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Original article

Agronomic response of cowpea cultivars [*Vigna unguiculata* (L.) Walp.] in San Juan y Martínez, Cuba

Respuesta agronómica de cultivares de frijol caupí [*Vigna unguiculata* (L.) Walp.] en San Juan y Martínez, Cuba

Yoerlandy Santana-Baños[1,2*], Sergio Carrodeguas-Díaz[1], Laureano Luis Sosa-Peña[1], Frank Leidis Rodríguez-Espinosa[1], Carlos Manuel Lopetegui-Moreno[3], Maykel Díaz-Barrio[4]

[1]Universidad de Pinar del Río "Hermanos Saiz Montes de Oca", Avenida José Martí No. 270, Pinar del Río, Cuba. CP 20100

[2]Becario Fundación Carolina. Universidad Pública de Navarra, Campus de Arrosadía, Pamplona-Iruñea, España. CP 31006

[3]Instituto de Investigaciones de Fruticultura Tropical. Oficina Nacional de Proyectos. Coordinación Técnica Proyecto Agrocadenas, Ave 7ma No. 3005 entre 30 y 32, Playa, La Habana, Cuba. CP 10500

[4]Ministerio de la Agricultura. Departamento de Protección de Plantas, Ave. Borrego y Calle Los Pinos, Rpto. Hermanos Cruz, Pinar del Río, Cuba. CP 20100

ABSTRACT: Cowpea bean [*Vigna unguiculata* (L.) Walp.] is an important grain legume with agronomic and productive potential under edaphoclimatic conditions in Cuba, but little known and studied in agroecosystems of Pinar del Río. In “San Juan y Martínez” municipality, four cowpea cultivars were established ('INIFAT 93', 'INIFAT 94', 'IPA 206' and 'TITÁN') with the aim of evaluating their growth and yield. The sowing was carried out in spring (04/02/2019), at a frame of 0.60 x 0.15-0.20 m, in a leached Yellowish Ferrallitic soil dedicated to the cultivation of tobacco (*Nicotiana tabacum* L.). A randomized block experimental design with four treatments (cultivars) and four replicates was used. Higher biological productivity and agricultural yield were obtained in the cultivars 'TITÁN' and 'INIFAT 94', which exceeded more than 32 % the production of 'INIFAT 93', although this reached a harvest index higher than 50 % and all expressed indices of vain pods less than 30 %. The increase in the number of pods with shorter length and greater mass of grains per pod enhanced crop yield. The results suggest the use of 'INIFAT 94' and 'TITÁN' in the production of grains in tobacco agroecosystems of Pinar del Río, but different spatial and temporal arrangements must be studied, the contribution of biomass to the soil, the incidence of pests, among other aspects with influence on the productivity and sustainability of the crop.

Keywords: agroecosystem, biomass, grains, productivity.

RESUMEN: El frijol caupí [*Vigna unguiculata* (L.) Walp.] es una importante leguminosa de grano con potencialidades agronómicas y productivas en condiciones edafoclimáticas de Cuba, pero poco conocido y estudiado en agroecosistemas de Pinar del Río. En la localidad “San Juan y Martínez”, se establecieron cuatro cultivares de frijol caupí (‘INIFAT 93’, ‘INIFAT 94’, ‘IPA 206’ y ‘TITÁN’) con el objetivo de evaluar su crecimiento y rendimiento. La siembra se realizó en primavera (02/04/2019), a un marco de 0,60 x 0,15-0,20 m, en un suelo Ferralítico Amarillento Lixiviado dedicado al cultivo del tabaco (*Nicotiana tabacum* L.). Se empleó un diseño experimental de bloques al azar con cuatro tratamientos (cultivares) y cuatro réplicas. Se obtuvo mayor productividad biológica y rendimiento agrícola en los cultivares ‘TITÁN’ e ‘INIFAT 94’, los que excedieron más de 32 % la producción del cultivar ‘INIFAT 93’, aunque este alcanzó un índice de cosecha superior a 50 % y todos expresaron índices de vainas vanas inferiores a 30 %. El incremento del número de vainas con menor longitud y mayor masa de granos por vaina favorecieron el rendimiento del cultivo. Los resultados sugieren la utilización de los cultivares ‘INIFAT 94’ y ‘TITÁN’ en la producción de granos en agroecosistemas tabacaleros de Pinar del Río, aunque se deben estudiar diferentes arreglos espaciales y temporales, el aporte de la biomasa al suelo, la incidencia de plagas, entre otros aspectos, con influencia en la productividad y sostenibilidad del cultivo.

