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AGRONOMIC RESPONSE OF NEWLY-INTRODUCED COMMON BEAN (*Phaseolus vulgaris* L.) CULTIVARS IN CUBA

Respuesta agronómica de cultivares de frijol común (*Phaseolus vulgaris* L.) de reciente introducción en Cuba

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ABSTRACT. This study was carried out within the areas from "José Castellanos" Strengthened Credit and Service Cooperative (SCSC), located in Santa Cruz del Norte municipality, with the aim of evaluating the agronomic response of 12 common bean cultivars, introduced into the collection of Local Agricultural Innovation Program (LAIP), which is developed at the National Institute of Agricultural Sciences (INCA), in order to diversify the present germplasm. The study arose from the need of having better crop cultivars to replace the existing ones, regarding their response to the specific conditions of each country area. Sowing was performed in the second half of January 2009, including the pre-commercial cultivars Santiago-3 (S-3) and Hg-8 (Holguín-8), preserved at LAIP work collection. Both sowing and cultural practices followed the guidelines established by technical instructions. Among other results, it was generally observed that the cultivars under study showed significant differences ($p \leq 0.05$) in pod number per plant (PNP), grain number per pod (GNP), 100-grain weight (100GW) and yields in kg ha^{-1}. Grain length and width had distinct responses between cultivars; therefore, these traits can be used to characterize bean germplasm. After a complete analysis of results, Hg-8, R-5, R-11, R-6 and R-4 cultivars were highlighted for their best agronomic response in the evaluated group.

Key words: crops, germoplasm, legumes, yield, sowing

RESUMEN. El presente estudio se realizó en áreas de la Cooperativa de Créditos y Servicios Fortalecida (CCSF) "José Castellanos", del municipio Santa Cruz del Norte, con el propósito de evaluar la respuesta agronómica de 12 cultivares de frijol común, introducidos en la colección del Programa de la Innovación Agropecuaria Local (PIAL) que se desarrolla en el Instituto Nacional de Ciencias Agrícolas (INCA), para la diversificación del germoplasma existente. El estudio realizado obedeció a la necesidad de contar con mejores cultivares de los diferentes cultivos, capaces de sustituir a los ya existentes, por su respuesta a las condiciones específicas de cada zona del país. La siembra se realizó en la segunda quincena de enero de 2009, incluyendo los cultivares precomerciales Santigo-3 (S-3) y Hg-8 (Holguín-8), conservados en la colección de trabajo del PIAL. La siembra y las atenciones al cultivo se realizaron en correspondencia con las indicaciones establecidas en el instructivo técnico. Entre otros resultados se observó que los cultivares en estudio mostraron, en general, diferencias significativas ($p \leq 0{,}05$) en cuanto al número de vainas por planta (NVP), número de granos por vainas (NGV), peso de 100 granos (P100G) y rendimiento en kg ha^{-1}. El largo y ancho del grano mostraron respuestas diferentes entre los mismos, por lo que pueden constituir caracteres empleados para la caracterización del germoplasma de frijol. En el análisis integral de los resultados, los cultivares Hg-8, R-5, R-11, R-6 y R-4 resaltaron como los de mejor respuesta agronómica del grupo evaluado.

Palabras clave: cultivos, germoplasma, legumbres, rendimiento, siembra

INTRODUCTION

Common bean (*Phaseolus vulgaris* L.) is one of the most consumed edible vegetables worldwide, providing an important source of proteins, vitamins

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and minerals to people's diet in America, especially in developing countries (1).

In Cuba, its yield is from 900 to 1100 kg ha^{-1} for state and non-state agricultural sectors respectively, with a total production of 68.1,000 tons, which cannot meet its demand[A].

