Evaluation of an Andean common bean reference collection under drought stress

Evaluación de una colección de referencia de fríjol andino bajo condiciones de sequía

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ABSTRACT

More than 60% of common bean (*Phaseolus vulgaris* L.) production worldwide is impacted by the risk of drought. In this study, the goal was to evaluate 64 bush bean genotypes from the CIAT reference collection to identify possible sources of drought resistance in the Andean gene pool. Phenotypic traits such as yield, 100-seed weight (P100) and days to physiological maturity (Dpm) were evaluated on selected accessions of this collection which was grown in an 8x8 lattice with two repetitions under three environments: intermittent drought (SI) and irrigation (R) in Palmira as well as early drought (ST) in Darién, Colombia. The genotypes included 20 from the Nueva Granada 1 (NG1) sub-race, 19 from the Nueva Granada 2 (NG2) sub-race, 10 from race Peru (P), 14 Andean control genotypes and one Mesoamerican check. The variables were analyzed through a combined ANOVA across environments, while simple correlations between yield and others variables were determinate. The genotypes with better adaptation to drought showed higher yields, 100-seed weight and fewer days to physiological maturity. The coefficients of correlations among yield and 100-seed weight were significant and positive, while Dpm showed negative correlation. Fourteen genotypes were identified as drought tolerant: G4001, G5625, G6639, G16115, G17070, G18255, G21210 and G22247 from the NG1 sub-race; G5708, G14253, G18264 and LRK31 from the NG2 sub-race; and DRK47 and G22147 from race Peru.

Key words: andean races, water deficit, phenotypical traits, adaptation.

RESUMEN

Más del 60% de la producción mundial de fríjol común (*Phaseolus vulgaris* L.) crece bajo riesgo de sequía. Para identificar posibles fuentes de resistencia a la sequía en el acervo genetico andino se indagaron 64 genotipos de fríjol arbustivo de la colección de referencia del CIAT. Se evaluaron atributos fenotípicos como el rendimiento, el peso de 100 semillas (P100) y los días a la madurez fisiológica (Dam) en accesiones seleccionadas de esta colección, los cuales se sembraron en un diseño en lattice 8x8 con dos replicaciones y tres ambientes: sequía intermitente (SI) y riego (R) en Palmira y también sequía temprana (ST) en Darién, Colombia. De los genotipos evaluados, 20 pertenecen a la sub-raza Nueva Granada 1 (NG1), 19 a la sub-raza Nueva Granada 2 (NG2), 10 de la raza Perú (P), 14 son controles andinos y un control mesoamericano. Las variables se analizaron por medio de ANDEVAs combinadas entre los ambientes; además, se determinaron coeficientes de correlación simples entre el rendimiento y las demás variables evaluadas. Los genotipos con mayor adaptación a la sequía presentaron alto rendimiento, mayor P100, además de menor número de días a la madurez fisiológica. Los coeficientes de correlaciones entre el rendimiento y P100 fueron significativos y positivos, mientras que Dam presentó correlación negativa. Se identificaron 14 genotipos como tolerantes a condiciones de sequía: G4001, G5625, G6639, G16115, G17070, G18255, G21210 y G22247 de la sub-raza NG1; G5707, G14253, G18264 y LRK31 de la sub-raza NG2; y DRK47 y G22147 de la raza Perú.

Palabras clave: razas andinas, déficit hídrico, atributos fenotípicos, adaptación.

Introduction

Drought affects more than 60% of world production of common bean (*Phaseolus vulgaris* L.) (White and Singh, 1991), and the second cause largest to decrease in yield (Singh, 1995). In Latin America about 73% of the common bean crops grow in environments where there is often drought conditions restricting the production (Acosta-Gallegos *et al*., 1999). In addition, the common bean is a species very susceptible to drought compared with other legumes (Pimentel *et al*., 2001). The effect of drought on the common bean depends on the type (severe, moderate) and duration (early, intermittent and terminal) and the same stage of development where the cultivation is (Terán and Singh, 2002; Nielsen and Nelson, 1998).

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TABLE 1. Description and characteristics of the 64 genotypes of common bean reference collection and controls used in the study.

