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EVALUATION OF AGRO-MORPHOLOGICAL BEHAVIOR BASED ON THE VARIABILITY CHARACTERIZATION OF COMMON BEAN (*Phaseolus vulgaris* L.) LINES FOR LATE SOWINGS

Evaluación del comportamiento agro-morfológico a partir de la caracterización de la variabilidad en líneas de frijol común (*Phaseolus vulgaris* L.) sembradas en época tardía

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ABSTRACT. Among the main factors affecting bean production is the wrong varietal distribution over diverse environmental conditions under which it is grown. The research work was aimed at evaluating the agro-morphological behavior based on the variability characterization of promising common bean lines for late sowings. Thus, seeding was performed on January 20, 2014, using a randomized block design and four repetitions in "El Mulato" farm, belonging to "Orlando Cuellar" Strengthened Credit and Service Cooperative (SCSC), San José de las Lajas municipality, Mayabeque province. The evaluation was carried out on 14 agro-morphological variables that included phenological and morphological parameters, yield and its components, as well as rust (*Uromyces appendiculatus*) resistance. Results from analyzing statistical parameters and main components allowed detecting genetic variability among the evaluated lines. It was also detected that pod number per plant and 100-grain weight were the highest correlated variables with yield. In general, six out of the evaluated lines combined a high-yielding potential and from mid to high rust resistant reaction, standing out SCR 15 line, with a greater yield potential than those so far reported in Cuba. This suggests assessing these lines in regional trials for a further generalization-extension of the possible cultivars that contribute to focus an appropriate management of these genotypes and their use as rust resistant sources in bean breeding programs.

Key words: cultivar, genotypes, yield, rust, varieties

RESUMEN. Entre los principales factores que afectan la producción de frijol se encuentra la mala distribución de variedades para las diversas condiciones ambientales en que se cultiva. El objetivo de este trabajo fue evaluar el comportamiento agro-morfológico, considerando la caracterización de la variabilidad de líneas de frijol común promisorias para siembras tardías. La siembra se realizó el 20 de enero de 2014 con un diseño de bloques al azar y cuatro repeticiones en la finca "El Mulato", perteneciente a la Cooperativa de Créditos y Servicios Fortalecida (CCSF) "Orlando Cuellar", en el municipio San José de las Lajas, Mayabeque. La evaluación se realizó usando 14 variables agro-morfológicos que incluyeron parámetros fenológicos, morfológicos, rendimiento y sus componentes, y resistencia a la roya (*Uromyces appendiculatus*). Los resultados del análisis de parámetros estadísticos y componentes principales, permitió detectar la variabilidad genética entre las líneas evaluadas. Además, se detectó que las variables de mayor correlación con el rendimiento fueron el número de vainas por plantas y la masa de 100 granos. De forma general, seis de las líneas evaluadas combinan alto potencial de rendimiento y reacción entre intermedia y altamente resistente ante la roya, destacándose la línea SCR 15, con rendimiento potencial muy superior a los reportados en Cuba hasta la fecha. Esto sugiere evaluar estas líneas en ensayos regionales para una posterior generalización-extensión de los posibles cultivares que contribuyan a enfocar un manejo adecuado de estos genotipos y su empleo como fuentes de resistencia a la roya en los programas de mejoramiento genético del frijol.

Palabras clave: cultivares, genotipos, rendimiento, roya, variedades

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INTRODUCTION

Common bean (*Phaseolus vulgaris* L.) is a native crop of America, which is intensely grown throughout the whole tropical area and some temperate regions of the planet. At present, its production has reached a universal character, constituting a valuable human diet component, since it is an important source of proteins, vitamins and minerals, with special relevance in American peoples' diet from developing countries (1). Considering that common bean is a very important crop for Cuba (2), it is necessary to implement some strategies to increase its average annual yields that are below the national demand with a production of 68,1 thousand tons[A], so the country has to spend a large amount of currency to import this grain[B].

Among the main factors affecting bean production is the wrong varietal distribution over diverse environmental conditions, either climatic or technological ones (3), under which it is grown, that enhances pest development and may restrict crop yields (4).

