



Cultivos Tropicales

ISSN: 1819-4087

Ediciones INCA

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Cultivos Tropicales, vol. 43, no. 3, 2022, pp. 1-5

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Agronomic characteristics and productivity of bean (*Vigna unguiculata* (L.) Walp.) cultivar in Caazapá-Paraguay

Características agronómicas y productividad de cultivares de poroto (*Vigna unguiculata* (L.) Walp.) en Caazapá-Paraguay

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ABSTRACT: Beans (*Vigna unguiculata* (L.) Walp.) are widely used in the diet of Paraguayan families, due to their high protein content. It is planted in crop rotation systems to take advantage of the capacity of its roots to fix atmospheric nitrogen, in accordance with agroecological practices. The aim of this work was to evaluate the agronomic yield of seven bean cultivars in the agroecological conditions of Caazapá, Paraguay. The experiment was established at the Experimental Field of the Faculty of Agricultural Sciences, National University of Asunción, Caazapá Branch, Paraguay (26° 09' 28" South and 56° 21' 00" West). A randomized complete block experimental design with seven treatments and four replications was used. Treatments consisted of the bean cultivars Pytã'i (Colorado Chico), San Francisco'í (San Francisco Chico), San Francisco Guazú (San Francisco Grande), Moteado, Crema, Negrito and Tronquito. The following agronomic characteristics were evaluated: pod length, number of seeds per pod, 100-seed mass, podded grain yield, and dry grain yield and grain index. The data were subjected to analysis of variance and the means compared by Tukey's test at 5 % probability of error. The cultivars Crema, Pytã'i, San Francisco'í and Moteado stood out for their higher dry bean yield and bean index, while San Francisco Guazú stood out for its higher 100-seed mass.

Key words: bean, cowpea, variety, yield, legume.

RESUMEN: El poroto (*Vigna unguiculata* (L.) Walp.) es muy utilizado en la alimentación de las familias paraguayas, debido a su elevado contenido en proteínas. Se siembra en sistemas de rotación de cultivos para aprovechar la capacidad que tienen sus raíces de fijar el nitrógeno atmosférico, en correspondencia a las prácticas agroecológicas. El objetivo del trabajo fue evaluar el comportamiento agronómico de siete cultivares de poroto en las condiciones agroecológicas de Caazapá, Paraguay. El experimento fue establecido en el Campo Experimental de la Facultad de Ciencias Agrarias, Universidad Nacional de Asunción, Filial Caazapá, Paraguay (26° 09' 28" Sur y 56° 21' 00" Oeste). Se utilizó un diseño experimental de bloques completos al azar con siete tratamientos y cuatro réplicas. Los tratamientos consistieron en los cultivares de poroto: Pytã'i (Colorado Chico), San Francisco'í (San Francisco Chico), San Francisco Guazú (San Francisco Grande), Moteado, Crema, Negrito y Tronquito. Se evaluaron las siguientes características agronómicas: longitud de vainas, número de semillas por vaina, masa de 100 semillas, rendimiento de granos con vainas, rendimiento de granos secos e índice de granos. Los datos fueron sometidos al análisis de varianza y las medias comparadas por la prueba de Tukey al 5 % de probabilidad de error. Los cultivares Crema, Pytã'i, San Francisco'í y Moteado se destacaron por su mayor rendimiento de granos secos e índice de granos, mientras que San Francisco Guazú sobresalió por su mayor masa de 100 semillas.

Palabras clave: frijol, caupí, variedad, rendimiento, leguminosa.

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Received: 20/01/2021

Accepted: 12/10/2021

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INTRODUCTION

The bean, *Vigna unguiculata* (L.) Walp., also known as cowpea bean is a widespread legume in Paraguay, mainly used in human consumption due to its high nutritional value.

The protein content of the bean is 23 to 25 %, it contains all the essential amino acids and, on average, 63 % of carbohydrates. Its composition also includes vitamins and minerals, as well as a large amount of dietary fiber and low lipid content (1). In Paraguay, in the 2017/2018 crop year, the area planted was 73,000 ha, with a yield of 850 kg ha⁻¹ (2). This yield is low, due to the lack of cultivars with high productive potential, because in research works carried out in the country (3), productivities between 1,600 to 2,970 kg ha⁻¹ were obtained, much higher than the national average.

It is a traditional crop in Paraguayan family agriculture, closely linked to food security, and it is of great social, economic and environmental importance, planted in a monoculture system or associated with corn (*Zea mays* L.) and cassava (*Manihot esculenta* Crantz). The plant has the capacity to fix atmospheric nitrogen in its roots, which is why it is used as green manure in crop rotation systems to recover degraded soils (4). Part of the nitrogen fixed may be used by the crop and the remainder used by the next crop, reducing the need to apply mineral fertilizers.

In Paraguay, the availability of food supply exceeds population needs as a whole. However, access and utilization show different difficulties for its realization, which make undernourishment and poor nutrition prevail (5). In this sense, beans are an alternative to improve the nutritional quality of the diet of Paraguayan families, since they are a less expensive source of protein than meat.