Palabras clave: agroecosistema, biomasa, granos, productividad.

*Author for correspondence: yoerlandy@upr.edu.cu

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INTRODUCTION

Cowpea [*Vigna unguiculata* (L.) Walp.] is an important grain legume native to Africa and widely cultivated and consumed in tropical countries (1,2). Its importance is related to its protein, mineral, carbohydrate and other nutritional attributes (3,4). Its high rusticity and acceptable level of tolerance to drought, temperature anomalies, saline stress, and harmful organisms, among other benefits, also justify the use of this crop.

The production and area dedicated to the cultivation of cowpea beans in the world have increased in recent years, with values that reach 7.2 million tons in 12.5 million hectares and average yield of 0.58 t ha^{-1}. The Caribbean region reaches about 31.9 thousand tons with 43.3 thousand hectares harvested, for an agricultural yield of over 0.70 t ha^{-1} (5,6). In Cuba, this crop can reach agricultural yields between 0.5 and 2.0 t ha^{-1} (7,8), depending on the development conditions, the yield potential of cultivars and other biotic and abiotic factors.

It is suggested that this crop has productive and agronomic potentialities under the climatic and edaphic conditions of Cuba (9,10), which together with the recent affectations in common bean (*Phaseolus vulgaris* L.) increases the interest. It constitutes a promising alternative for the production of grains given the possibility of sowing it in spring, without competing with other crops of agricultural importance.

In this context, the response of cultivars to local edaphoclimatic conditions is essential in the selection of those with greater adaptation due to the influence of genotype-environment interaction (11). However, there are limited studies that demonstrate the productive potential of cowpea bean in agroecosystems of Pinar del Río, Cuba, particularly in tobacco-growing areas, where it can be used as an alternative crop in its main economic line.

In addition, this crop constitutes an acceptable food option little exploited in social consumption and other destinations in the province; hence, knowing its response in local agroecosystems of production can contribute to the availability of the grain. Therefore, the objective was to evaluate the growth and yield of four commercial cultivars in the soil and climatic conditions of San Juan y Martínez.

MATERIALS AND METHODS

This research was developed between April and July 2019 in a tobacco agroecosystem of "San Juan y Martínez", Pinar del Río, Cuba, located at 22° 18′ 13″ North latitude and 83° 47′ 39″ West longitude. The soil was classified as Ferrallitic Yellowish leached (12), with pH values (H_2O) =

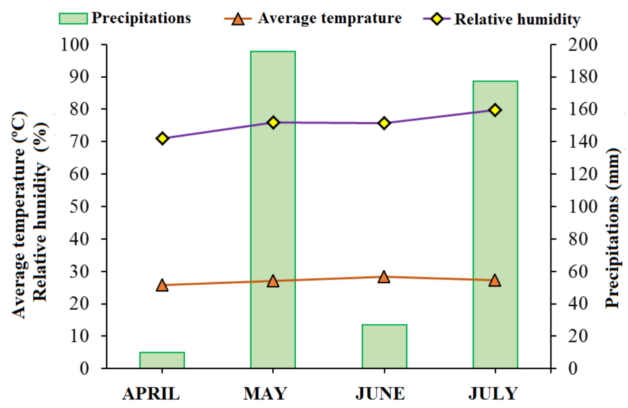


Figure 1. Average values of mean temperature, relative humidity and rainfalls in "San Juan y Martínez", Pinar del Río, Cuba, during the experiment

5.98 and organic matter 1.74 %. An average temperature of 27.1 ° C and relative humidity of 75.6 %, with accumulated rainfall of 409.8 mm, according to data obtained from Meteorological Station No. 314 of the provincial Meteorological Center (Figure 1), characterized climatic conditions during the trial.

Certified seeds of four commercial cowpea cultivars (treatments) were used (Table 1) (10,13,14), distributed in a randomized block design with four replications. The total area of the trial was 450 m^2, with experimental units in 28 m^2 plots. The cultivar 'INIFAT 93' was considered as a commercial production control.

Planting was done manually, in the first decade of April, at a distance of 0.60 m between rows and 0.15 to 0.20 m between plants, with about 12 plants per linear meter. Cultural practices were carried out as recommended for this crop in Cuba (10-15). During the trial there was incidence of pest organisms such as aphids (*Aphis craccivora* Koch), leafhoppers (*Empoasca kraemery* Ross and Moore) and leafminers (*Liriomyza trifolii* Burguess), which were controlled with the pesticides Nicosave (tabaquine), Unifate PS 75 (acephate) and Kospi SC 13 (imidacloprid 10.0 + bifenthrin 3.0) (16). Irrigation was also carried out using the surface furrow method to cover the crop's water needs, particularly in April and June, when rainfall was scarce (15-17).