In Cuba, three seasons are considered for growing beans: September-October as the early season, when bacterial and fungal pests usually occur, due to high humidity and temperatures; October-November as the optimal season, when its best yields are usually recorded, and December-January as the late season, when wet periods are at least of 10 consecutive hours due to cold fronts (5), which combined with moderate to fresh temperatures (17-27 °C) causes rust appearance by *Uromyces appendiculatus* fungus in pre-flowering (R5) and flowering (R6) stages (6), so that it has a negative influence on yield, decreasing from 8 to 54 %, depending on the tolerance degree of different varieties, since this pathogen is considered the main cause of crop losses in late sowing (7).

Varietal management is a viable choice to agro-ecological pest control if taking into account the varietal resistance to a particular pathogen; besides, production costs are reduced by the non-use of pesticides to phytosanitary control (8). In search of new cultivars, the first step is to know and properly exploit the preserved genetic heritage (9). Based on it, this research study was aimed at evaluating the agro-morphological behavior, considering the variability characterization of promising common bean lines for late sowings.

MATERIALS AND METHODS

This research work was conducted in "El Mulato" production area, belonging to "Orlando Cuellar" Strengthened Credit and Service Cooperative (SCSC), since this farm is considered a target environment for the new genotypes selected.

Nine advanced lines were evaluated in the study, which were introduced to the Local Agricultural Innovation Program (LAIP) headed by the National Institute of Agricultural Sciences (INCA). Besides, the commercial cultivars BAT 93 (Deceiver) as a control with good agronomic performance in late sowings, Ica Pijao as a susceptible control to rust attack (10) and Cuba Cueto 25-9N were evaluated, the latter being the genotype grown by farm producer (Table I).

Soil preparation and cultural practices followed the technical guide for common bean cultivation (2), except for phytopathological control, which was not performed to predict its influence on the natural pest occurrence.

For genotype evaluation, 14 morphoagronomic variables were regarded, according to some descriptors recommended to characterize bean genotypes (11), as well as the natural rust occurrence caused by *Uromyces appendiculatus* fungus (Table II), due to its varietal importance for late sowings.

Table I. Genetic material evaluated

No	Genotype	SC	Origin
1	SEN 81	black	CIAT
2	SURU	white	PIF
3	SEN 74	black	CIAT
4	RBF 15-70	black	PIF
5	SCR 5	red	CIAT
6	SEN 95	black	CIAT
7	XRAV 40-4	black	PIF
8	MHN 322-49	black	PIF
9	SCR 15	red	CIAT
10	CC 25-9N	black	INIFAT
11	Ica Pijao	black	IIGranos
12	BAT 93 (Engañador)	beige	IIGranos

SC (seed color); CIAT (International Center for Tropical Agriculture); PIF (Bean Research Program in Honduras), INIFAT ("Alejandro de Humboldt" Institute of Fundamental Researches in Tropical Agriculture) IIG (Grain Research Institute)

[A] Oficina Nacional de Estadísticas. *Sector Agropecuario. Indicadores Seleccionados* [en línea]. cod. Anuario Estadístico de Cuba, 2015, [Consultado: 19 de febrero de 2016], Disponible en: <http://www.one.cu/mensualprincipalesindicadoresagropecuario.htm>.

[B] Banco Central de Cuba. *Información Económica*, vol. 9, no. 34, 1 de agosto de 2014, RNPS 2330, [Consultado: 19 de febrero de 2016], Disponible en: <http://www.bc.gob.cu/Anteriores/InfoBCC/2014/Informacion%20Economica%20No.%2034%20del%20010814.doc>.

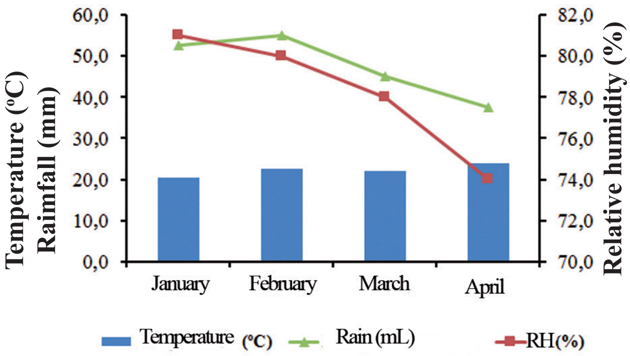
Table II. Variables for evaluating agro-morphological performance of common bean lines

