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AGRONOMIC RESPONSE OF *Phaseolus vulgaris* CULTIVARS IN AGROCLIMATIC CONDITIONS OF "SAN JUAN AND MARTÍNEZ", CUBA[a]

RESPUESTA AGRONÓMICA DE CULTIVARES DE *Phaseolus vulgaris* EN CONDICIONES AGROCLIMÁTICAS DE "SAN JUAN Y MARTÍNEZ", CUBA

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ABSTRACT: The production of grain legumes is very important for food and should be promoted in tobacco (*Nicotiana tabacum* L.) farming systems little diversified. The research was carried out in soil and climatic conditions in the tobacco locality "San Juan and Martínez", Cuba, with the objective of determining the agronomic response of four common bean cultivars (*Phaseolus vulgaris* L.). Commercial cultivars were used 'CUL´-156', 'Buenaventura', 'Guamá 23' and 'Chévere', distributed in an experimental design of blocks randomly with four replicas. The crop is established in two sowing times (November 2017 - February 2018 y November 2018 - February 2019), in a Leached Yellowish Ferralitic soil. The agricultural yield of its components (number of legumes per plant, index non-effective legumes per plant, number of seeds per legume, dry mass of the legumes, dry mass of the seeds per legume and the mass of 100 seeds) was evaluated. The productive results showed a differentiated response between cultivars that justify the effect of the genotype-environment interaction in its crop. The average agricultural yield exceeded 65 % of the genetic potential in the cultivars with red testa seeds ('Buenaventura' and 'Guamá 23') and white testa ('Chévere'), a proportion higher than that of the commercial production control 'CUL-156' (63.6 %). The results of this study showed the possibility of diversifying the production of this legume in tobacco agroecosystems of "San Juan and Martínez" with cultivars of different colors in the seed coat.

KEYWORDS: Agroecosystem; common bean; seeds; agricultural yield.

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RESUMEN: La producción de leguminosas de grano es muy importante para la alimentación y debe promoverse en sistemas de cultivo de tabaco (*Nicotiana tabacum* L.) poco diversificados. La investigación se realizó en condiciones edafoclimáticas en la localidad tabacalera de “San Juan y Martínez", Cuba, con el objetivo de determinar la respuesta agronómica de cuatro cultivares de frijol común (*Phaseolus vulgaris* L.). Se utilizaron los cultivares comerciales ‘CUL-156’, ‘Buenaventura’, ‘Guamá 23’ y ‘Chévere’, distribuidos en un diseño experimental de bloques al azar con cuatro réplicas. La siembra se realizó en dos periodos (noviembre 2017 - febrero 2018 y noviembre 2018 - febrero 2019), en un suelo Ferralítico Amarillento Lixiviado. Se evaluó el rendimiento agrícola de sus componentes (número de legumbres por planta, índice de legumbres no efectivas por planta, número de semillas por legumbre, masa seca de la legumbre, masa seca de semillas por legumbre y masa de 100 semillas). Los resultados productivos mostraron una respuesta diferenciada entre cultivares que justifica el efecto de la interacción genotipo-ambiente en este cultivo. El rendimiento agrícola promedio superó el 65 % del potencial genético en los cultivares con semilla de testa roja (‘Buenaventura’ y ‘Guamá 23’) y testa blanca (‘Chévere’), proporción superior a la del testigo de producción comercial ‘CUL-156’ (63,6 %). Los resultados de este estudio mostraron la posibilidad de diversificar la producción de esta leguminosa en agroecosistemas tabacaleros de “San Juan y Martínez” con cultivares de diferentes colores de testa.

PALABRAS CLAVE: Agroecosistema; frijol común; rendimiento agrícola; semillas.

1. INTRODUCTION

The common bean (*Phaseolus vulgaris* L.) is native to the Americas and constitutes, among the legumes of food grains, one of the species of major importance for human consumption (Peña *et al.*, 2015; Estrada *et al.*, 2016; Calero *et al.*, 2018). The world production is estimated at 30.4 million tons and 67 % is concentrated in India, Myanmar, Brazil, the United States, China, Tanzania, Mexico and Uganda (FAO, 2018).

This crop is affected by several factors including drought stress, nutritional deficiencies, inefficient land use, pest incidence, among others (Beebe *et al.*, 2011; Estrada *et al.*, 2016; Domínguez *et al.*, 2019), which produce an agricultural yield below the genetic potential of the cultivars employed in production.