Over the past decade, the non-state agricultural sector, mainly consisting of farms and small plots with very diverse conditions and low availability of agrochemical and energetic inputs, was mostly in charge of bean production in our country (2). A lack of inputs is added to the limited farmers' access to new, improved or not, cultivars with better agronomic performance under our agricultural production conditions. The cultivars employed by these farmers with limited resources are more susceptible to biotic and abiotic stresses, such as drought, low soil fertility, field and warehouse pests that are the main constraints to achieve better crop yields, since there are high-yielding cultivars, which could help improve Cuban reality in this context through an adequate management (3); thus, our country's economic policy should involve the allocation of necessary resources to transform the existing situation.

It is necessary to obtain high bean yields in the coming years for supplying our people's demand with national productions; consequently, new technologies have to be implemented, where better adapted cultivars to various environmental conditions play an important role.

The introduction of foreign genetic material has been widely recognized by several researchers, as an important choice to release new materials with better agroproductive response under different agricultural conditions (4, 5).

For all above mentioned, this study was conducted with the purpose of evaluating the response of some agronomic characters from new cultivars introduced to the country and two pre-commercial cultivars pertaining to the national program of bean breeding, for their possible exploitation in the productive systems of Cuba.

MATERIALS AND METHODS

This study evaluated 12 bean cultivars coming from the pest and disease resistance nursery of the International Center for Tropical Agriculture (CIAT), by combining rust (*Uromyces appendiculatus*) and common bacterial blight (*Xanthomonas axonopodis pv. Phaseoli*) resistance genes, among other important pathogens that were introduced to the Local Agricultural Innovation Program (LAIP), guided by the National Institute of Agricultural Sciences (INCA). The study included two pre-commercial cultivars of the national breeding program in Cuba (Table I).

In order to identify new high-yielding cultivars with an adequate adaptation level to the area, the response of new cultivars was assessed at the collective areas from "Jose Castellanos" SCSC, located in Santa Cruz del Norte municipality, Mayabeque province, on a half-deep carbonated brown soil with undulating micro-relief, according to the new version of Soil Genetic Classification of Cuba (6). Its geographical situation towards the end of the northern part of this province makes it poor of rainfall, since it occurs more regularly during the rainy season of the year, from May to October; thus, irrigation is necessary for bean crop development, considering that it is generally cultivated in the dry period (7).

Sowing was performed in a randomized block design and three replicates in the second half of January 2009, within the late period for growing beans in Cuba (7). Plots for each cultivar consisted of three 4-m rows at a spacing of 0.70 m over an area of 8,4 m^2 and a plant spacing of 0,10 m. Irrigation, fertilization and cultural practices followed the guidelines established for bean crop in Cuba (7).

[A] ONEI. Rendimiento agrícola por cultivos seleccionados de la agricultura no cañera. Sector no estatal [en línea]. 2013, [Consultado: 14 de marzo de 2013], Disponible en: <http://www.one.cu/aec2011/esp/09_tabla_cuadro.htm>.

Table I. Lines used in the study and grain morphological characters evaluated

No	Cultivar	Color	Bright	No	Cultivar	Color	Bright
1	R–1	Dirty white	Brilliant	8	R–9	Dirty white	Brilliant
2	R–2	Dirty white	Brilliant	9	R–10	Soft cream	Intermedium
3	R–3	Black	Opaque	10	R–11	Soft cream	Opaque
4	R–4	Dark cream	Intermedium	11	R 12	Dark coffee	Intermedium
5	R–5	Dirty white	Intermedium	12	R–13	Reddish coffee	Brilliant
6	R–6	Dark coffee	Intermedium	13	S–3	Reddish coffee	Intermedium
7	R–7	Dirty white	Brilliant	14	Hg-8	Black	Brilliant

Morphoagronomic trait evaluation

Morphoagronomic traits were evaluated according to the illustrative guide for describing common bean varietal characteristics[B]: some of them were selected for their relationship with bean yields and the others constituted consumers' strong visual attraction:

Yield components

Pod number per plant (PNP)
Grain number per pod (GNP)
100-grain average weight at 14 % humidity (g) (100GW)
Yield per hectare (kg ha^{-1})
Seed characters
Seed length (cm)
Seed width (cm)

For evaluating seed characters, samples were randomly taken from ten seeds, besides measuring length and diameter.

