Physiological evaluation of drought resistance in elite lines of common bean (*Phaseolus vulgaris* L.) under field conditions

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Introduction

About 60% of the bean crop is cultivated under the risk of either intermittent or terminal drought (White and Sing, 1991). The effects of drought on common bean are dependent on the intensity, type and duration of the stress. In Africa as much as 300,000 Mg of beans are lost to drought annually (Wortmann et al., 1998). Highland Mexico, Central America, northeast Brazil, and much of eastern Africa are bean producing areas where drought is endemic. Development of drought adapted bean varieties is an important strategy to minimize crop failure and improve food security in bean growing regions (Rao, 2001). Previous research indicated that the superior performance of common bean genotypes under drought was associated with their ability to mobilize photosynthates to developing grain and to utilize the acquired N and P more efficiently for grain production. The main objective of the present study is to evaluate drought adaptation of elite lines from the on-going breeding program (Beebe et al., 2008) to quantify phenotypic differences in drought resistance under field conditions and to define the physiological basis for improved drought adaptation.

Materials and Methods

A field trial was conducted at Palmira in 2006 (June to September). The trial included 20 genotypes (8 SER lines, 4 SXB lines, 2 NCB lines, RCB 273, Tio Canela 75, CARIOCA, SEA 5, Perola and DOR 390). A 4 x 5 partially balanced lattice design with 3 replicates was used. Two levels of water supply (irrigated and rainfed) were applied. Experimental units consisted of 2 rows, 3.72 m long by 0.6 m wide. A number of plant attributes were measured at mid-podfilling in order to determine genotypic variation in drought resistance. These plant traits included leaf chlorophyll content (SPAD), canopy temperature, leaf area index, canopy dry weight per plant, shoot nutrient (N, P) uptake, shoot and seed ash content; and shoot and seed TNC (total nonstructural carbohydrates). Total carbon and nitrogen and carbon and nitrogen isotope ratios ($\delta^{13}C$ and $\delta^{15}N$) were measured on the isotope ratio mass spectrometer. At the time of harvest, grain yield and yield components were determined. Stem biomass reduction, pod harvest index (dry wt of pods/dry wt of total biomass at mid-podfill x 100), grain filling index (100 seed weight of rainfed/100 seed weight of irrigated) and drought intensity index were also determined. Four genotypes (SEA 5, Tio Canela 75, SER 16 and DOR 390) were selected to determine differences in root growth and distribution across soil depth. Root length and root diameter were determined by image analysis system (WinRHIZO V. 2003b).

Results

The data on total rainfall and pan evaporation together with rainfall distribution indicated that the crop suffered significant terminal drought stress during active growth and development (Figure 1).

Figure 1. *Drought adapted advanced line compared with a commercial check cultivar " Tio Canela".*

The mean yield under rainfed conditions was 1876 $\mathrm{kg\ ha^{-1}}$ compared with the mean irrigated yield of 2940 $\mathrm{kg\ ha^{-1}}$. Under drought stress conditions in the field, the seed yield of 20 genotypes ranged from 1320 to 2317 $\mathrm{kg\ ha^{-1}}$. Among the lines tested, three lines SXB 418, SER 109 and NCB 280 were outstanding in their adaptation to rainfed (drought stress) conditions. Tio Canela 75, Perola and Carioca were the most poorly adapted lines under rainfed conditions based on the values of relative yield reduction (Figure 2).

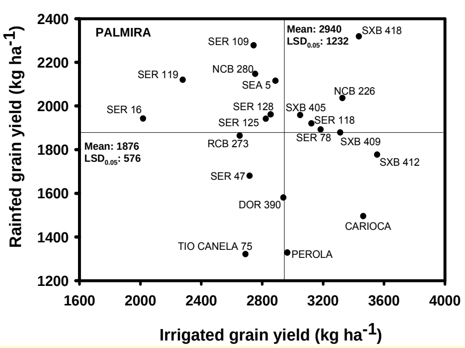

Figure 2. *Identification of genotypes that are adapted to drought and responsive to irrigation in a Mollisol at Palmira. Genotypes with greater seed yield under both rainfed and irrigated conditions were identified in the upper, right hand quadrant.*

