QTL analysis for Drought Resistance in a DURANGO X ANDEAN RIL population of common bean

Mukeshimana G[1]*, L. Butare[2], S. Beebe[3], and J.D. Kelly[1].

[1]Department of Crop and Soil Sciences, Michigan State University, MI;
[2]Rwanda Agricultural Board, Kigali, Rwanda; [3] International Center for Tropical Agriculture (CIAT), Cali, Colombia

Introduction

Common bean (*Phaseolus vulgaris* L) is the world's most important food legume. It constitutes an important staple in Rwanda where per capita consummation is among the world's highest (60 kg). As the competition from other crops for production area and resources is increasing, beans need to be resistant to both biotic and abiotic stresses to be productive in Rwanda cropping systems.

Objectives

- To evaluate a Recombinant Inbred Lines (RIL) population from a cross of SEA5 with CAL 96 for drought resistance
- To identify Quantitative Trait Loci (QTL) associated with drought resistance mechanisms

Materials and Methods

Site

Experiments were conducted for 2 growing seasons in RAB's dry-land Karama research station– Rwanda (2° 16´S, 30° 17´ E, 1,347 m elevation), and one season in CIAT's Palmira Experiment Station– Colombia (3°30'N, 76°30'W, 965 m elevation).

Germplasm

A Recombinant Inbred Line (RIL) population consisting of 125 lines, their parents (SEA5 and CAL96), and 5 checks: RWR1668, RWR2245, SER13, SER14, and SER16 were evaluated for drought resistance in Karama. In Palmira, a sample of 97 lines along with parents and a local check ICA Quimbaya were evaluated. SEA5 is a Durango derivative, creamy small sized bean line that was developed by the CIAT (Singh et al., 2001). CAL 96 is a large seeded Calima type that is widely adapted in East Africa.

Experimental design

A 12 x 11 rectangular lattice design with two replicates was used in Karama station, while a 10x10 lattice was used in Palmira. Experiments were irrigated until flowering in rainfed plots.

In addition, the population was screened with 92 Simple Sequence Repeat (SSR) and 12 Insertion deletion (INDEL) markers.

Response variables

Drought Intensity Index (DII) was calculated to quantify the severity of drought for each experiment in Karama.

To determine response to water stress, number of days to flowering (DFL), number of days to physiological maturity (DPM), number of pods/plant (NPPL), number of seeds/pod (NSPP), canopy biomass (CB), Harvest Index (HI), Pod Harvest Index (PHI), Seed yield (kg/ha), yield per day (g/d), and 100-seed weight, were determined for each RIL.

Data analysis

PROC MIXED (SAS 9.3, SAS Institute, Inc., Cary, NC) was used to analyze field data. SEA5 x CAL96 map was constructed using MapDisto. QTL analyses were performed using Interval Mapping method of the WinCartographer, and displayed using Mapchart.

Results and Discussion

Figure 1. Maturity difference between irrigated and rain fed treatments in Rwanda