Yield and its components were evaluated at the time of harvest. Ten plants were randomly selected per plot and each plant was analyzed for the following variables: foliage dry mass (g), pods and grains. For it each one of the parts were separated and kept in an oven for 72 h at a temperature of 65 ºC until constant weight, pod number (u),

Table 1. Characteristics of cowpea cultivars used in the experiment

Cultivar	Grain color	Growth habits	Economical cycle (days)	Yield (t ha^{-1})
'INIFAT 93'	Red	Determined	65 - 70	1.0
'INIFAT 94'	Black	Determined	75 - 80	1.7
'IPA 206'	Beige	No determined	90 - 100	2.0
'TITÁN'	Beige	Determined	72 - 80	1.6

number of grains per pod (u), calculated as the division of the total number of grains by the total number of pods per plant, mass of 100 grains (g), empty pod index (%), valued as the proportion of pods per plant with less than 50 % grain set, and harvest index (%), by the quotient of the dry mass of grains by the dry mass of the aerial part of the plant at harvest (18). To calculate the agricultural yield (t ha^{-1}), 6 m^2 were harvested from the center in each plot, the plants were threshed and the grains were dried to 14 % moisture.

With the data obtained, the assumptions of normality and homogeneity of variances were checked by means of the Kolmogorov-Smirnov and Levene tests, respectively (19). Analysis of variance and Tukey's test were applied for the comparison of means, with a confidence level of 95 % ($p \leq 0.05$), as well as Pearson's correlation between yield components. The statistical software Minitab® version 17.1.0 for Windows (20) was used.

RESULTS AND DISCUSSION

The agricultural yield, in all the cultivars evaluated, showed values higher than 1.00 t ha^{-1}, highlighting 'TITAN' and 'INIFAT 94' with means that expressed significant differences over 'IPA 206' and 'INIFAT 93' and exceeded more than 32 % of what was obtained in the latter (Table 2).

It is evident the possibility of promoting this crop as an alternative for grain harvesting in the face of the growing demand for consumption and the need for import substitution, with cultivars that exceed the average yield statistics of beans in 2018 (1.09 t ha^{-1}) in our country (21). It reaffirms itself as a grain legume with productive potential in climatic and edaphic conditions of Cuba (9,10).

In correspondence with the results obtained, other authors report similar and higher values of agricultural yield in cowpea beans (6,22). In Cuba, particularly, studies carried out in Villa Clara, where they included 'IPA 206', suggest 0.52 t ha^{-1}, in the same sowing date, although it can reach 1.3 t ha^{-1} when it is sown in June (23). Values between 0.84 and 1.72 t ha^{-1} are also highlighted for results obtained with 12 cultivars in a Fluvisol soil of this region (7).

The results constitute, in tobacco agroecosystems of Pinar del Rio, Cuba, the first report on the yield and its components for cowpea cultivars. The variability between these and the reports of authors previously mentioned, demonstrate the influence of the genotype-environment interaction on the grain production (11), as well as the research importance for the selection of cultivars for their productive potential in the prevailing agroclimatic conditions, without discarding the development of new trials that include indicators not evaluated and other localities of interest.

Regarding yield components (Table 2), variations were found among the cultivars studied that are related to grain production, although a compensatory character is observed among certain components of the same cultivar, an element related to the characteristics of the crop and development conditions, which influence the distribution of photoassimilates during the reproductive phase (16,24).

All the components studied, with the exception of 100 grains mass showed significant correlations with crop yield (Table 3), with a strong positive correlation (>0.70) with the number of pods per plant and a negative correlation with their length ($p \leq 0.01$). It justifies the advantages in agricultural yield of cultivars with a greater number of shorter pods. This is a condition of vital importance to reduce peduncle breakage and to reduce pod contact with soil moisture, thus avoiding pod rots that affect grain production. The strong relationship of the pod number per plant with agricultural yield in cowpea beans has been reported by several authors (7,25). The results obtained in this component showed an increase of >27 % in 'TITAN' with respect to other cultivars studied, although the average values agree with some reports that highlight between 19 and 30 pods per plant (10); however, more than 35 pods per plant can be obtained in this crop (24).

Pod length showed highly significant negative correlations with the components grain mass per pod and significant correlations with the number of grains per pod, evidencing its relationship with grain size, which could explain the strong inverse and highly significant relationship of the number of grains per pod with the hundred-grain mass. Other results show similar relationships and indicate that as the plant forms a greater number of vegetative and reproductive structures, seed weight decreases as an expression of a dynamic equilibrium in the source-dump relationship (24,26).

