of the reproductive growth stage (R1). Under stress 2 conditions, the r_s increased significantly for all evaluated genotypes.

Relationship between air temperature and leaf temperature. The T_L was influenced by water status and air temperature, insofar as drought increased T_L (slope). In experiment 1, stress 2 showed the greatest increase in T_L. For drought stress tolerant genotypes in experiment 2, the increase in T_L was lower due to the reduced levels of stress.

Stomatal resistance is a sensitive physiological measurement of plant stress. This variable depends on genotype, microclimatic conditions and substrate moisture content. In this research drought influenced r_L and T_L, and the atmospheric conditions affected the magnitude of these changes. The r_L and T_L responded to the substrate water content, but did not influence yield when low drought stress was imposed during the growing season (as in the case of experiment 2).

Short-term effects of drought stress were observed in the variables r_L and T_L, whereas the long-term effects of drought were observed in the leaf area index (LAI). During the R1 to R2 transition in growth stage under drought stress, SER 16 and SER 21 had the lowest differences in r_L and T_L. The highest reduction in LAI was observed in BAT 477 and the lowest yield was observed for Morales and BAT 477.

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