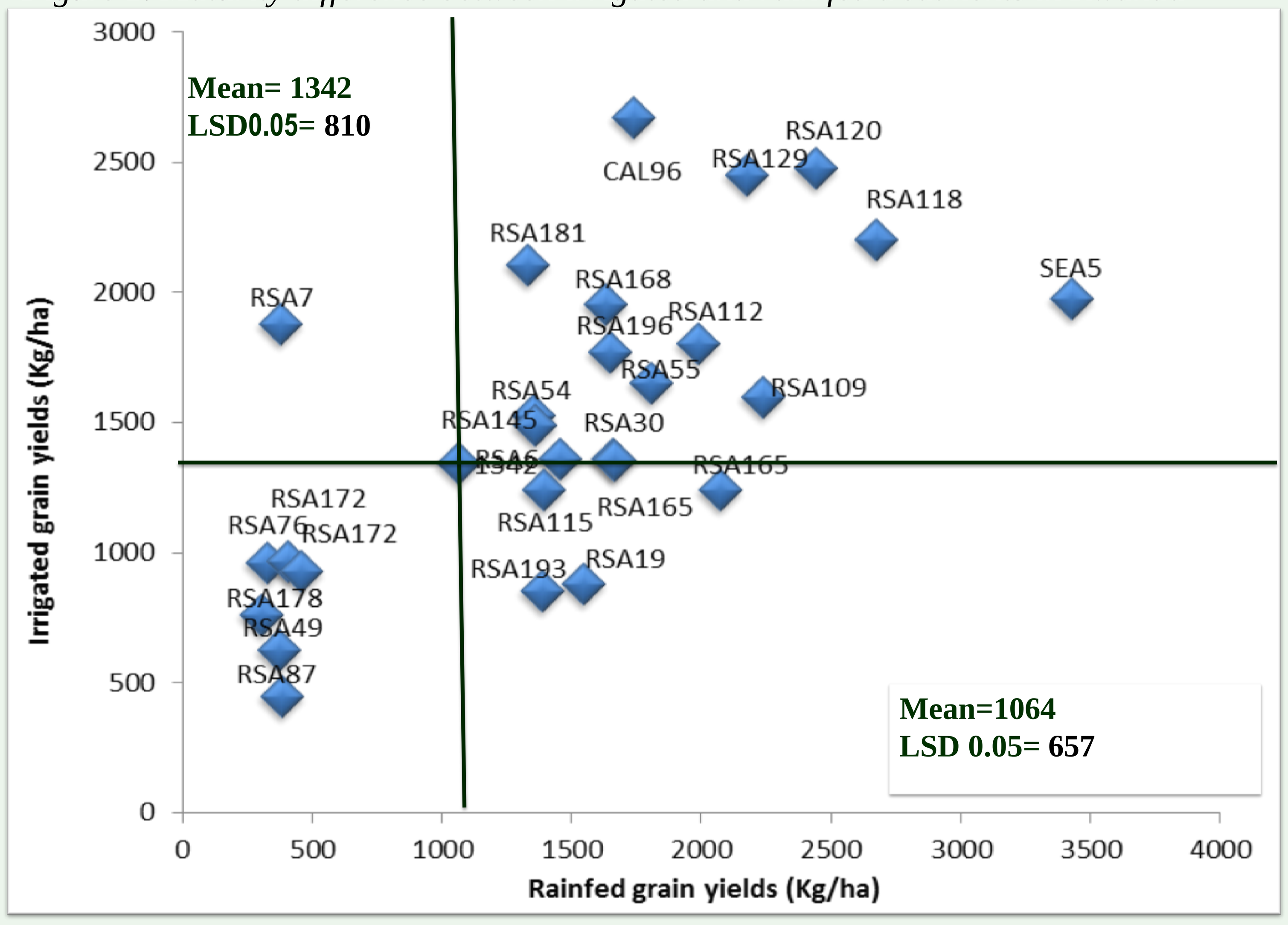

Fig2. Sample of RILs that performed well under both drought stress and non stress in Rwanda. Values represent means yields under drought and irrigation. Those RILs in the upper right quadrant represent the best yielders under drought stress and non stress.