In Cuba, the area destined to this crop exceeds 147,000 ha, with an average agricultural yield of 1.09 t ha^{-1} (ONEI, 2019), although domestic production still does not meet consumption needs (Martínez *et al.*, 2017; Hernández-Ochandía *et al.*, 2018). Therefore, regionalization studies are required in the common bean (Martínez *et al.*, 2019a) that guarantee the use of better adapted cultivars (Lima *et al.*, 2020) and agricultural yields according to their genetic potentials. Cabrera *et al.* (2017) also suggest that these elements demand applied research in different agroecosystems to contribute to the availability of this grain legume in the market.

The agricultural localities of Pinar del Río (Cuba), where tobacco monoculture prevails, have potential for increasing and diversifying common bean production. Its use allows an important contribution to cover the demand for this grain in the population’s diet. In addition to other benefits of the crop for soil improvement, the regulation of pests and diseases and the sustainability of agroecosystems in general.

For this, Cuban agriculture has at least 30 commercial cultivars in the production of common beans with great diversity of growth habits and color of the testa of the seeds (MINAG, 2017; Martínez *et al.*, 2019b). In the province of Pinar del Río, Cuba, the most commercially grown cultivars are the testa of their black seeds 'CUL 156', 'Tomeguín 93', 'BAT 304', which contribute more than 90 % of the total production of the territory (ONEI, 2019). Cultivars with red and white testa seeds are less frequently studied in local soil and climatic conditions, particularly in tobacco agroecosystems, where the planting of this crop for grain production is currently increasing and diversifying.

Therefore, the present work objective to determine the response of four commercial cultivars of common bean in soil in climatic conditions of the locality "San Juan and Martínez", Pinar del Río, Cuba.

2. MATERIALS AND METHODS

This research was carried out in a tobacco agroecosystem in "San Juan y Martínez", whose coordinates locate it at 22°18"13' N and 83°47"39' W of the province of Pinar del Río, Cuba. The soil was classified as Ferralitic Yellowish Leached Hernández *et al.* (2015), with pH (KCl) = 5.1 and organic matter 1.47 %. Below are the climatic conditions that characterized the planting times, according to the data of the Meteorological Station No. 314 belonging to the Provincial Meteorological Center of Pinar del Río (Figure 1). Four cultivars (treatments) of common bean were used (Table 1), distributed in a Random Block design with four replicas. In each planting period the cultivated area was 450 m^2 with experimental units of 28 m^2. The cultivar 'CUL-156' was included as a control based on the commercial production of this grain in the study area, used for more than five years for cultivation; while 'Buenaventura', 'Guamá 23' and 'Chévere' are also commercial cultivars, although its productive response has not been determined in soil and climatic conditions of the locality "San Juan and Martínez".

Sowing was done manually, in the first half of November, at a planting distance 0.60 m between rows and 0.07 between plants. All the cultural attentions were carried out as established in the technical guide for the cultivation of the common bean in Cuba (Faure *et al.*, 2013). In the fertilization a dose of 0.4 t ha^{-1} formula 12-6-16-3 (N-P-K-Mg) was applied at the time of sowing and foliar ammonium nitrate (6.0 g L^{-1}) 15 days before the start of flowering (Izquierdo *et al.*, 2018). The irrigation was carried out superficial by furrow. Six irrigations were applied (always in the afternoon) and the 75 % total average net norm (3 500 m^3 ha^{-1}) established according to the development stages of the crop was guaranteed (Faure *et al.*, 2013).

Harvesting was carried out when the plants reached physiological maturity, which was characterized by leaf drop, change of color of the legumes from green-purple to brown once they reached their optimum drying. When the seeds reached 14 % moisture (Maqueira *et al.*, 2021), the plants were harvested. These were left to dry for 48 hours in the field, after which they were threshed by hand and stored in jute sacks.