No	Code	Variables	No	Code	Variables
1	PH	Plant height (cm)	8	NGV	Number of grains per pod
2	VB	Number of brach	9	MG	Mass of 100 grains
3	LP	Lenght pod (cm)	10	Rend.	Yield (t ha^{-1})
4	IF	Flowering beginning days	11	LG	Grain length
5	DF	Flowering days	12	AG	Width of grain
6	DMC	Days of crop maturity	13	Al.G	Height of grain
7	NVP	Number of pods per plant	14	R	Rust incidence (*Uromyces apendiculatus*)*

* *Scale classifying germplasm reaction to rust pathogen into three discrete categories: resistant, intermediate or susceptible, according to Van Schoonhoven and Pastor-Corrales, 1991

Sowing took place on January 20, 2014, in a lixic ferralic Nitisol (rhodic, clayey, eutric) (12). Experimental plots had five 5-m-long rows at a spacing of 0,60 m between them and 0,10 m between plants. They were distributed in a randomized block design with four replications.

The average values of relative humidity, temperature and rainfall were recorded at the meteorological station of Tapaste, 500 m far from the experimental area, during the experimental period (Figure).



Behavior of climatic variables (temperature, relative humidity and rainfall) during the experimental period

For the morphoagronomic variables of each genotype, 10 plants were randomly selected from the central rows of each plot and to evaluate rust occurrence, the values of disease levels were taken at the R8 stage (pod filling), when the greatest severity was observed, also using the scale that classifies germplasm reaction to rust pathogen into three discrete categories: resistant, intermediate or susceptible (11). The scale was as follows:

Degrees	Description
1	Highly resistant: Absence of pustules at first glance (immune)
3	Resistant: Presence, in most plants, of only a few pustules, usually small, covering about 2 % of the leaf area
5	Intermediate: Presence, in all plants, of pustules, usually small or intermediate, covering about 5 % of the leaf area
7	Susceptible: Presence of pustules, usually large and often surrounded by chlorotic halos, covering about 10 % of the leaf area
9	Highly susceptible: Presence of large and very large pustules with chlorotic halos, covering more than 25 % of the leaf area and causing premature defoliation

For determining grain yield, one linear meter was taken from both central rows in four plots of each genotype and was converted into kg ha^{-1}.

Statistical analysis

Basic statistics (mean, standard deviation and variation coefficient) were obtained for each variable evaluated. To determine the most contributing variables to total variability in the collection, a main component analysis (MCA) was performed. Pearson's single correlation coefficient was calculated to measure the degree of association between pairs of traits. A two-way classification variance analysis was applied to those variables related to yield and to that of rust occurrence, after proving the theoretical assumptions of normality and variance homogeneity, besides verifying significant differences between treatments by Tukey's multiple range test 0.05. Statistical analysis was performed through SPSS version 15.0.1 (13).

RESULTS AND DISCUSSION

Out of the 14 variables evaluated, just yield and rust reaction showed VC>50 % whereas the remaining 12 presented VC≤50 % (Table III). It was notable that phenological variables (FI, mean= 35,12, DF, mean= 40,31, DHM, mean= 82,98) were among the lowest VC. The average values of these parameters are among producers' preferences in Cuba, since genotypes that complete their life cycle prior to 100 days of sowing are generally chosen. In addition, a relatively short life cycle will be very important in those genotypes proposed for late sowings, as they finish their cycle when agroclimatic conditions are still favorable for the crop.

Table III. Statistical parameters of quantitative characteristics evaluated in 12 common bean genotypes for late sowings

Variable	Mean	SD	VC
PH (cm)	55,52	18,37	33,09
BN	2,72	1,08	39,69
FI	35,12	4,09	11,66
DF	40,31	3,31	8,2
DHM	82,98	5,97	7,19
PNP	16,46	7,4	44,95
GNP	5,65	0,89	15,84
PL (cm)	9,77	1,62	16,57
GW (g)	24,38	6,21	25,46
Y (kg)	2422,38	1312,68	54,19
GL (mm)	10,43	1,29	12,37
GW (mm)	6,31	0,52	8,18
GH (mm)	4,64	0,67	14,5
Rust	3,3	2,4	72,71

Plant height in cm (PH), branch number (BN), flowering initiation (FI), days to flowering (DF), days to harvest maturity (DHM), pod number per plant (PNP), grain number per pod (GNP), pod length in cm (PL), 100-seed weight in g (SW), yield kg ha^{-1} (Y), grain length (GL), grain width (GW) and grain height (GH), standard deviation (SD) and variation coefficient (VC).