Genotype	Common name	Gene pool	Race*	Origin	C1**	C2**	W100(g)	Habit***
G 738	PILIGUE	Andean	NG1	Guatemala	6		67	I
G 1688	PRETO FORRO 5	Andean	NG1	Brazil	8		38	II
G 1836	GENTRY 20670 (SELECCION)	Andean	NG1	Costa Rica	2	7	35	II
G 1939	GENTRY 21351 OJO DE LIEVRE	Andean	NG1	Mexico	2	6	39	II
G 2875	GENTRY 22252 CACAHUATE	Andean	NG1	Mexico	2	6	50	II
G 4001	34-P	Andean	NG1	Costa Rica	7	2	43	II
G 5142	GUANAJUATO 113	Andean	NG1	Mexico	2	6	45	II
G 5625	MORELOS 30-A=MEX-519	Andean	NG1	Mexico	6		61	I
G 6639	502	Andean	NG1	Haiti	8		51	I
G 7776	COL NO 269 = ALCAGUETA	Andean	NG1	Ecuador	3		38	II
G 7945	MANZE JOUTE	Andean	NG1	Haiti	6	2	52	I
G 9846	E7887	Andean	NG1	Ecuador	5	6	48	I
G 11957	M7585-7-1	Andean	NG1	Mexico	2	6	43	III
G 13094	MAYOCOBA	Andean	NG1	Mexico	3		51	I
G 16115	NA	Andean	NG1	Peru	5		51	I
G 17070	E8454E-1	Andean	NG1	Ecuador	5		54	I
G 18255	VELAZCO LARGO	Andean	NG1	Cuba	5		68	I
G 18942	FACHINEIRO COL.NO.10	Andean	NG1	Brazil	3		58	I
G 21210	MONTE OSCURO	Andean	NG1	Colombia	6	5	62	I
G 22247	POMPADOUR H	Andean	NG1	Rep. Dominicana	6	2	46	II
AND 1005		Andean	NG2	Colombia	7	2	62	II
G 4644	LIMONCILLO	Andean	NG2	Colombia	6	5	60	I
G 5034	ROXO GIGANTE OU MANTEIGAO	Andean	NG2	Brazil	9		45	I
G 5708	SANGRETORO	Andean	NG2	Colombia	6		49	I
G 6873	GALO DE CAMPINA	Andean	NG2	Brazil	6	1	46	I
G 7895	TRACE ROJO=PER-40	Andean	NG2	Peru	6		44	I
G 9603	JALO EEP 558	Andean	NG2	Brazil	3		62	III
G 11512	YUNQUILLA	Andean	NG2	Ecuador	6		36	I
G 11585	CUZCO 9	Andean	NG2	Peru	3		51	I
G 11727	TACOYUNYA	Andean	NG2	Peru	2		48	III
G 11759A	TIACHO	Andean	NG2	Peru	2		30	IIA
G 11787	CHAUCHA	Andean	NG2	Peru	2	6	34	IIIB
G 14253	PERU 13	Andean	NG2	Peru	3		44	I
G 16104E	NA	Andean	NG2	Peru	7		28	I
G 18264	POMPADOUR CHECA 50	Andean	NG2	Rep. Dominicana	7	2	52	III
G 19841	NA	Andean	NG2	Peru	2	7	23	III
G 23829	NA	Andean	NG2	Peru	7		32	II
LRK 31	LIGHT RED KIDNEY	Andean	NG2	Colombia	5		74	I
PVA 1111	INTA	Andean	NG2	Colombia	5		53	I
DRK 47		Andean	P	Colombia	6		66	I
G 2567	POROTO CUARENTON=ECU-258	Andean	P	Ecuador	2	7	40	II
G 2686	ASHPA=PER-23	Andean	P	Peru	7	2	40	I
G 4721	SAN MARTIN 8	Andean	P	Peru	2	6	53	II
G 8209	ANCASH 4	Andean	P	Peru	2	7	56	IIIB
G 11521	ASHPA POROTO	Andean	P	Ecuador	3	8	55	I
G 19876	NA	Andean	P	Peru	3	7	60	II
G 22147	PERU 69	Andean	P	Peru	6		85	I
G 23604	ÑUÑA	Andean	P	Peru	9	8	25	II
PVA 773	ICA CAUCAYA	Andean	P	Colombia	6	2	56	I
Control	AFR 298	Andean			6		49	I
Control	AFR 619	Andean			6	2	50	I
Control	CAL 143	Andean			6	2	37	I
Control	CAL 143	Andean			6	2	37	I

* Races: NG1 (Nueva Granada 1), NG2 (Nueva Granada 2), P (Peru).

** C1 (primary color) and C2 (secondary color): 1. White; 2. Cream; 3. Yellow; 4. Coffee; 5. Rose; 6. Red; 7. Purple; 8. Black; 9.Other.

*** Habit: I (Determined shrub); II (Undetermined shrub); III (Indeterminate prostrated); IV (Indeterminate climbing).

Genotype	Common name	Gene pool	Race*	Origin	C1**	C2**	W100(g)	Habit***
Control	CAL 96	Andean			6	2	56	I
Control	KAT B1	Andean			3		39	I
Control	KAT B9	Andean			6		42	I
Control	SAB 258	Andean			6		34	I
Control	SAB 645	Andean			6	2	39	I
Control	SELIAN 97	Andean			6		25	I
Control	SEQ 1003	Andean			5	8	42	I
Control	SEQ 1027	Andean			2	6	44	I
Control	SEQ 1027	Andean			2	6	44	I
Control	URUGUEZI	Andean			6	2	39	I
Control	SEQ 11	Mesoamerican			7	2	35	II

* Races: NG1 (Nueva Granada 1), NG2 (Nueva Granada 2), P (Peru).