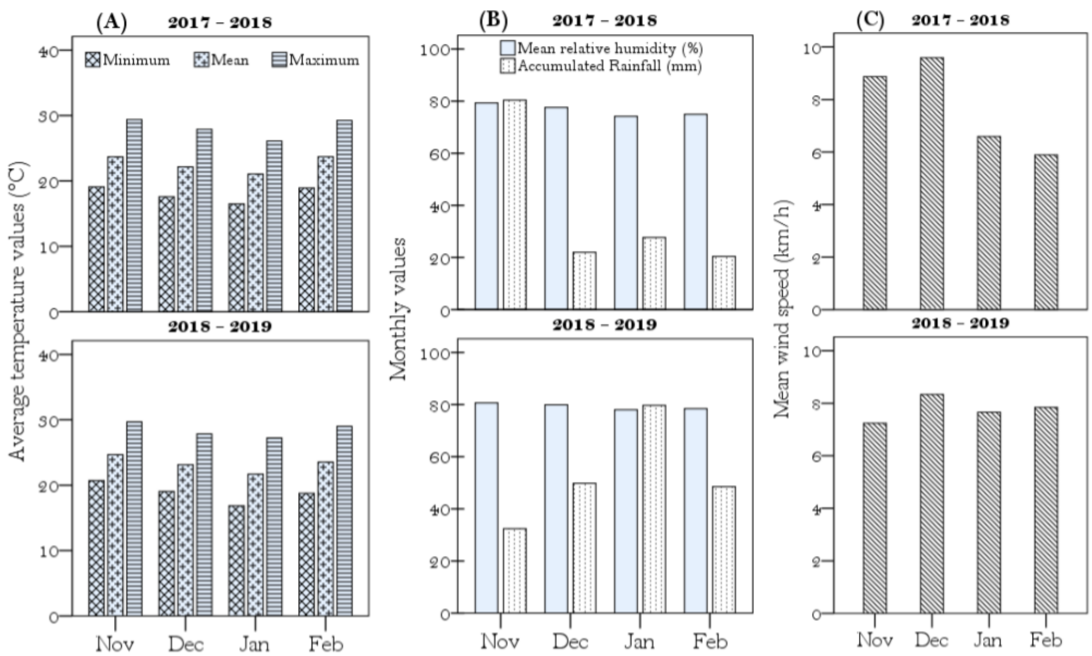

Figure 1: Monthly values of the climatic variables in the municipality of "San Juan and Martínez", during the period of the field experiments (Nov 2017 - Feb 2018 and Nov 2018 - Feb 2019). Legend: (A) Average values of temperature, (B) Relative humidity and accumulated rainfall and (C) Wind speed. Source: Elaborated by the authors using data from of the Provincial Meteorological Center of Pinar del Río, Cuba

Table 1: Characteristics of the common bean cultivars used. Source: Faure et al. (2013)

Cultivar	Color	Growth type	Potencial yield (t ha^{-1})
'CUL 156' (control)	Black	Indeterminate bush	3.17
'Buenaventura'	Red	Indeterminate bush	2.93
'Guamá 23'	Red	Determinate bush	3.10
'Chévere'	White	Indeterminate prostrate	3.10

Table 2: Analysis of variance (F-value) for agricultural yield and its components in two planting periods (Nov 2017 - Feb 2018 and Nov 2018 - Feb 2019). Source: Own elaboration

Source of variation	LP	ILP	SL	ML	MSL	M100S	AY
Cultivar	11.33**	1.72ns	115.10**	44.16**	34.85**	138.48**	0.75ns
Sowing	0.06ns	18.70**	0.07ns	3.52ns	0.67ns	1.37ns	4.25*
Cultivar*Sowing	10.29**	1.32ns	9.09**	2.30ns	1.46ns	7.24**	11.10**
SE	0.37	1.30	0.12	0.04	0.03	1.04	0.07

Legend: LP= Legumes per plant, ILP= index of non-effective legumes per plant, SL= seeds per legume, ML= mass per legume, MSL= mass of seeds per legume, M100S= mass of one hundred seeds, AY= agricultural yield, SE= standard error of the mean, **= significant for $p \leq 0.01$, $*$ = significant for $p \leq 0.05$, ns= non-significant.

To estimate agricultural yield, 8 square meters were harvested per experimental plot (replicate). Components were determined on 40 randomly selected plants in four linear meters per replicate (10 per linear meter). These included number of legumes per plant, index of non-effective legumes per plant, number of seeds per legume, dry mass of the legumes, dry mass of the seeds per legume and the mass of 100 seeds). Biomass values represent the dry weight of legumes and seeds. These were separated and kept in an oven for 48 h at a temperature of 70°C. An Adventurer^{TM} Pro Precision (OHAUS®) digital scale was used (precision 0.01 g).

In the data obtained, the assumptions of normality and homogeneity of variance were verified, using the Kolmogorov-Smirnov and Levene tests, respectively. Double classification Variance Analysis and Tukey test were applied for the comparison of means, with a confidence level of 95 % ($p \leq 0.05$). Regression analysis was also performed for agricultural yield. The statistical program Minitab version 17.1 for Windows, was used (MINITAB, 2015).