By means of the main component analysis with 14 variables, it was possible to explain 93.33 % of total variability with the first two components. The most contributing characters in the first two components proved to be pod length (PL), 100-grain weight (GW), grain length (GL) and grain width (GW) in the first component, whereas days to harvest maturity (DHM), pod number per plant (PNP) and yield (Y) in the second component, showing the highest absolute values (Table IV).

These variables are widely used to characterize bean genotypes[C], besides that they are very important for being related to yield (PNP, GNP, Y, GL and GW), cooking tastes (GL and GW) and crop phenology (FI), which are among producers' criteria for selecting the variety to be cultivated.

[C] Gill, L. H. R. *Diversidad genética del frijol común y su implicación en el mejoramiento genético asistido en México*. Tesis de Doctorado, Altamira, Tamaulipas, 2009, 112 p.

Table IV. Main component matrix

Variable	Component	
	1	2
PH	0,57	-0,30
BN	-0,11	0,32
FI	-0,69	0,36
DF	-0,56	0,68
DHM	-0,23	0,77
PNP	0,10	0,83
GNP	-0,54	0,00
PL	0,71	-0,10
GW	0,75	0,56
Y	0,44	0,81
GL	0,87	-0,11
GW	0,81	-0,02
GH	0,66	0,42
Rust	-0,58	-0,10
Percent of contribution	35,15	58,18
Total contribution		93,33

Another important aspect of the most contributing variables to variability among the lines evaluated is that they are easily determined, so that it would save time and make the characterization of different materials more humane. All these features correlated positively, except for FI that correlated negatively with the first component.

Agronomical characteristics play an important role in the variance analysis between cultivated species and creole or wild parents[A]. On the other hand, bean grain characters have been studied in many researches (14) that have allowed finding biological variation of physical characteristics related to grain size and weight.

Some investigations have confirmed the variability between intra and inter bean landrace species related to seed and plant physical characteristics that generally correspond to extensive geographic areas (14), which highlights the importance of these grain characters, since they contribute to characterize the existing diversity in a bean collection and such classic methods enable to estimate genetic diversity between and within groups of varieties cultivated. Few studies on variability in *Phaseolus* species employ bean characters as variables for its description. However, the study of these characters has proved to be useful in detecting variability between bean entries, particularly with grain shape, size and color (15).

Correlation analysis allowed detecting that yield showed a significant and positive correlation with pod number per plant (0,83) and 100-grain weight (0,76) (Table V). It is evident to find positive relationships between PNP and yield, since its contribution to final grain yield in bean cultivars have been previously reported (16). In this regard, some authors have pointed out that pod number per plant is the main component of final dry grain yield of common bean, indicating its direct participation in the final crop yield (17).

Furthermore, 100-grain weight has also been reported with highly significant and positive correlation with yield (17), although smaller (r= 0,5027); however, this variable has not always shown a positive correlation with this leguminous productivity, but it has reported a significant and negative correlation in cowpea lines (*Vigna unguiculata* L.) grown under rainfed and irrigation conditions (18).

It was notable that rust occurrence was not correlated with yield (-0,34), which could be due to its indirect influence through other yield components, such as 100-grain weight that showed a significant and negative correlation with this variable (-0,60*), indicating a GW reduction with an increased rust susceptibility and its subsequent effect on the final grain yield (Table V).

Table VI presents the variance analysis of PNP and GW variables, which showed the highest correlation with yield and rust response, because this character is very important to the proposed bean genotypes for late sowings.

In general, good yields were obtained considering that the overall average was higher than 2400 kg ha^{-1} (Table VI).

SCR 15 line showed the best results with PNP of 27,8, the highest GW of 33 g, a highly resistant behavior to the natural rust occurrence and yields exceeding the control (BAT-93), which is recommended for late sowings (10). This genotype yield is also considered the first yield report surpassing 3,300 kg ha^{-1} under the agro-climatic conditions of the crop.