Gathered information processing

After proving the theoretical assumptions of normality and homogeneity of variance, a two-way classification variance analysis was applied to the information gathered by using SPSS statistical package version 20 (8) and significant differences between treatments were verified by means of Tukey multiple range test for an error probability of 0,05 %.

[B] Rosas, J. C.; Guachambala, M. y Ramos, R. A. Guía ilustrada para la descripción de las características de variedades del frijol común. Programa Colaborativo de Fitomejoramiento Participativo en Mesoamérica, 1994, 20 p.

RESULTS AND DISCUSSION

In general, a great variation was observed in yield components of all cultivars evaluated, indicating that there is variability between them, allowing to select the best materials and the most adaptive ones to the conditions of this locality (9).

The generation of varieties that respond to new and changing environmental conditions stands out as one of the solutions to face and mitigate the effect of climate change on modern agriculture, but in the search for new varieties, the first step is to know and duly exploit the preserved genetic heritage (10); thus, various methodologies have been developed and the most commonly used, over the years, has been the morpho-agronomic descriptors in different crops.

When assessing pod number per plant, it was found that tested lines ranged from 24,30 to 8,60 pods per plant (Table II), detecting statistical differences ($p \leq 0,05$) between them for this trait.

The highest PNP was obtained by pre-commercial cultivar Hg-8 (24,3 pods per plant), which statistically differs from the other cultivars under study. This response may be due to the fact that the cultivar was selected under our country conditions. Afterwards, a group of R-5 and R-3 cultivars (16,20 and 15,6 pods per plant, respectively) was detected that did not differ from R-1, R-4, R-9, R-6, R-11 and R-10 cultivars, reaching from 14,5 to 10,8 pods per plant. The other cultivars obtained between 8,6 and 10 pods per plant.

Table II. Yield and its components of common bean lines evaluated at "Jose Castellanos" SCSC, in Santa Cruz del Norte municipality

No	Cultivars	PNP	CI	GNP	CI	M100 G (g)	CI	Yield (kg ha^{-1})	CI
1	R-1	14,5 bcd	±1,24	5,69 a	0,11	10,02 j	±0,19	1176,74 fg	0,86
2	R-2	10,1 def	±1,68	4,12 bcde	0,17	17,03 hi	±0,26	1035,20 g	0,98
3	R-3	15,6 bc	±1,49	5,29 a	0,40	17,19 h	±0,16	1985,38 bcd	1,59
4	R- 4	13,9 bcde	±1,58	4,06 bcde	0,20	25,25 ef	±0,43	2031,41 bcd	1,62
5	R-5	16,2 b	±1,51	4,64 b	0,10	25,06 f	±0,42	2666,94 ab	1,80
6	R- 6	12,7 bcdef	±0,77	4,25 bcd	0,06	27,15 d	±0,43	2081,40 bcd	0,76
7	R-7	9,7 def	±1,37	3,76 de	0,28	24,51 f	±0,30	1247,92 efg	1,29
8	R - 9	13,6 bcde	±2,39	3,56 e	0,43	26,01 e	±0,13	1776,97 cdef	1,63
9	R-10	10,8 cdef	±0,96	4,19 bcd	0,22	28,57 c	±0,47	1899,06 cde	1,83
10	R-11	12,2 bcdef	±1,12	3,83 cde	0,13	33,42 b	±0,22	2244,69 bc	1,37
11	R-12	9,9 def	±0,61	4,45 b	0,23	19,54 g	±0,39	1260,13 efg	0,93
12	R-13	9,0 df	±0,87	4,43 bc	0,10	24,51 f	±0,30	1388,49 cdef	0,96
13	S-3	8,6 f	±0,83	4,12 bcde	0,36	36,33 a	±0,26	1690,80 cdefg	1,98
14	Hg-8	24,3 a	±1,64	5,53 a	0,14	16,27 i	±0,11	3288,12 a	6,21
Mean		13,00		4,42		23,63		1840,94	
SE		0,42		0,06		0,58		62,77	
VC (%)		38,71		16,49		28,94		40,34	