3. RESULTS AND DISCUSSION

The analysis of variance showed a significant effect of the cultivar factor on the productive variables analyzed, except for the index of non-effective legumes per plant and the agricultural yield. It was precisely in these components that the sowing period had a significant influence, while legumes per plant, seeds per legume and the biomasses of legume and seeds did not undergo significant variations in this factor. The cultivar- sowing interaction was also significant for agricultural yield and three of its important components (legumes per plant, seeds per legume and 100-seed mass) (Table 2).

Other results related to environment and genotype in the crop found significant effects of the factors cultivar and crop cycle (= sowing period) on agricultural yield and its competencies. In addition, the cultivar-cropping cycle interaction influenced seed yield and 100-seed mass, not so for the number of legumes per square meter and seeds per legume (Romero-Félix *et al.*, 2018). A previous analysis on the productivity of common bean (‘CUL-156’, ‘Buenaventura’, ‘Chévere’ and others) in localities of Pinar del Río (Cuba)

Table 3: Components of agricultural yield in the evaluated cultivars. Source: Own elaboration

CULTIVAR	LP (u)	ILP (%)	SL (u)	ML (g)	MSL (g)	M100S (g)
Sowing Nov 2017 - Feb 2018						
'CUL 156' (control)	13.67 a	29.02 a	7.38 a	1.48 b	1.30 b	17.62 c
'Buenaventura'	12.80 a	34.22 a	4.77 b	1.49 b	1.19 bc	23.04 b
'Guamá 23'	9.25 b	33.83 a	4.34 c	1.99 a	1.59 a	40.01 a
'Chévere'	12.11 a	30.08 a	5.16 b	1.32 c	1.01 c	19.60 bc
SE±	0.46	1.31	0.21	0.07	0.06	1.61
Sowing Nov 2018 - Feb 2019						
'CUL 156' (control)	10.05 c	26.85 a	6.76 a	1.64 b	1.29 b	18.94 b
'Buenaventura'	16.21 a	32.69 a	5.58 b	1.39 c	1.14 c	20.53 b
'Guamá 23'	9.62 c	27.91 a	3.91 c	2.23 a	1.70 a	44.22 a
'Chévere'	13.27 b	26.96 a	5.61 b	1.47 c	1.14 c	20.42 b
SE±	0.48	1.34	0.15	0.05	0.03	1.38
Mean of the two sowing periods						
'CUL 156' (control)	12.75 b	27.94 a	7.10 a	1.59 b	1.31 b	18.41 c
'Buenaventura'	14.33 a	33.46 a	5.19 b	1.45 c	1.17 c	22.81 b
'Guamá 23'	9.43 c	30.87 a	4.13 c	2.11 a	1.65 a	40.34 a
'Chévere'	12.69 b	28.52 a	5.38 b	1.39 c	1.08 c	20.01 bc
SE±	0.37	1.30	0.12	0.04	0.03	1.04

Different letters in the same column indicate significant differences (Tukey test; $p \leq 0.05$).
Legend: LP= Legumes per plant, ILP= index of non-effective legumes per plant, SL= seeds per legume,

ML= mass per legume, MSL= mass of seeds per legume, M100S= mass of one hundred seeds, SE= standard error of the mean.

showed significant differences in the cultivar factor for all the components evaluated (Santana-Baños *et al.*, 2021).

The components of the crop agricultural yield expressed significant differences between the cultivars in the two sowing periods, except for the index of non-effective legumes (Table 3). 'Buenaventura' reached more than 12 legumes per plant at harvest. This suggests a better productive response of the cultivar to the prevailing conditions. Some authors affirm the importance of this component because of its high contribution to the agricultural yield of the crop (Zilio *et al.*, 2011; De La Fé *et al.*, 2016).

An adequate balance was also verified between the production of legumes and the formation of the seeds since the index of non-effective legumes yielded average values of less than 35 % in all cultivars in the two harvests. This result suggests an effective distribution of photoassimilates to the formation of legumes and seeds under the evaluated conditions. Plant nutrition and vegetative development achieved, along with other crop management factors, have a marked influence on this variable.