There are numerous bean cultivars in Paraguay, differentiated by their morphology and yield potential, which need to be evaluated in different agroecosystems. The objective of this work was to select higher yielding cultivars in the soil and climatic conditions of Caazapá district, Caazapá department.

MATERIALS AND METHODS

The research work was developed between October 2016 and January 2017, in the Experimental Field of the Faculty of Agricultural Sciences (FCA), National University of Asuncion (UNA), Caazapá Branch, located in Caazapá district, Caazapá department, Paraguay, located between the geographical coordinates 26° 10' South latitude and 56° 21' West longitude and altitude of 142 m.

The climate is humid subtropical and mesothermal, with an average annual rainfall of 1,600 mm. The monthly averages of temperature, relative humidity and precipitation during the execution of the experiment are presented in Table 1, which are adequate for the growth and development of the bean crop during the period in which the research was carried out.

The soil of the area belongs to the Ultisol order and sandy loam texture (6). The main chemical characteristics of the experimental plot the soil in the 0 to 20 cm depth layer, according to the analysis carried out at the Soil Laboratory of the FCA/UNA are the following: pH=4.70, organic matter=1.20 %, P=9.10 (mg kg⁻¹), Ca²⁺=1.00 cmolc kg⁻¹, Mg²⁺=0.52 cmolc kg⁻¹, K⁺=0.18 cmolc kg⁻¹, Na⁺ 0.02 cmolc kg⁻¹, Al³⁺+H⁺=1.56 cmolc kg⁻¹. These results indicate that pH is acidic, organic matter, P and Ca²⁺ contents are low, Mg²⁺ and K⁺ are medium, Na⁺ is low and Al³⁺+H⁺ is high.

The treatments were represented by seven bean cultivars: Pytã'i (Colorado Chico), San Francisco'í (San Francisco Chico), San Francisco Guazú (San Francisco Grande), Moteado, Crema, Negrito and Tronquito. They come from the germplasm collection of the FCA-UNA.

The experimental design used was a randomized complete block design with four replicates. Each experimental unit consisted of four 4 m long rows. The separation between blocks was 1.5 m.

Soil preparation was carried out conventionally with plowing and harrowing. Planting was done manually on October 7, 2016 at 0.70 m distance between rows and 0.25 m between plants, with two plants per hole, resulting in a density of 10 plants per linear meter in all treatments. Weed control was carried out by two manual pruning operations. Crop nutrition was carried out according to the Guide for the fertilization of annual and perennial crops of Paraguay (7).

Harvesting was carried out on two periods (22-12-2016 and 11-01-2017), given that they are indeterminate growth cultivars, when the pods were completely dry. Evaluations were carried out using plants from the central rows of each experimental unit and were as follows: pod length and number of seeds per pod, obtained from 10 pods, mass of 100 seeds, yield of grains with pods, yield of dry grains with moisture correction at 13 % and grain index. The grain index is the percentage corresponding to the ratio between the mass of grains of 20 pods and the total mass of those pods with grains, obtained by the following formula (8):

Table 1. Monthly averages of minimum, mean, maximum temperatures, relative humidity and precipitation during the experiment in Caazapá, Paraguay

Month/year	Min T° (°C)	Med T° (°C)	Max T° (°C)	RH %	Precipitation (mm)
October 2016	16.4	21.9	28.3	74.0	222.1
November 2016	17.0	22.8	29.8	73.2	236.6
December 2016	20.1	25.4	31.0	73.6	126.9
January 2017	21.8	27.6	33.6	77.0	113.6

Source: Directorate of Meteorology and Hydrology (DMH) processed by the Meteorology Division of the Faculty of Agricultural Sciences, UNA

$$GI = (MG20V/M20V)*100$$

where:

MG20V=mass of 20 pods of beans

M20V=mass of 20 pods with grains

MG20V=masa de granos de 20 vainas

M20V=masa de las 20 vainas con granos

The data were subjected to the double classification analysis of variance and where significant statistical differences existed, the means were compared by Tukey's test at 5 % probability of error. The statistical package InfoStat version 2017 (9) was used.

RESULTS AND DISCUSSION

Analysis variance evaluated detected significant differences for 100-seed mass, podded grain yield and dry grain yield, indicating that the cultivars show genetic differences for these characteristics. Pod length, number of seeds per pod and grain index showed no statistical differences (Table 2).

Pod length ranged from 16.74 to 18.37 cm (Table 2) with no significant statistical differences among cultivars. The means of this work are in the range of 14.90 cm and 22.50 cm, cited by other researchers (10), when comparing cowpea cultivars in Brazil. However, they are lower than those reported by other researchers (11,12), who, when evaluating different genotypes of cowpea, found means between 16.40 cm and 22.47 cm.

No significant differences were observed between cultivars in the number of seeds per pod. These results coincide with another study (12), which also found no statistical differences for this characteristic, obtaining means between 10.15 and 14.15 seeds per pod, evaluating 20 bean genotypes in Brazil.