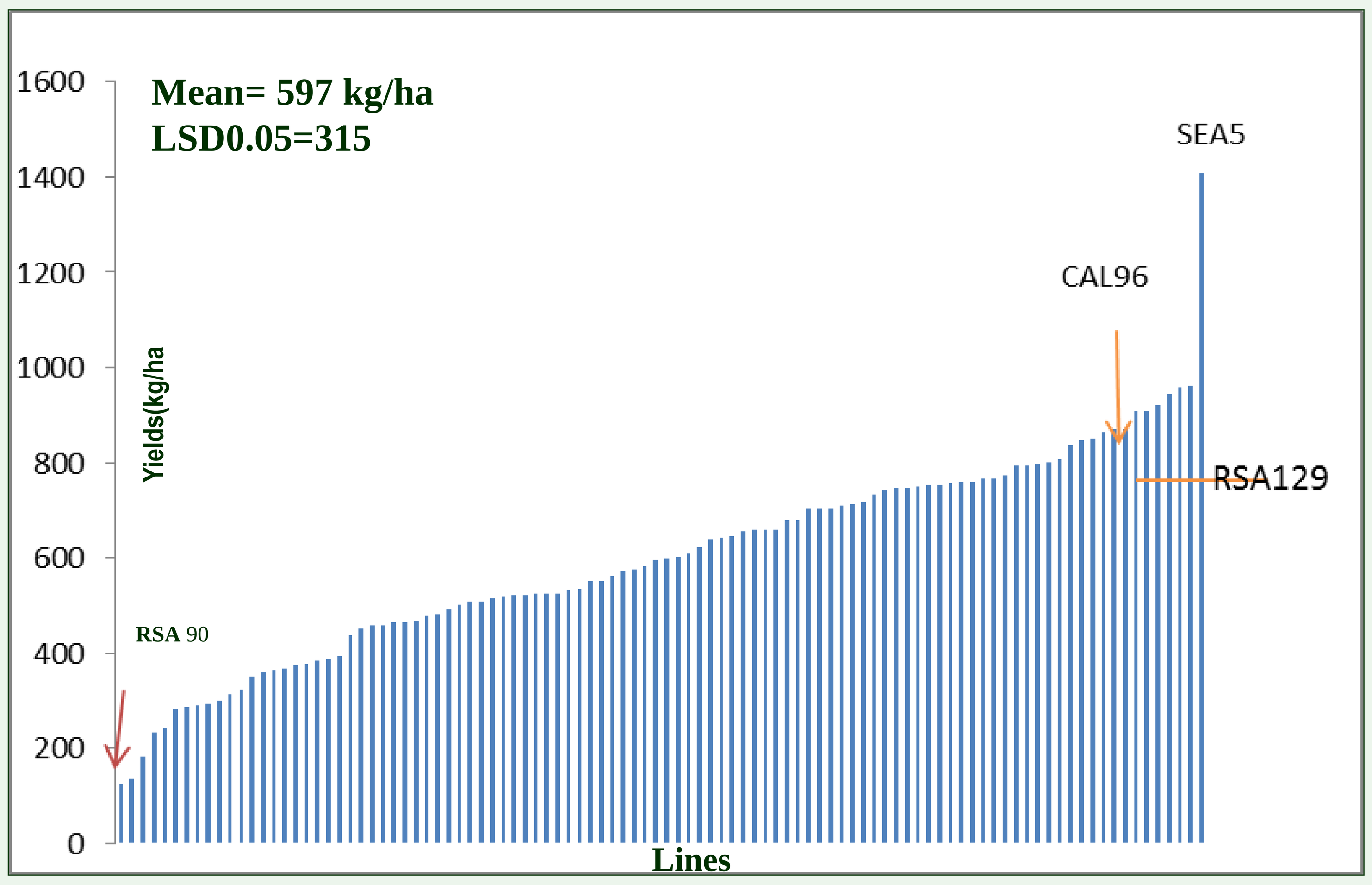

Fig 3. Seed yields under rain fed conditions in Colombia

Table 1. Pearson Correlation Coefficients between variables in Karama 2-season

Variables	DFL	DPM	NPPL	NSPP	CB	HI	PHI	100SW	YLD
DPM	-0.20***								
NPPL	-0.41***	0.41***							
NSPP	0.07ns	0.05ns	0.16***						
CB	0.15***	0.04ns	0.20***	0.16***					
HI	-0.21***	-0.08ns	0.32***	0.09ns	0.04ns				
PHI	0.06ns	-0.19***	-0.09*	-0.01ns	0.16***	0.66***			
100SW	0.16**	0.01ns	-0.06ns	-0.05ns	0.44***	0.11*	0.32***		
YLD	-0.15**	0.24***	0.54***	0.25***	0.60***	0.53***	0.33***	0.31***	
YLDD	-0.13**	0.16**	0.51***	0.25***	0.61***	0.55***	0.36***	0.32***	1***