It should be noted that the cultivars with greater pod length ('INIFAT 93' and 'IPA 206') could be used for consumption as beans, without the need to take them to grain production, since they showed lower yields. This possibility allows the diversification of the crop not only agronomically but also as a source of human food in local tobacco production scenarios.

Tabla 2. Agricultural yield and its components in cowpea cultivars harvested in San Juan y Martínez, Pinar del Río, Cuba

Cultivar	AY (t ha^{-1})	PP (u)	PL (cm)	GP (u)	PM (g)	MGP (g)	M100G (g)
'INIFAT 93'*	1.04 b	19.69 c	19.82 a	12.53 b	2.35 b	1.53 c	14.49 b
'INIFAT 94'	1.40 a	25.38 b	15.54 c	13.12 b	2.77 a	2.08 a	18.09 a
'IPA 206'	1.12 b	24.33 b	17.74 b	10.16 c	2.20 b	1.58 c	19.03 a
'TITÁN'	1.55 a	32.42 a	15.20 c	14.76 a	2.32 b	1.80 b	14.41 b
Se x. ±	*0.09*	*0.85*	*0.56*	*0.39*	*0.05*	0.04	*0.40*

Different letters in the same column indicate significant differences (Tukey; $p \leq 0.05$).

AY-agricultural yield, PP-number of pods per plant, PL-pod length, GP-number of grains per pod, PM-pod mass, MGP-mass of grains per pod, M100G-mass of 100 grains, * commercial production control, Se x.-standard error

Table 3. Correlations between cowpea yield components under soil and climatic conditions of San Juan y Martínez, Pinar del Río, Cuba

Pearson Correlation	PP	PL	GP	PM	MGP	M100G	AY
PP	1	-0.563**	0.080ns	-0.041ns	0.100ns	0.002ns	0.868**
PL		1	-0.283*	-0.075ns	-0.439**	-0.064ns	-0.531**
GP			1	0.286*	0.498**	-0.737**	0.327*
PM				1	0.756**	0.213ns	0.304*
MGP					1	0.165ns	0.565**
M100G						1	0.075ns
AY							1

PP-number of pods per plant, PL-pod length, GP-number of grains per pod, PM-pod mass, MGP-mass of grains per pod, M100G-mass of 100 grains, AY-agricultural yield, ns no significant correlation, * significant correlation for ≤0.05. ** Correlation significant for p≤0.01

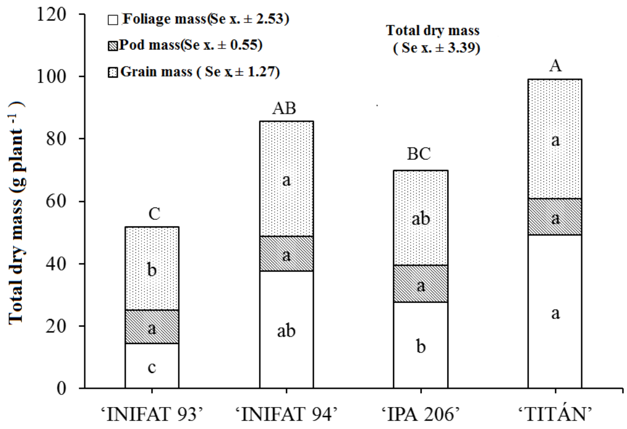
The mass of grains per pod showed a positive and highly significant correlation with agricultural yield and, in turn, highly significant correlations with the number of grains per pod and pod mass, components that also showed significant and positive correlations with crop yield. The highly significant and strong relationship between pod mass and grain mass per pod justifies that, in all cultivars, grain mass represented more than 65 % of pod mass.

Total dry biomass production, at harvest, was higher in cultivars that reached higher agricultural yield (Figure 2), which in turn expressed higher proportions of grain and foliage masses, although these were unequal among cultivars; whereas, pod dry mass was similar and reached proportions ≤21 %. Some studies carried out in cowpea corroborate that the dry mass of the aerial part is a component related to grain productivity (27).

The values of dry biomass accumulation obtained, in any of the cultivars, exceed those reported for the crop (42 g plant^{-1}) under edaphoclimatic conditions of Villa Clara, Cuba. These authors state that environmental changes can interfere in the dry biomass production of a plant species, although there are factors inherent to the plant such as age, distribution of assimilates, variety, and water and nutrient contents (28).