The number of seeds per legume expressed values between 3.91 and 7.38, in the cultivars 'Guamá 23' and 'CUL-156' respectively, with significant differences between them and with the other cultivars evaluated. The variables dry mass of the legumes and dry mass of seeds per legumes showed significant differences between the cultivars, with average values statistically higher than the rest in 'Guamá 23' (2.11 g and 1.65 g). This result is associated with the fact that this cultivar has larger seeds than the other study objects. Therefore, the mass of 100 seeds reached a significantly higher average in this cultivar (40.34 g).

Other authors referred values lower than 4.0 seeds per pod legume in the 'CUL-156' cultivar for the same planting date. They also affirm that the variation of this influences the result obtained Maqueira *et al.* (2017). In an agroecosystem of Santi Spíritus, Cuba, between 3.0 and 4.0 seeds per legume is also obtained with the cultivar 'Buenaventura' (Calero *et al.*, 2018).

The dry masses of legumes and seeds per legume had a similar answer, with significantly higher means in 'Guamá 23' cultivar. The relationship between these variables indicates that the dry mass of seeds exceeds 75 % of the total mass of the legume in all cultivars.

The mass of 100 seeds expressed significant differences between cultivars in under the evaluated conditions. The cultivars 'Buenaventura' (19 g) and 'Chévere' (18 g) exceeded their average value while 'Guamá 23' and 'CUL-156' they reached a potential greater than 80 % of the mass of 100 seeds (49 g and 20 g) found by Faure *et al.* (2013). Other authors refered to averages greater than 20 g in the cultivar 'Buenaventura' (Calero *et al.*, 2018) and values between 17.6 and 19.2 g in 'CUL-156' (Maqueira *et al.*, 2017).

The agricultural yield of the cultivars expressed a differentiated response between sowing periods, except for 'Chévere'. The greatest variation was observed in 'CUL-156', with an agricultural yield in the period November 2017 - February 2018 that exceeded by 15 % the values obtained in the rest of cultivars. In the second harvest (November 2018 - February 2019) the cultivars 'Buenaventura' and 'Guamá 23' exceeded 2.0 t ha^{-1} and were significantly higher than 'CUL-156'. However, all cultivars exceeded 60 % of their potential agricultural yield in each harvest (Figure 2).

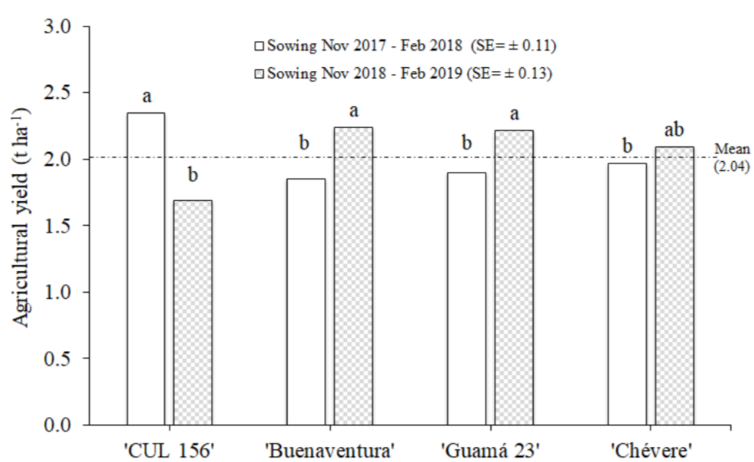

Figure 2: Agricultural yield of the common bean cultivars in the periods evaluated. Different letters in the same column indicate significant differences (Tukey test; p≤0.05). Source: Own elaboration

The differentiated response in ‘CUL-156’ was inverse with respect to the other cultivars, which suggests evaluating the response of the crop with certified seeds of different origin, delving into the effect of different water levels due to the differences in rainfall between the planting, as well as in the management of crop nutrition.

Research carried out in agroecosystems of the central region of Cuba also found agricultural yield values above 2.0 t ha^{-1} in common bean cultivars where ‘Chévere’ was included (Martínez *et al.*, 2015). They also point out differences in the agricultural yield of 14 cultivars introduced in Cuba and evaluated in the western region (De La Fé *et al.*, 2016).

The results of the agricultural yield in the cultivars provide important information for the choice of these according to the production objective that is pursued, since, in most of the areas producing common beans, the potential agricultural yields are never reached (Domínguez *et al.*, 2016). Recent research indicates that ‘Buenaventura’ expressed more than 60 % of its genetic potential in agroecosystems of Pinar del Río, Cuba (Izquierdo *et al.*, 2018; Carrodeguas *et al.*, 2021) due to its possible tolerance to edaphoclimatic variations between localities.