** C1 (primary color) and C2 (secondary color): 1. White; 2. Cream; 3. Yellow; 4. Coffee; 5. Rose; 6. Red; 7. Purple; 8. Black; 9.Other.

*** Habit: I (Determined shrub); II (Undetermined shrub); III (Indeterminate prostrated); IV (Indeterminate climbing).

Drought causes reduction in yield, yield components and biomass accumulation (Ramírez-Vallejo and Kelly, 1998; Nielsen and Nelson, 1998, Castañeda *et al*., 2006, Terán and Singh, 2006; Muñoz-Perea *et al*., 2006; Gómez *et al*., 2010). Abebe *et al*. (1998) found a reduction in yield of 62% in the dry environment compared with the control environment. The greater sensitivity to drought in common bean occurs during the reproductive stage, from pre-flowering to pod-filling (Nielsen and Nelson, 1998; Castañeda *et al*., 2006).

Genotypic and phenotypic differences have been reported for drought resistance in common bean (Abebe *et al*., 1998), which is necessary for the selection of genotypes with adaptation to drought, is effected through a combination of criteria related to the yield, days to maturity and yield components in different moisture conditions.

Genetic improvement to get drought-resistant crops is a slow and difficult, because other factors such as diseases and heat stress affect the selection of genotypes (Subbarao *et al*., 1995; Beebe *et al*., 2008). The use of genetic variability is essential for the improvement of common bean in areas such as increased yield and tolerance to abiotic factors such as drought (Singh, 2001; Terán and Singh, 2002). To find sources of resistance to drought, consider their evolutionary origin and center of domestication understanding that improvement is the basis of genetic diversity (Terán and Singh, 2002), therefore it is important to investigate within germplasm collections common bean.

The core collection is a handy collection consists of 1440 accessions were chosen to represent the genetic diversity of the collection or global basis so they can be used in breeding programs (Brown, 1989; IPGRI, 2000). Meanwhile, the reference collection is even more representative sample of the base collection of only 200 genotypes were selected based on molecular markers to represent the greatest diversity of cultivated common bean shrub found in the core (Blair *et al*., 2009; CIAT, 2008). The core and reference collections represent two fairly large numbers of genotypes.

The objective of this study was to evaluate 64 genotypes shrub collection from CIAT bean reference, subject to conditions of drought stress to identify sources of resistance to drought in Andean heritage, through the characterization of phenotypic attributes.

Materials and methods

Plant material

The stock Andean bean is divided into races according to agro-morphological characteristics (Singh *et al*., 1991) that are reflected by polymorphism in molecular markers (Blair *et al*., 2007). Breeds belonging to this pool identified by Singh *et al*. (1991) and Blair *et al*. (2007, 2009), were race Nueva Granada —which has two sub-races, New Granada 1 (NG1) and Nueva Granada 2 (NG2)—, race Peru (P) and race Chile, although the latter did not present a clearly distinguished from the other Andean races. For this study, we used 63 genotypes of the reference collection of Andean stock and stock Mesoamerican genotype used as control. Of these 20 genotypes belonging to the Andean sub-race Nueva Granada 1 (NG1), 19 sub-race of Nueva Granada 2 (NG2), 10 race Peru (P), and 14 Andean controls (Blair *et al*., 2009) (Tab. 1).

Location of trial

The study was conducted during the dry season from July to October 2008, in the towns of Palmyra and Darien, Colombia. The town of Palmira (3° 29' N, 76° 21' W) is at 965 meters and has an annual rainfall of 839 mm, with average temperature 24° C, soil Mollisol (Aquic Haplustoll), pH 7.7 and 70.5 ppm of phosphorus. The town of Darien (3° 55' N, 76° 28' W), is 1,500 meters and has an average annual rainfall of 1,650 mm, with average temperature 20 °C, Inceptisol soil (typic Dystrandept), pH 5.7 and 4.1 ppm of phosphorus which required soil fertilization with 80 kg of phosphorus.

Agricultural practices to control pests, weeds and diseases were performed manually, chemical and mechanical. the seed was treated with captan carboxin and also benomyl applications were made, and oxicarboxin inorganic sulfur to control diseases. For weed control conducted a pre-emergent chemical control with s-metolachlor linuron and then at 25 and 62 days after planting (Dap), control was performed with ammonium and glyphosate glufocinato. Manual-mechanical control of weeds was done at 14, 25, 38, 51 and 62 Dap. Insecticides were applied according to the degree of infestation and phenological stage for insect pest control with the active ingredients: carbaryl, milbemectin imidacloprid, deltamethrin, as recommended by the manufacturer. In addition, there were two foliar fertilizations with zinc and boron (220 g ha^{-1} and 400 g ha^{-1}, respectively) at 14 and 33 Dap, to avoid possible deficiencies due to the basic pH of the Palmira soils.