Table 2. Pearson Correlation Coefficients between variables in Palmira

Variable	DFL	DPM	NPPL	NSPP	CB	HI	PHI	100SW	YLD
DPM	0.55***								
NPPL	-0.02ns	0.00ns							
NSPP	-0.01ns	-0.25***	-0.13*						
CB	0.01	0.10	0.63	0.10					
HI	0.01ns	-0.29***	0.17**	0.51***	-0.06ns				
PHI	-0.07ns	-0.25***	0.06ns	0.48***	0.09ns	0.66***			
100SW	-0.01ns	0.09ns	0.03ns	-0.14*	0.40***	0.15*	0.20		
YLD	0.01ns	-0.24***	0.21***	0.43***	0.28***	0.44***	0.27***	0.11ns	
YLDD	0.0ns	-0.3***	0.2***	0.4***	0.3***	0.4***	0.3***	0.1ns	1.0***

ns: no significant; * :Significant at α= 0.05; **: significant at α= 0.01; ***: significant at α= 0.001

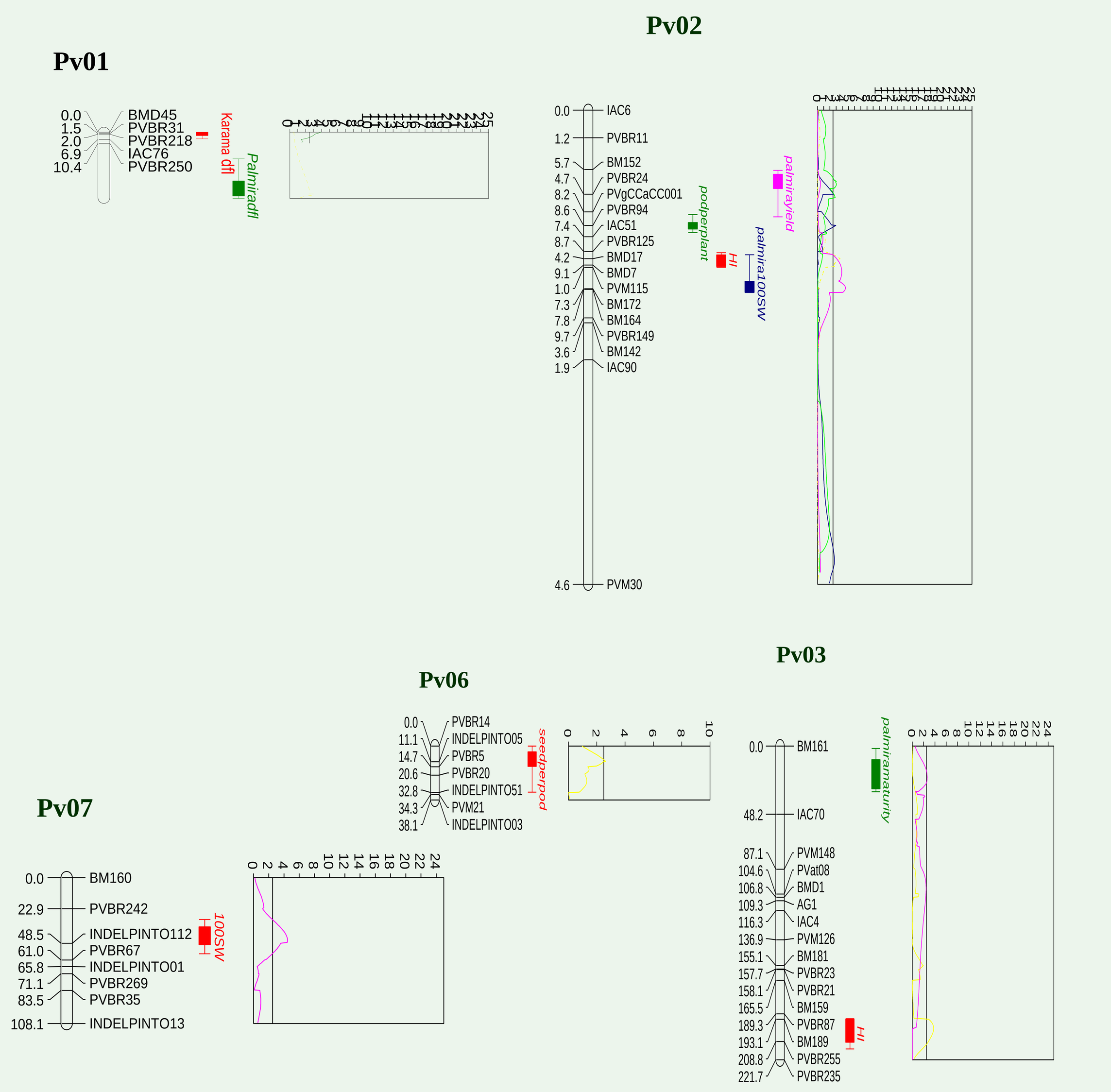

Fig. 4. QTLs associated with drought tolerance traits

Seed yields ranged from 300 to 3428 kg/ha under drought conditions and 400 to 3527 kg/ha under irrigation in Karama. Overall seed yield reduction was 30% under drought stress. In Palmira, yields ranged from 123kg/ha to 1407 kg/ha. In both sites, no RIL out-yielded SEA5 parent while some RILs had higher yields than CAL96 under drought conditions.

A range of seed size from 13.8 to 45.1 g/100-seed under drought stress was observed in the progeny. There is a large variation in seed color and many of the RILs have unacceptable color. Transferring drought resistance traits from Durango race to Andean gene pool may require a different breeding strategy rather than inbreeding per se.

Drought stress significantly reduced the number of pods/plant ($p<0.0001$) and the number of seeds/pod ($p<0.0001$) in both sites.