Table V. Correlation matrix

	PH	BN	FI	DF	DHM	PNP	GNP	PL	GW	Y	GL	GW	GH	Rust
PH	1													
BN	0,27	1												
FI	-0,54	0,19	1											
DF	-0,53	0,12	0,87**	1										
DHM	-0,12	0,25	0,27	0,65*	1									
PNP	-0,15	0,33	0,05	0,34	0,58*	1								
GNP	-0,08	0,17	0,07	0,16	0,18	0,04	1							
PL	0,85**	0,29	-0,57	-0,51	-0,22	0,13	-0,05	1						
GW	0,09	0,05	-0,24	-0,02	0,11	0,46	-0,45	0,42	1					
Y	0,02	0,28	-0,18	0,16	0,49	0,83**	-0,08	0,31	0,76**	1				
GL	0,44	-0,15	-0,45	-0,45	-0,35	-0,06	-0,70*	0,57	0,63**	0,21	1			
GW	0,39	-0,41	-0,57	-0,34	-0,06	-0,02	-0,44	0,40	0,52**	0,25	0,76**	1		
GH	0,17	-0,13	-0,19	0,08	0,17	0,18	-0,24	0,31	0,78**	0,49	0,54	0,71**	1	
Rust	-0,06	0,15	0,27	0,26	0,24	-0,07	0,59*	-0,15	-0,60*	-0,34	-0,34	-0,32	-0,35	1

* Significant correlation at 0,05 level (bilateral) ** Significant correlation at 0,01 level (bilateral)

Table VI. Result of variance analysis for the variables related to yield and rust reaction in 12 bean genotypes

Line or variety	Variables				
	PNP	GW (g)	Rust SV	Rust C	Y (kg ha^{-1})
SEN 81	10,2 d	23 e	1	AR	1424,68 de
SURU	16,9 bcd	26,05 d	5	I	3030,95 bc
SEN 74	19,7 bc	29 c	2,2	R	2381,71 cd
RBF 15-70	10,9 d	14,93 g	7,2	S	1017,23 e
SCR 5	15,2 bcd	29 c	2,6	R	2812,34 bc
SEN 95	13,1 cd	31 b	2	R	2472,45 cd
XRAV 40-4	9,4 d	13,60 g	3	R	888,57 e
MHN 322-49	13,1 cd	29 c	2,2	R	2387,88 cd
SCR 15	27,8 a	33 a	1	AR	4772,57 a
CC 25-9N	22,4 ab	24,02 e	5,2	I	3671,00 ab
Ica Pijao	19,4 bc	17 f	7.2	S	1450,51 de
BAT 93 (Deceiver)	19,4 bc	23 e	1	AR	2758,62 bc
Mean	16,45	24,38	3,3		2422,38
SD	7,39	6,20	2,39		1312,68

Values with the same letter indicate similar statistical response with Tukey's test α= 0,05

PNP (pod number per plant), GW (100-grain weight), Y (yield, SV (scale value), C (category) and SD (standard deviation of the mean)

It is important to emphasize that Cuba Cueto 25-9N cultivar, despite showing an intermediate reaction to the natural rust occurrence, which is inconsistent with earlier authors (10) who classified it as susceptible, showed high yield, also exceeding the control BAT-93 for these late sowings. This response can be due to the pathogenesis and diversity of fungal pathotypes present in the studied area.

The response of different genetic materials may vary. In this regard, it has been suggested that *U. appendiculatus* is a genetically variable fungus with numerous physiological races; that is the reason why the bean has been adapted by using about 11 resistance genes generically known as Ur (5). In addition, resistance genes have proved to form groups conferring specific-race resistance; therefore, various gene combinations may confer resistance to different races (19).

On the other hand, RBF15-70 genotype showed susceptible reaction to rust occurrence with a similar behavior for this character to the susceptible control Ica Pijao.

The remaining genotypes showed higher yields than 1 000 kg ha^{-1}, with resistant to intermediate rust reaction, suggesting the use of the materials studied as sources of resistance to this important pest in bean breeding programs in Cuba or as potential cultivars, as well as to evaluate them in regional trials for a further generalization and extension of results.

CONCLUSIONS

- ♦ Variability was detected among the lines evaluated. The most contributing variables to genotype variability were pod length, grain weight, grain length, grain width, days to harvest maturity, pod number per plant and yield.
- ♦ The variables of pod number per plant and 100-grain weight are indicators that allow selecting bean genotypes with better agronomic response under late season conditions.
- ♦ Except RBF15-70 line, all evaluated genotypes showed highly resistant to intermediate reaction to the natural rust occurrence. The average yield of all genotypes exceeded 2000 kg ha^{-1} whereas SCR 15 line presented higher yields than 4500 kg ha^{-1} and immune response to the natural rust occurrence.

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