Experimental design

Design was used in 8 x 8 lattice partially balanced with 2 repetitions. Environments evaluated were irrigation (R), intermittent drought (SI) and early drought (ST). The first two are located in the town of Palmyra and the latest in Darien, Colombia. For R, a total of six irrigations of 31 mm each were applied, while for SI only two irrigations were necessary to ensure the establishment of the crop. ST was not carried out in supplementary irrigation. The experimental unit consisted of two rows of 3 m in length; with a row spacing of 0.6 m planting density were 15 seeds per linear meter.

Variables evaluated

The variables evaluated were yield, number of days to physiological maturity (Dam) and weight of 100 seeds (P100). The number of days to maturity was estimated by means of daily observations by evaluating the number of days from planting until at least 50% of the experimental unit pods present a green discoloration of the characteristic color of maturity in each genotype.

To determine the weight of 100 seeds were harvested randomly five plants per experimental unit and based on the seed obtained, we calculated this variable. The whole plot was harvested, we determined the weight and seed moisture at harvest, and then make a correction to 14% moisture and express seed yield kg ha^{-1}.

Statistical analysis

The variables studied were subjected to analysis of variance between environments combined and determined the least significant difference (LSD) between treatments. Also, the coefficients were determined simple correlations between performance and the other variables assessed. We used the GLM procedure of SAS® statistical software (version 9.1.3) (SAS Institute, 2004).

Results and discussion

In Palmira maximum and minimum temperature recorded during the crop cycle was 33°C and 16°C respectively. The potential evaporation was 416 mm, while precipitation totaled 163 mm, distributed unevenly. The data of precipitation and evaporation with rainfall distribution indicate that there was an intermittent type of stress during the period of crop growth and development (Ludlow and Muchow, 1990). Meanwhile, in Darien there was a maximum and minimum temperature of 27°C and 13°C respectively. The precipitation was 280 mm, no evaporation data were obtained but the precipitation data, along with its distribution suggest that introduced drought early in the crop because during the first trifoliate leaf stage to third trifoliate leaf rainfall was 5.3 mm (Fischer and Maurer, 1978).

Performance

The mean squares of environments, genotypes and genotype by environment interaction showed highly significant differences (P <0.001) for performance (Tab. 2). The least significant difference (LSD), allowed separating environments with differences between the environments of drought and irrigation (Tab. 3). The yield coefficient of variation was 23.1%.

TABLE 2. Mean squares and significance of combined analysis of variance across environments for yield, number of days to maturity and weight of 100 seeds of 64 genotypes of common bean reference CIAT collection evaluated under irrigated conditions and intermittent drought in Palmira, and early drought in Darien (Colombia) from July to October 2008.

		Mean squares ^		
Source of variation	**D.F**	**Yield**	**Dam**	**P100**
Environment (A)	2	7409255.4***	4020.2***	3768.6***
Experimental error (a)	3	667180.4*	31.2**	439.9***
Genotipe (G)	63	983787.2***	171.1***	468.1***
G x A	126	308193.3***	21.1***	44.6***
Experimental error (b)	192	121263.3	5.7	28.3

^: Dam: Number of days to maturity; P100: 100-seeds weight.
*Significance P <0.05, ** Significance P <0.01, *** Significance P <0.001.

TABLE 3. Average performance, number of days to maturity (Dam), 100-seeds weight (P100) and arithmetic (MA) of 64 genotypes of common bean reference collection at CIAT, under irrigated conditions (R), intermittent drought (SI) in Palmira, and early drought (ST) in Darien (Colombia), from July to October 2008.