HI and PHI varied significantly among lines ($p<0.0001$). Under irrigation conditions, CAL 96 consistently had a higher HI and PHI than SEA 5 in both locations. Transgressive segregations for HI and PHI were observed.

The number of days to maturity was influenced by both genotype (<0.0001) and water treatment p(<0. 0001). Under drought, the average number was 82 days compared to 84 days in Karama while the maturity varied between 58 and 71 days in Palmira

Positive correlations were observed between canopy biomass, partitioning indexes and yield components in both locations.

A SEA5xCAL96 linkage map of 1034cM was constructed and QTLs associated with drought tolerance traits were identified on linkage groups Pv01, Pv02, Pv03, Pv06, and Pv07. Interestingly, QTLs conditioning the number of pods per plant ($R2=12\%$), HI($R2= 17\%$), 100seed weight($R2=21\%$), and yield ($R2=57\%$) co-located on Pv02. QTLs conditioning the HI were identified on both Pv02 and Pv03.

Conclusions

Lines yielding more than the Andean parent CAL96 under drought conditions were identified.

QTLs conditioning drought traits were identified. Once confirmed, they may be used for marker assisted breeding to transfer drought resistance in common bean.

Literature cited

Singh S.P, H Terán and J.A Gutiérrez. 2001. Registration of SEA 5 and SEA 13 Drought Tolerant Dry Bean Germplasm. Crop Sci. 41:276–277.

Acknowledgements

This research is supported by the Dry Grain Pulses Collaborative Research Support Program (PULSE CRSP). The Genetic population was provided by CIAT.

The field experiments in Colombia were supported by the Borlaug LEAP

*Corresponding author: mukeshim@msu.edu