SE: standard error; VC: variation coefficient; PNP: pod number per plant; GNP: grain number per pod; 100GW: 100-grain weight; CI: confidence intervals

Values with at least one letter in common indicate a similar statistical response according to Tukey test α= 0,05

It has been reported that an average of eight pods per plant and a population density of 250 000 effective plants per hectare can yield more than 1500 kg ha^{-1}, which will be related to grain weight and number per pod. However, to achieve a population density of 250 000 plants per hectare, it is necessary to ensure a series of determining factors, such as quality seed that is often the main factor limiting agricultural production, since production is directly affected by a low germinating power (11). Regarding this statement, a pod number below 10 is considered low, even though it depends on the conditions under which every cultivar develops.

Concerning the group under study, there was a considerable number of lines, with a relatively high pod number per plant, which is a result of particular interest for crop breeding, given the high contribution of this trait to the final bean yield, reported by other researchers (12, 13, 14). In this regard, some authors have indeed pointed out that the final dry grain yield showed a high correlation coefficient with pod number per plant, indicating the direct participation of such yield component on the final production of each cultivar, giving greater importance to the lines under study, as this character had good behavior among them (15).

This approach is supported by several researches performed to characterize and evaluate various forms of common bean. In this sense, some authors have reported that pod number per plant was identified as a yield component and it was associated with the highest yield potential, when characterizing cultivated, wild and intermediate forms of common bean with climbing habit (16). Meanwhile, other authors reported that pod number per plant is influenced by the environment, which determines final yield (17).

For grain number per pod (GNP) (Table II), Hg-8, R-1 and R-3 cultivars were highlighted, without statistically significant differences between themselves and even with the others. In a second group, R-5, R-12 and R-13 cultivars, with an average value of four grains per pod, were slightly higher than the average group or equal to it, without statistically significant differences between them. The lowest average value of GNP corresponded to R-9 line, which did not differ statistically from R-2, R-4, R-7, R-11 and S-3 cultivars.

Grain number per pod is an important yield component in common bean crop that, together with pod number per plant, defines crop yields to a great extent (13, 14). According to some authors' statements (14), grain number per pod effectively contributes to grain yield increase, so that it can be a good criterion to select new cultivars.

As it is shown in Table II, 100-grain weight varied significantly ($p \leq 0.05$) between the cultivars evaluated. Thus, according to the scale of values established by CIAT[C], the cultivars under study were classified into two groups: the first one consisting of R-4, R-5, R-6, R-9, R-10, R-11 and S-3 cultivars, with 100-grain weight that falls into the mid grain category and a second group of cultivars with 100-grain weight that falls into the small grain category, without registering those that classified as large grains (100-seed weight≥40 g).

Similar results have been presented by other researchers (18), who agreed in pointing out the absence of large grain cultivars in their studies.

Hg-8 cultivar, which presented the highest pod number per plant and grain number per pod, also agreed in reaching the highest final grain yield (3288,12 kg ha^{-1}) with a significantly greater response ($P \leq 0.05$) than the other cultivars evaluated, except R-5 and close to the historical yield of the best cultivars evaluated in Cuba (7).

Moreover, R-3, R-4, R-6 and R-11 cultivars showed good yields, above the average of 1840,95 kg ha^{-1} of all cultivars studied and without significant differences with R-5 cultivar. The other cultivars presented higher average yields than those reported in the country, both in the state (630,0 kg ha^{-1}) and non-state (1100,0 kg ha^{-1}) sector for 2011, allowing to suggest them as possible cultivars to be considered for sowing areas destined to production for consumption, together with other traits, such as size, color and shape, which constitute consumers' strong visual attraction.