		Yield (kg ha^{-1})				Dam				P100 (g)			
Genotypes	**Races**	**Mean**				**Mean**				**Mean**			
		R	**SI**	**ST**	**MA**	**R**	**SI**	**ST**	**MA**	**R**	**SI**	**ST**	**MA**
G 738	NG1	1248	1222	1260	1244	74	66	78	73	50	40	60	50
G 1688	NG1	1518	2047	1294	1620	64	65	77	68	28	28	33	29
G 1836	NG1	920	1770	1123	1271	69	67	78	71	37	32	39	36
G 1939	NG1	947	1817	1392	1385	70	63	79	71	40	41	51	44
G 2875	NG1	785	1695	1522	1334	66	67	80	71	41	43	50	45
G 4001	NG1	1795	2130	1522	1816	73	71	80	74	40	37	50	43
G 5142	NG1	755	1598	1437	1263	65	64	76	68	50	45	41	45
G 5625	NG1	1212	2041	1751	1668	66	65	78	70	47	44	58	50
G 6639	NG1	1292	1764	1771	1609	64	64	78	68	36	36	54	42
G 7776	NG1	744	1015	1898	1219	79	77	76	77	34	30	45	36
G 7945	NG1	1671	1761	1365	1599	64	64	81	70	38	37	39	38
G 9846	NG1	615	487	1376	826	82	85	75	81	36	30	43	36
G 11957	NG1	1257	1361	1571	1396	65	67	80	71	43	31	47	40
G 13094	NG1	1062	1595	1790	1482	65	67	78	70	36	31	52	40
G 16115	NG1	1542	2300	1744	1862	62	63	76	67	41	41	50	44
G 17070	NG1	1316	2083	1778	1725	62	62	75	66	43	40	31	38
G 18255	NG1	1705	2455	1867	2009	63	64	75	67	41	39	56	46
G 18942	NG1	873	1528	1949	1450	66	66	79	70	39	33	48	40
G 21210	NG1	1669	1757	1911	1779	68	66	78	71	62	44	65	57
G 22247	NG1	1324	1904	1943	1723	70	69	77	72	32	30	45	36
NG1 Mean		**1212**	**1716**	**1613**	**1514**	**68**	**67**	**77**	**71**	**41**	**37**	**48**	**42**
AND 1005	NG2	1364	1419	2080	1621	66	70	80	72	47	39	52	46
G 4644	NG2	840	1985	1305	1377	64	64	76	68	43	50	63	52
G 5034	NG2	1634	1745	1077	1486	66	64	77	69	40	36	38	38
G 5708	NG2	1668	1986	1845	1833	64	66	78	69	44	31	45	40
G 6873	NG2	1321	1733	1317	1457	66	67	77	70	35	32	36	34
G 7895	NG2	492	1269	2054	1271	75	68	76	73	36	30	44	37
G 9603	NG2	1178	1286	1709	1391	71	67	79	72	43	36	39	40
G 11512	NG2	1042	1812	1688	1514	62	64	75	67	33	37	37	36
G 11585	NG2	841	1899	1896	1545	73	68	82	74	37	32	45	38
G 11727	NG2	545	1681	2230	1485	82	80	81	81	33	29	46	36
G 11759A	NG2	728	1710	2198	1545	83	82	81	82	32	31	44	35
G 11787	NG2	48	0	840	296	88		94	91	25		27	26
G 14253	NG2	1706	1803	1831	1780	64	70	75	69	37	35	40	37
G 16104E	NG2	1016	1546	1349	1304	63	65	75	68	31	30	31	31
G 18264	NG2	1596	2008	1482	1695	66	66	75	69	44	41	47	44
G 19841	NG2	0	0	458	153			94	94			23	23
G 23829	NG2	809	1061	1844	1238	77	74	78	76	21	18	22	20
LRK 31	NG2	2018	1868	1800	1895	68	68	75	70	49	40	55	48
PVA 1111	NG2	1459	1500	1847	1602	67	67	79	71	38	30	48	39
NG2 Mean		**1069**	**1490**	**1624**	**1394**	**70**	**69**	**79**	**73**	**37**	**34**	**42**	**38**
DRK 47	P	1221	1799	1469	1496	73	64	81	73	60	54	67	60
G 2567	P	1412	1066	1416	1298	71	72	81	75	39	32	47	39
G 2686	P	608	1617	1544	1257	68	69	79	72	35	32	40	36
G 4721	P	928	1232	1973	1378	79	90	85	84	44	39	53	45
G 8209	P	337	643	1364	781	85	90	84	86	46	34	46	42
G 11521	P	197	1391	1348	979	70	68	78	72	60	53	55	56
G 19876	P	113	201	1650	655	90	90	90	90	30	30	50	37
G 22147	P	1286	2174	1577	1679	66	67	80	71	59	53	62	58
G 23604	P	178	372	1297	616	79	75	81	78	25	20	25	23
PVA 773	P	1916	1727	1430	1691	71	70	77	72	41	41	52	45

Races: NG1: Nueva Granada 1, NG2: Nueva Granada 2, P: Peru.
A: Irrigation, IF: Drought intermittent ST: Early Drought, MA: Media arithmetic.
* Comparison of the average per genotype in each environment. ** Comparison average temperature.
Empty cells are not generated information.

