

Physiological basis of improved adaptation to drought in common bean

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Introduction

Common beans (*Phaseolus vulgaris* L.) are cultivated by small farmers in Latin America and eastern and southern Africa, where unfavorable climate conditions and minimum use of inputs frequently limit productivity (Beebe et al., 2012, 2013). Drought is responsible for yield losses between 10 and 100%. About 60% of the bean-producing regions have prolonged periods of water shortage and drought is the second most important factor in yield reduction after diseases (Rao, 2014). The development of bean varieties adapted to water stress conditions through breeding is a useful strategy to ensure food security in marginal areas. Studies conducted for the past few years indicated that the superior performance of common bean genotypes under drought stress was associated with their ability to remobilize photosynthates from vegetative structures to developing grain. Pod harvest index was identified as a useful trait to consider in the breeding program in addition to grain yield for identifying bean genotypes that are better adapted to drought stress conditions. We evaluated drought adaptation of 36 genotypes including the elite lines and checks from the on-going breeding program with the main objective of defining the physiological basis for improved drought resistance.

Materials and Methods

Two field trials were conducted during the dry season (June to September in each year of 2012 and 2013), at the main experimental station of the International Center for Tropical Agriculture (CIAT) in Palmira. The trial included 36 genotypes: ALB 213, ALB 6, ALB 60, ALB 74, ALB 88, BAT 477, BAT 477 NN, BFS 10, BFS 29, BFS 32, BFS 67, DOR 390, G 40001, INB 827, INB 841, MIB 778, NCB 226, NCB 280, Perola, RCB 273, RCB 593, SCR 16, SCR 2, SCR 9, SEA 15, SEN 56, SER 118, SER 119, SER 125, SER 16, SER 48, SER 78, SMC 141, SMC 43, SXB 412 and Tio Canela 75. A 6 x 6 partially balanced lattice design with 3 replicates was used. Two levels of water supply (irrigated and rainfed) were applied. Stomatal conductance and canopy biomass were measured at mid-pod filling. At the time of harvest, grain yield and yield components were determined. Ground samples of grain at harvest were sent to UC Davis Stable Isotope Facility in USA for ¹³C analysis. Carbon isotope discrimination (CID) was calculated according to Farquhar et al. (1989). Isotopic discrimination between ¹³C and ¹²C (CID) in grain was related to whole plant water use efficiency (WUE) and effective use of water (EUW). Water use efficiency (WUE) is defined as "more crop per drop", while effective use of water (EUW) implies maximal soil moisture capture for transpiration. Pod partitioning index (PPI) (dry wt of pods at harvest/dry wt of canopy biomass at mid-podfill x 100), pod harvest index (PHI) (dry wt of seed at harvest/dry wt of pod at harvest x 100), were also determined.



Irrigated



Drought stress

Results

Under rainfed conditions, leaf stomatal conductance presented a significant positive correlation with grain yield (GY) ($r=0.31^{***}$). Grain CID showed a positive and significant correlation with GY under rainfed ($r=0.36^{***}$). Results from two field trials on stomatal conductance and grain CID showed that many of the higher yielding bean genotypes under drought stress are using more water, maximizing their capture of soil water for transpiration, with better plant growth and biomass partitioning, through effective use of water (EUW) as proposed before (Blum, 2009). The lines NCB 280, SMC 141, SCR 16, SEN 56, BFS 67, NCB 226 and SEA 15 are classified as water spenders that are able to access more water resulting in higher yield (Figure 1). Results also revealed a few genotypes that are combining higher WUE with better GY under rainfed conditions, classified as water savers, such as BFS 29, SER 16, ALB 6, ALB 60 and *P. acutifolius* (G 40001), useful genotypes for targeting to semiarid to dry environments (Figure 1).

The PHI value reflects the ability to mobilize photosynthates from pod wall to seed. A positive and highly significant correlations of PHI with GY under both irrigated and drought conditions were observed ($r=0.61^{***}$ and 0.48^{***} respectively). The positive and significant correlations between GY and biomass partitioning indices (PPI and PHI) under drought stress highlight the importance of photosynthate remobilization from plant biomass to pod formation (PPI) and grain production (PHI). The lines BFS 29, SEA 15, BFS 10, NCB 280, SEN 56, SCR 16 and SMC 141 were superior in their ability to partition greater proportion of biomass to pod and grain production (Figure 2). Breeding programs should focus on the selection of best-performing materials that combine greater values of CB as a result of EUW, with greater mobilization of photosynthates to pod development and grain filling.

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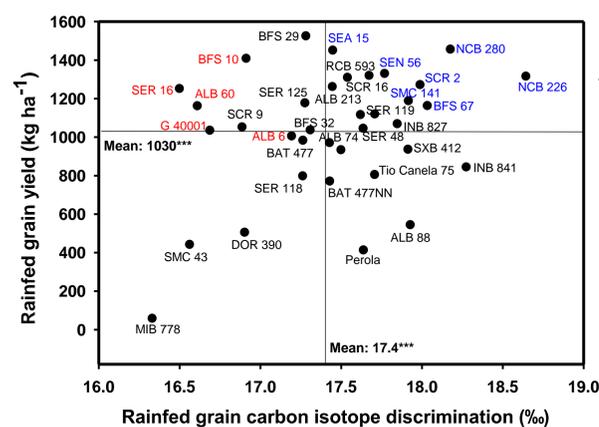


Figure 1. Identification of genotypes with greater values of grain yield and grain carbon isotope discrimination (CID) under rainfed conditions on a Mollisol at Palmira. Water savers (red) and water spenders (blue) are highlighted.

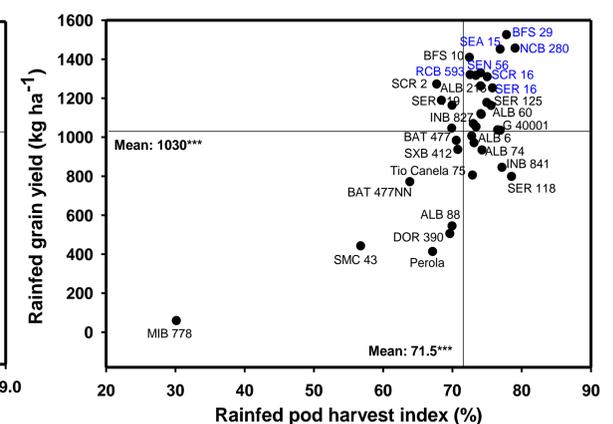


Figure 2. Identification of genotypes with greater values of grain yield and pod harvest index (PHI) under rainfed conditions on a Mollisol at Palmira.

Conclusions

Adaptation to drought in common bean is related to two key processes, EUW (through a better developed root system to help the plant to access water to maintain transpiration rates and vegetative growth) and the ability to remobilize photosynthates from vegetative structures to the pods and subsequently to seed production. Several lines were identified as drought adapted such as NCB 280, NCB 226, SEN 56, SCR 2, SCR 16, SMC 141, RCB 593 and BFS 67 and their resistance was associated with superior EUW combined with better photosynthate remobilization to pod and grain production. Traits such as rooting depth, grain CID related with EUW, PPI and PHI should be considered as useful plant traits to be included in bean breeding programs that are aimed at improving drought adaptation.

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