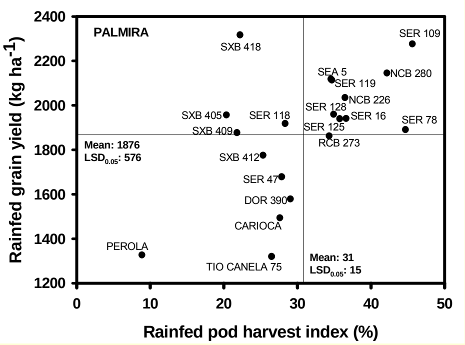

Figure 3. *Identification of genotypes that combine superior seed yield with superior pod harvest index under rainfed conditions in a Mollisol at Palmira. Genotypes with greater pod harvest index and seed yield were identified in the upper, right hand quadrant.*

The relationship between rainfed grain yield and rainfed pod harvest index showed that SER 109 was outstanding in its ability to produce pod biomass under rainfed conditions (Figure 3). Several drought adapted lines showed higher values of pod harvest index and lower values of pod wall biomass proportion under rainfed conditions indicating greater mobilization of photosynthates to production of pods and grain filling (Figures 3 and 4).

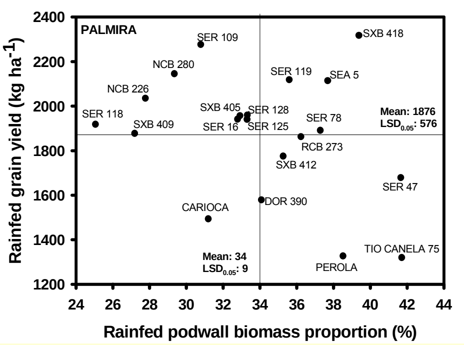

Figure 4. *Identification of genotypes that combine superior seed yield with lower pod wall biomass proportion when grown under rainfed conditions in a Mollisol at Palmira. Genotypes that were superior in grain yield combined with lower podwall biomass were identified in the upper, left hand quadrant.*

Correlation coefficients between grain yield and shoot attributes under rainfed conditions indicated that seed yield was positively related to pod harvest index, stem biomass reduction, pod N uptake, shoot N uptake, pod P uptake and shoot P uptake, leaf area index, canopy temperature and canopy temperature depression (CTD: canopy temperature - ambient temperature) at 1 p.m. (Table 1).

Since CTD is a negative value, a positive correlation with yield implies that more negative values of CTD (i.e., more canopy cooling) correspond to low yield. CTD is an indication of the ability of transpiration to cool the leaves under a demanding environmental load, such that more negative values of CTD should be an indicator of the ability to access more soil moisture.

Table 1. *Correlation coefficients (r) between rainfed grain yield and other shoot attributes of 20 lines. *, **, *** Significant at the 0.05, 0.01 and 0.001 probability levels, respectively.*

Plant traits	Irrigated	Rainfed
Leaf area index (m^2/m^2)	0.48***	0.31*
Seed N content (%)	-0.025	-0.26*
Seed P content (%)	-0.20	0.08
Leaf N content (%)	0.30*	-0.36**
Leaf C content (%)	-0.18	-0.28*
Leaf δ13C	-0.13	-0.21
Pod harvest index (%)	-0.23	0.42***
Harvest index (%)	0.13	-0.17
Podwall biomass proportion (%)	-0.18	-0.28*
Stem biomass reduction (%)	0.20	0.33**
Canopy temperature at 1 p.m. °C		0.32*
CTD at 1 p.m. °C		0.32*

Four genotypes, Perola, Carioca, SEA 5 and Tio Canela showed more negative values of CTD, but three of these genotypes were poor yielding. This was corroborated by studies of root distribution of 4 genotypes through the soil profile, indicating a negative correlation between root production and grain yield. In contrast, lines such as drought resistant SER 16 presented relatively less amount of roots and less negative CTD with higher grain yield compared with the other 3 genotypes.

Conclusions

- Field evaluation of elite lines at Palmira resulted in identification of three lines (SXB 418, SER 109 and NCB 280) that were outstanding in their adaptation to drought stress conditions. The superior performance of these lines under drought stress was associated with higher values of leaf area index and canopy biomass, pod harvest index, and lower proportion of pod wall biomass.
- The results indicate that SER 16 was more water use efficient than DOR 390 and Tio Canela 75 due to its greater ability to mobilize photosynthates to grain.
- It appears that greater rooting depth and access to moisture alone will not assure good yield under drought. Further work is needed to verify these observations.

References

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