		Yield (kg ha^{-1})				Dam				P100 (g)			
Genotypes	Races	Mean				Mean				Mean			
		R	SI	ST	MA	R	SI	ST	MA	R	SI	ST	MA
P Mean		**943**	**1237**	**1481**	**1220**	**73**	**72**	**81**	**75**	**40**	**36**	**45**	**40**
AFR 298	Control	1442	2209	1232	1628	72	68	80	73	51	46	57	52
AFR 619	Control	2531	1492	1954	1992	77	70	79	75	65	36	45	48
CAL 143	Control	996	1509	1765	1423	74	69	82	75	42	32	48	41
CAL 143	Control	1568	1586	1969	1708	70	68	80	73	44	32	50	42
CAL 96	Control	997	2290	1653	1647	70	67	81	73	59	53	65	59
KAT B1	Control	1170	2285	1703	1720	63	60	81	68	39	38	35	37
KAT B9	Control	1919	1900	1525	1781	62	58	75	65	43	39	48	43
SAB 258	Control	1451	1459	1365	1425	60	60	73	64	34	33	39	36
SAB 645	Control	463	2596	1779	1613	60	62	79	67	45	34	57	45
SELIAN 97	Control	2540	1689	2445	2225	67	70	74	70	28	22	28	26
SEQ 1003	Control	2110	2566	1486	2054	69	67	82	73	45	40	48	44
SEQ 1027	Control	2031	2236	1584	1950	74	69	78	73	57	39	48	48
SEQ 1027	Control	1960	1927	1777	1888	73	69	82	75	44	36	55	45
URUGEZI	Control	1396	1962	1500	1619	68	70	79	72	32	46	44	41
SEQ 11	Control	2331	2669	2059	2353	67	68	78	71	33	36	42	37
Control mean		**1538**	**1889**	**1662**	**1696**	**69**	**67**	**79**	**72**	**43**	**38**	**47**	**43**
General mean		**1212**	**1641**	**1623**	**1492**	**70**	**69**	**79**	**72**	**41**	**36**	**46**	**41**
DMS (0.05)*		**826.0**	**602.3**	**656.9**		**5.0**	**5.0**	**4.5**		**10.7**	**8.5**	**12.8**	
DMS (0.05)**		**A**	**A**	**B**	**86.5**	**B**	**C**	**A**	**0.7**	**B**	**C**	**A**	**1.3**

Races: NG1: Nueva Granada 1, NG2: Nueva Granada 2, P: Peru.
A: Irrigation, IF: Drought intermittent ST: Early Drought, MA: Media arithmetic.
* Comparison of the average per genotype in each environment. ** Comparison average temperature.
Empty cells are not generated information.

In Palmira, under the conditions of SI was the performance range of 0 - 2669 kg ha^{-1} with an overall average of 1,644 kg ha^{-1}. For R the range was from 0 - 2,540 kg ha^{-1} with an overall average of 1,213 kg ha^{-1}, negatively affected by the fungus *Sclerotium rolfsii* Sacc., which can cause considerable losses to crops in dry seasons, hot and heavy soils (Abawi, 1994). Meanwhile in ST, the performance range was 458 to 2,444 kg ha^{-1} with an overall average of 1,614 kg ha^{-1}.

The controls showed the highest values for the mean arithmetic (MA) of performance defined as the average among the three environments genotype evaluation, followed by genotypes of the sub-race-group NG1. The high performance of NG1 may have been for the best adaptation of these genotypes to tropical and subtropical environments of high temperatures, while P genotypes of race had the lowest MA, possibly because of their limited adaptation to different environments where normally takes place in high altitude cold areas (Singh *et al.* 1991).

By yield, the 64 genotypes could be classified into four groups. The first group corresponds to the genotypes that had high performance in the three environments, such as controls SEQ11, SEQ1027, together with the genotypes G18255, G16115, G21210, G22247, G17070, G5625, G6639 and G4001 (in the sub-race NG1) LRK31, G5708, G14252 and G 18 264 (sub-race of the NG2) and DRK47 and G22147 (breed P) (Tab. 3). The good fit of the controls may have been caused by being improved genotypes to withstand drought conditions while the accessions may be due to race are mainly from New Granada which is adapted to dry conditions and higher temperatures (Singh *et al.*, 1991).

In the second group are low-yielding genotypes in three environments: G11787, G19841 (sub-race of the NG2), G23604 and G8209 (breed P) (Tab. 3), *ie* the lowest degree of adaptation to the environments tested. In the third group are the genotypes that responded to the drought conditions but had low performance in R as the control and accessions SAB645 G11585, G5625, G11512, and G11759A (sub-race of the NG2) (Tab. 3), favoring dry conditions return. In the latter group, the genotypes are presented in irrigation performance, but with below average performance in drought, such as G7945, G1688 (the sub-race NG1), G14253, G5034, G18264 (sub-race of the NG2) and G2567 (breed P), which had little or no adaptation to drought, that is they are susceptible genotypes. Muñoz-Perea *et al.* (2006), performed a similar grouping according to the degree of adaptation of common bean to drought conditions. Only considered genotypes adapted to this condition and the division between these genotypes was based on the yield in non-stress conditions, whereas in our study were considered the multiple responses of genotypes to the environments evaluated for grouping.