Regarding the behavior of cultivars in the 100-seed mass, results showed statistical differences (Table 2), where San Francisco Guazú reached the highest average, differing significantly from the other cultivars. The values obtained with San Francisco'í, San Francisco Guazú and Moteado are higher than those reported for the same cultivars in research conducted in the Central Chaco, Paraguay, where averages of 11.68 g, 20.05 g and 14.05 g, respectively, were obtained (3).

The mass of 100 seeds is a genetic characteristic of each cultivar and is also influenced by the environment, there being a negative correlation between the number of seeds per pod and the mass of 100 seeds (13). Seed size is an important characteristic at the commercialization time, since the largest seeds are the most preferred and have the best price in the market.

In the yield of grains with pods (Table 3), the Crema cultivar surpassed San Francisco Guazú and Tronquito, but maintained similarity in yield to Pytá'í, San Francisco'í, Moteado and Negrito. The values obtained are lower than those reported in research carried out in the Chaco Central, Paraguay (3), where the means were between 2.80 and 4.35 t ha⁻¹. These differences in yield may be due to the higher soil fertility and more favorable temperature conditions for the crop in the Chaco Central during the experiment.

Crema cultivar (Table 3) outperformed San Francisco Guazú, Negrito and Tronquito in grain yield, but showed similarity in yield to Pytá'í, San Francisco'í and Moteado. Differences in yield may be related to genetic variability among cultivars. It is important to highlight that the evaluated cultivars presented productivities above 1.20 t ha⁻¹, much higher than the national average of 0.85 t ha⁻¹ and of the department of Caazapá of 0.96 t ha⁻¹, respectively (2). However, they are lower than the averages obtained in research carried out in the Chaco Central, Paraguay (3) and the most productive cultivars in experiments carried out in Tocantins State, Brazil (14) and in Camajuaní, Cuba (15). Differences in yield may be due to the fact that they are different cultivars and to the climatic and soil conditions, which were more favorable for the growth and development of the crop. On the other hand, these results are superior to those obtained in similar investigations carried out in Colombia, Egypt and Brazil (16-19).

The Pytá'í and San Francisco'í cultivars have red and mottled gray kernels, respectively, which respond to the preference of national consumers. Crema cultivar, which proved to be the most productive, is characterized by its shorter cooking time and can also be used for the preparation of salads, due to the different coloration of the kernels, and also for the preparation of flour.

Table 2. Main yield indicators and their components of the bean cultivar trial, Caazapá, Paraguay

Cultivars	PL (cm)	NSV (unit)	M100S (g)
Pytá'í	17.15 ^{ns}	14.25 ^{ns}	14.60 bcd
San Francisco'í	17.32	13.75	13.32 d
San Francisco Guazú	17.68	12.75	22.46 a
Moteado	17.86	12.50	15.18 bc
Crema	18.37	14.50	13.39 cd
Negrito	16.66	12.50	16.21 b
Tronquito	16.74	14.25	13.67 cd
Mean	17.39	13.50	15.54
CV (%)	4.54	7.38	5.02

PL = pod length, NSV = number of seeds per pod, M100S = hundred seed mass.

Means with different letters in the columns differ from each other by Tukey's test at 5 % probability of error.

^{ns} = not significant at 5 % probability of error by F test

Table 3. Main yield indicators evaluated in the bean cultivar trial, Caazapá, Paraguay

Cultivars	YGP (t ha ⁻¹)	YDG (t ha ⁻¹)	GI (%)
Pytä'i	2.14 abc	1.58 ab	73.83 ^{ns}
San Francisco'i	1.93 abc	1.35 ab	69.94
San Francisco Guazú	1.66 c	1.23 b	74.09
Moteado	2.26 ab	1.58 ab	69.91
Crema	2.42 a	1.82 a	75.20
Negrito	1.93 abc	1.34 b	69.43
Tronquito	1.81 c	1.30 b	71.82
Mean	2.02	1.45	72.03
CV (%)	16.81	13.71	3.37

YGP = yield of grains with pods, YDG = yield of dry grains, GI = grain index. Means with different letters in the columns differ from each other by Tukey's test at 5 % probability of error. RGV = rendimiento de granos con vainas

The grain index variable (Table 3) did not show significant statistical differences, with means between 69.46 and 75.07 %. These values are higher than those reported in the country, in the agroclimatic conditions of the Chaco Central, where averages between 64.63 and 70 % were obtained (3). In this regard, the literature highlights that there is a positive correlation between the grain index and the productivity of dry beans (8).

Considering the importance of bean cultivation for Paraguayan family farmers, from the point of view of food security, economics and environment, these results, by identifying more productive cultivars for this locality, lay the groundwork for further research with similar objectives in other agroecosystems. On the other hand, since the results come from a single planting, they can be considered preliminary and it is suggested that they be repeated at least two more times to obtain conclusive results.

CONCLUSIONS

Crema, Pytä'i, San Francisco'i and Moteado bean cultivars were the most productive, due to their better adaptation to the soil and climatic conditions of the Caazapá district, Caazapá department.

ACKNOWLEDGE

Authors would like to thank the National University of Asuncion, Faculty of Agricultural Sciences and the National Council of Science and Technology (CONACYT) for funding the research (Project 14-INV-114).

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