Grain characters

When assessing grain length and width (Table III), statistically significant differences ($p \leq 0,05$) were detected among cultivars. It was observed that grain length ranged between 0,78 and 1,47 cm for R-1 and S-3 cultivars respectively, showing significantly different extreme values with each other and with other cultivars under study, for an average length of 1,09 cm, while grain width ranged from 0,47 to 0,75 cm for R-1 and R-10 cultivars respectively, without significant differences between them.

[C] van Schoonhoven, A. y Pastor, C. M. A. Sistema estándar para la evaluación de germoplasma de frijol. Inst. Centro de Investigaciones en Agricultura Tropical, Cali, Colombia, 1987, p. 56.

Table III. Grain characters of common bean lines evaluated at "Jose Castellanos" SCSC, in Santa Cruz del Norte municipality

Cultivar	No.	GL (cm)	CI	GW (cm)	CI
R - 1	1	0,78 g	±0,06	0,47 e	±0,02
R - 2	2	1,00 ef	±0,05	0,49 de	±0,01
R - 3	3	1,03 cdef	±0,03	0,57 bc	±0,02
R - 4	4	1,16 bc	±0,03	0,69 a	±0,03
R - 5	5	1,11 bcde	±0,05	0,61 b	±0,02
R - 6	6	1,14 bcd	±0,04	0,74 a	±0,02
R - 7	7	1,15 bcd	±0,06	0,50 de	±0,02
R - 9	8	1,08 bcdef	±0,03	0,69 a	±0,03
R - 10	9	1,20 b	±0,03	0,75 a	±0,04
R - 11	10	1,15 bcd	±0,05	0,71a	±0,03
R - 12	11	1,02 def	±0,08	0,56 bcd	±0,03
R - 13	12	0,94 f	±0,07	0,53 cde	±0,02
S - 3	13	1,47a	±0,05	0,70 a	±0,00
Hg - 8	14	0,96 f	±0,05	0,58 bc	±0,01
Mean		1,09		0,62	
SE		0,01		0,01	
VC (%)		16,15		16,8	

Values with at least one letter in common indicate a similar statistical response according to Tukey test α=0,05
SE: standard error; VC: variation coefficient; GL: grain length; GW: grain width

These traits are greatly important for the materials evaluated, due to its size and color diversity, which are significant visual attractions for this grain marketing and consumption forms. In this respect, some authors[D] have detected relationship between seed size and water absorption capacity that, in turn, is related to the phenomenon of hard head, associated with extended cooking times, so that the higher the absorption capacity is, the lower the cooking times generally are.

In the complete analysis of cultivar responses tested, Hg-8, R-5, R-11, R-6 and R-4 cultivars were distinguished for the best agronomic response. The first of them (Hg-8) was characterized by presenting mid-size grains with a high pod production per plant and grains per pod, which places it as a high-yielding potential cultivar, compared with the others under study. The second one (R-5) is distinguished by its agronomic performance and characterized by mid-size grain, good pod production per plant and grains per pod with nice yield (2666,94 kg ha^{-1}). Meanwhile, R-11, R-6 and R-4 cultivars were mainly characterized by presenting mid-size grains, grain number per pod near or slightly above the average cultivars evaluated, exceeding a yield of 2000 kg ha^{-1}, which makes them perfect choices to diversify offers of this product for human consumption.

[D] Aguirre, S. E. A. y Gómez, A. C. A. ''Evaluación de las características fisicoquímicas en la especie de frijol *Phaseolus vulgaris* de las variedades; Pinto Saltillo, Bayo Victoria y Negro San Luis''. En: XII Congreso Nacional de Ciencia y Tecnología de Alimentos, Guanajuato, 2010.

CONCLUSIONS

The introduction of these cultivars in the productive practice allows farmers to combine high-yielding cultivars in their fields with remarkable grain trait differences, such as color and size, of particular interest for bean crop.

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