The performance is the best selection criteria used to determine the drought resistance of a genotype (Terán and Singh, 2002). White and Singh (1991) and Abebe *et al.* (1997), report the use of MA as a criterion to identify genotypes with high yield under drought conditions. Based on the foregoing, the genotypes that are mentioned in the first group would be selected for the possible onset of breeding programs, but according to Beebe *et al.* (2008), now other attributes are also considered varietal selection of sources of resistance to drought and ability to mobilize photosynthates. Unfortunately the irrigation, could not be used as a control environment, for which he was regarded as an evaluation environment. The high temperatures that occurred in Palmira during the growing season caused a heat stress. Root growth, reduces the size of the seed and the abortion of flowers and pods were affected for stress (Shonnard and Gepts, 1994; Rao, 2001). Besides this, the fungus *Sclerotium rolfssi* Sacc, affected the performance in this environment; the attack of this fungus was favored by the environmental conditions of R, since temperature and high relative humidity, followed by dry periods favor the establishment and disease development (Abawi, 1994; Blum-B. *et al*., 2003).

Number of days to physiological maturity

The mean square of the number of days to maturity (Dam) were highly significant between environments, genotypes and genotype by environment interaction (Tab. 2) and comparing the averages using the DMS environments, each environment formed a distinct group (Tab. 3), indicating that this variable was affected by the concentration of water in the soil. The coefficient of variation was low with a value of 3.4%.

In R, Dam was the range of 60 to 90 d, with an average of 70 d. Whereas in SI, the range was from 58 to 90 d, with an average of 69 d and finally in ST the range was from 73 to 94 days with an average of 79 d. There was a reduction in the average of 1 d (1.5%) compared IS and R. Also there was a reduction in the average of 10 d (13%) in SI compared with ST in contrast there was an increase in the average of 10 d (11%) in Dam when comparing ST with R being in different locations. Terán and Singh (2002), in Mesoamerican heritage accessions and breeding lines, found a 3% decrease in the number of days to maturity between irrigation environments and drought in Palmira attributed to high temperatures that occurred on the site of study. Singh (1995), says that drought accelerates the maturity as a mechanism of resistance to drought escape, especially when stress increases after flowering. Singh (2007) reported a reduction of up to 4 d, in three accessions and 17 cultivars of race Durango. Contrary to the above, Muñoz-Perea *et al.* (2006) reported an increase in the number of days maturity intermittent drought conditions Creole cultivars and genotypes Kimberly Mesoamerican heritage, USA, supported in that this type of stress, plants exhibit a disruption of metabolic processes before recovering step of modifying the reproductive vegetative state. The Dam increased from ST and R, is given by the environmental conditions at Darien, as a lower temperature reduces the metabolic activity of the plant, resulting in a longer duration of phenological stages (Lambers *et al*., 2000).

In general, the genotypes of the sub-race reached physiological maturity NG1 fastest followed by the controls (Tab. 3), explained why the race Nueva Granada as reported by Singh *et al.* (1991), is the race earlier in the Andean stock, while the genotypes of P is the race that the longer it takes to mature.

Genotypes had lower number of days to maturity and performance in the three environments were: G18255, G17070, G16115, G1688, G5625 and G6639 (in the sub-race NG1) LRK31, G11512, G14253 and G18264 (from the sub NG2-race), G22147 (breed P) and controls KATB9, KATB1, SAB645, and SEQ11 SEQ1003. Meanwhile, G19876, G23604, G8209 (breed P), G7677 (the sub-race NG1), G19841 and G11787 (sub-race of the NG2) showed the highest Dam accompanied by low yields in some cases without forming pods, showing its poor adaptation to the environment assessment. Muñoz-Perea *et al.* (2006), claim that precocious cultivars have a lower net water requirement throughout the entire life cycle, compared with those who mature later, this means a reduction in the effect of drought on the crop. Studies White and Singh (1991) and Beebe *et al.* (2008) reported that late maturing lines, suffer a greater decrease in performance under drought stress. According to Acosta-Diaz *et al.* (2004), lower high-performance Dam in drought conditions is associated with a high capacity to mobilize photosynthates to pods.

Weight of 100 seeds

The mean square of the 100-seeds weight (P100) was highly significant between environments, genotypes, and significant genotype by environment interaction (Tab. 2). Comparing the averages for the environment and DMS, found that each environment P100 formed in a different group (Tab. 3), indicating a direct effect of moisture content

TABLE 4. Simple correlation coefficients (r) between yield and other attributes of 64 genotypes of common bean reference CIAT collection evaluated under irrigated conditions and intermittent drought in Palmira, and early drought in Darien (Colombia) from July to October 2008.