It was shown that the cultivars with red testa seeds (‘Buenaventura’ and ‘Guamá 23’) and white (‘Chévere’) can favor the productive diversification of the seeds in the tobacco agroecosystems of “San Juan and Martínez"(Cuba), with production values that exceed the average agricultural yield in the province of Pinar del Río (1.3 t ha^{-1}) and Cuba (1.09 t ha^{-1}) (ONEI, 2019).

The results show that common bean should be one of the most widely used crops for diversification of production in tobacco agroecosystems, given its importance as human food, the benefits it brings to the soil due to its interaction with rhizobacteria and the recycling of nutrients, among other elements.

The estimation of agricultural yield in common bean from the number of legumes per plant (Figure 3) is an issue addressed by several authors who suggest a high correlation and dependency between these variables (Zilio *et al.*, 2011; Izquierdo *et al.*, 2018).

The results obtained indicate that the number of legumes determined more than 60 % of the productivity of the crop. This result differs from those obtained by Lescay *et al.* (2017) who in a study of common bean cultivars reported an extremely low relationship between these variables.

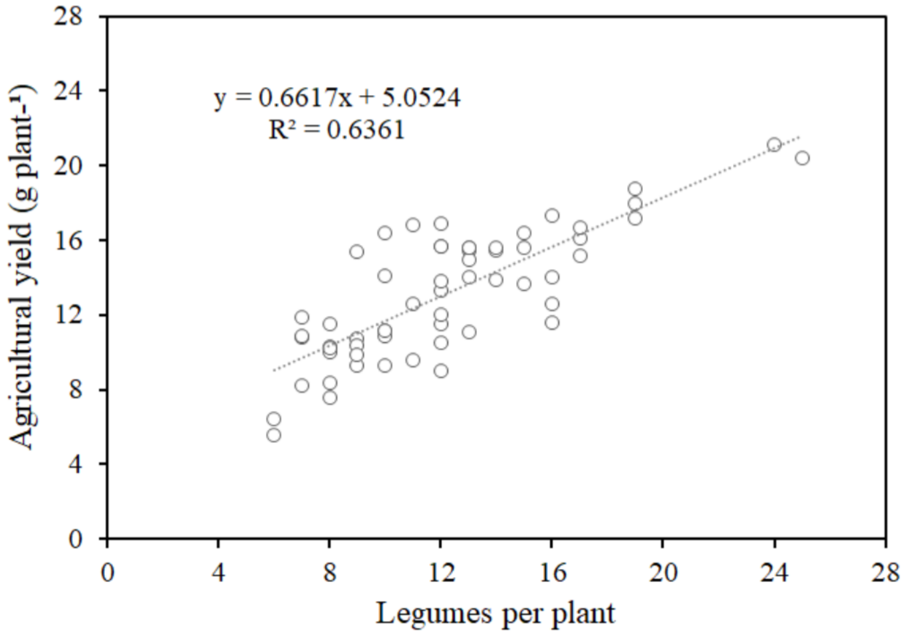

Figure 3: Results of the regression analysis between agricultural yield and number of legumes in the crop. R^2-estimation coefficient for the lineal regression. Source: Elaborated by the authors.

4. CONCLUSIONS

In agricultural yield it varied among the cultivars and exceeded 50 % of its potential in both harvests. The cultivars 'Buenaventura', 'Guamá 23' and 'Chévere' exceeded 65 % of their agricultural yield potential. It is possible to diversify common bean production in the tobacco agroecosystem of the municipality of "San Juan y Martínez"with black, red and white testa cultivars.

Author contributions

Sergio Carrodeguas Díaz and Yoerlandy Santana-Baños: Conceptualization.

Yoerlandy Santana-Baños, Sergio Carrodeguas Díaz, Yosbel López Quintana, José Carlos González Sotolongo and Edenys Miranda Izquierdo: Research.

Yoerlandy Santana-Baños and Michel Ruiz Sánchez: Methodology. Sergio Carrodeguas Díaz and Michel Ruiz Sánchez: Supervision. Yosbel López Quintana and José Carlos González Sotolongo: Data curation.

Yoerlandy Santana-Baños, Michel Ruiz Sánchez and Edenys Miranda Izquierdo: Formal analysis.

Yoerlandy Santana-Baños and Sergio Carrodeguas Díaz: Writing - Original Draft Preparation.

Yoerlandy Santana-Baños, Sergio Carrodeguas Díaz and Michel Ruiz Sánchez: Writing - Review & Editing.

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