	Irrigation yield (R)	Drought yield	
Attribute		Intermittent (SI)	Early (ST)
Yield intermittent drought	0.60***	-	0.34***
Yield early drought	0.32***	-	-
Number of days to maturity	– 0.39***	–0.52***	–0.23*
100-seed weight (g)	0.22*	0.61***	0.08*

* Significance P <0.05, ** Significance P <0.01, *** Significance P <0.001.

on this variable. The coefficient of variation was 13.2%; usually, this is less than the coefficients of variation of other components of performance due to its higher heritability.

In R the range of P100 was 21 to 65 g, with an average of 41 g, whereas in SI the range was from 18 to 54 g, with an average of 36 g and, finally ST range was from 22 to 67 g, with an average of 46 g (Tab. 3). There was a reduction in the average weight of 100 seeds of 5 g (11%) in SI compared with R and 10 g (22%) in SI compared with ST. Singh (2007), reported a reduction in 14% P100 genotypes of the Mesoamerican heritage, under conditions of moderate type drought. Muñoz-Perea *et al*. (2006) found a 22% reduction in the P100 in 13 cultivars and three accessions of Mesoamerican heritage under intermittent drought conditions and terminal. The reduction in P10 is caused by a decrease in photoassimilate and water that goes to the seed filling period, the effect of drought (Muñoz-Perea *et al*., 2006). The controls had higher P100 in MA with 43 g, followed by NG1 with 42g, while P showed P100 race with 38 g lower in MA (Tab. 3).

This feature made a big difference between the sites of study, so their results are presented separately. Genotypes showed the highest P100 high performance under SI and R in Palmira, were: G21210, G18255, G17070, G4001, G7945, G16115, G22247, G5625, G6639 (the sub-race NG1) LRK31, G5708, G4644, G14253 and G18264 (sub-race of the NG2), and G22147 DRK47 (breed P) and controls AFR619, SEQ1003, SEQ1027, AFR298 and KATB9. SEQ11 SELIAN97 and controls showed low levels of P100 but had higher yields in R and SI respectively. In ST (Darien) most P100 genotypes and high performance were: G21210, G18255, G5625, G6639, G1842 (the sub-race NG1), AND1005, G11727, G14254 (sub-race of the NG2), G4721 of (Race P) and controls SAB645, and SEQ1003 CAL143. According to Gebeyehu (2006), the resistant genotypes have a strong relationship and good translocation landfill source of carbohydrates that allows them to maintain high values of P100 regardless of moisture conditions.

Correlations between performance and phenotypic variables

Was presented positive correlations and highly significant between yields in the three environments (Tab. 4). This result indicates that genotypes with high performance in SI, probably had a high-performance R and ST. This result accords with what was suggested by Schneider *et al*. (1997), where the selection of genotypes with resistance to drought, is equally effective under different stress levels. In the study, the highest correlation was obtained between the environments of Palmira, as would be expected to be made in the same locality.

There was a negative correlation between yield and highly significant Dam IS and R, and significant ST (Tab. 4). This result agrees with that presented by Abebe *et al*. (1998) and Singh (1995), where the genotypes had lower Dam under drought, reached the highest yields. Muñoz-Perea *et al*. (2006), say a quick physiological maturity intermittent drought is associated with the escape mechanism.

The correlation between performance and P100 was positive, being highly significant in itself, significant R and without significance in ST. This compares with Muñoz-Perea *et al*. (2006), who report a significant positive correlation but intermittent drought conditions. Terán and Singh (2002) found a negative correlation under drought and irrigated in Mesoamerican heritage accessions and breeding lines from crosses race, this supported where performance is a function of the number of seed and plant to increase its number compensation ago, reducing the size of the seed. By contrast, in this study the genotypes had a larger P100 of seed were generally indicating high performance in the Andean heritage works a different mechanism for obtaining high performance.

Conclusions

The field evaluation of the 63 genotypes of the reference collection at CIAT, identified 14 genotypes that showed a superior adaptation to stress conditions caused by drought.

The materials G18255, G17070, G16115, G21210, G4001, G5625, G6639 and G22247 sub-race of the New Granada 1, LRK31, G14253, G18264 and G5708 of the sub-race Nueva Granada genotypes 2 and G22147 DRK47 of race and Peru, were the most prominent. This result suggests that resistance to drought conditions is not limited to one race or group, which should further investigate the different inputs germplasm Andes.

The adaptation of these genotypes to stress conditions and good response in irrigated conditions were associated with fewer days physiological maturity, high yield and weight of 100 seeds.

By the other hand, the results for the weight of 100 seeds, suggest that the body of an Andean drought tolerance mechanism could be the good grain filling.

In some genotypes, the phenotypic plasticity allowed a better adaptation to environmental conditions by reducing the effects of drought on bean plants.

As presented in the study, it is important to use different environments for evaluation and determination of the different phenotypic attributes for the selection of genotypes resistant to drought conditions, optimizing the selection process.

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