The dry mass of foliage, in 'INIFAT 93', was significantly lower than that obtained in the other cultivars, which allowed it to reach a higher proportion of grain mass with respect to the total mass. It is an aspect that may be related to its erect determined growth; however, the significant increase of foliage in 'TITÁN' responds to a branched growth that allows greater vegetative development. These differences in foliage may influence the photosynthetic efficiency of the cultivars and, therefore, the production of dry mass in reproductive structures (29), which would explain a greater proportion of empty pods in 'INIFAT 94' and 'TITÁN' (Figure 3), since their high production of stems, leaves and pods, may cause competition in the distribution and accumulation of photoassimilates (26).

The production of dry biomass is also of great importance because its incorporation into the soil, in the successional system, recycles nutrients and favors the nutrition of the next crop, demonstrating that it increases the organic matter and the values of pH, nitrogen, phosphorus and potassium (30,31). It is estimated that the values obtained



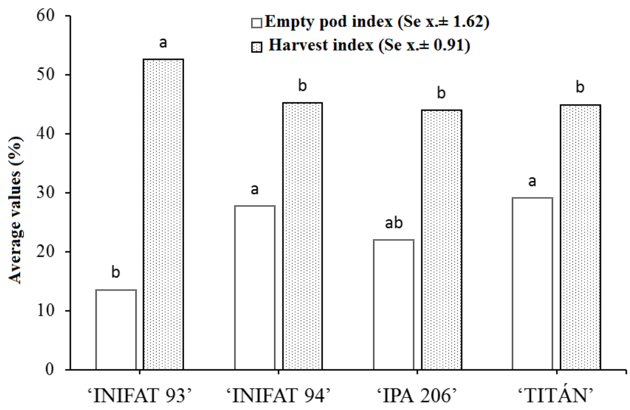
Different letters (upper and lower case) indicate significant differences between cultivars (Tukey; p≤0.05)

Figure 2. Total dry mass (foliage + pods + beans) of cowpea cultivars at harvest in San Juan y Martínez, Pinar del Río, Cubaempty pods index

with 'TITAN' and 'INIFAT 94' exceeded 3.8 t ha^{-1} of dry mass (only foliage). The result suggests developing future trials where the contribution of the cultivars studied to soil improvement is studied in depth, either by the contribution of dry biomass or as green manure, with the aim of promoting the crop among the alternatives of alternation in tobacco agroecosystems with low fertility.

For the first time, harvest indices are reported for cowpea cultivation under soil and climatic conditions in Pinar del Rio, Cuba, reaching values between 44 and 53 % (Figure 3), with a higher average in the cultivar 'INIFAT 93'. These results are similar to those obtained in beans, which oscillate around 50 %, although factors such as the date and distance of sowing, the genetic characteristics of the cultivars and the climatic conditions prevailing in the development of the crop can influence (18,32). It suggests evaluating different spatial and temporal arrangements for the selection of variants that guarantee the highest productivity of the cultivars studied in the edaphoclimatic conditions of the locality. However, the average temperature during the trial was between 25 and 30 °C (Figure 1), considered ideal for this crop (27). Rainfall accumulated in May also favored the development of the cultivars, with a possible influence on the efficiency in the conversion of economically useful dry mass, which could be affected in those with significant increases in foliage and, as a consequence, a higher proportion of empty pods due to the lower use of light, water and nutrients for grain formation. The negative effect of the empty pod index (Figure 3) seems to be accentuated when it exceeds 20 %, although all cultivars expressed values below 30 %.

The above results suggest the development of future trials that will further investigate the efficiency of biomass production, because, although the production of total dry mass (biological productivity) of the plant is important. It is also necessary to ensure that part of this production is destined to the economically useful biomass of the plant (agricultural productivity), which is expressed in the harvest index (18).



Different letters in the bars of each index indicate significant differences (Tukey; p≤0.05)

Figure 3. Empty pod and harvest indices in cowpea cultivars under edaphoclimatic conditions of San Juan y Martínez, Pinar del Río, Cuba

CONCLUSIONS

- Cultivars 'TITAN' and 'INIFAT 94' express higher biological productivity and agricultural yield in the edaphoclimatic conditions of "San Juan y Martinez", which exceed more than 32 % 'INIFAT 93' production; however, the latter reaches a harvest index higher than 50 % and all express indices of empty pods lower than 30 %.
- It is also corroborated that an increase in the number of pods with shorter length and higher mass of grains per pod favors crop yield.
- The results suggest the use of 'INIFAT 94' and 'TITAN' as an alternative for grain production in tobacco agroecosystems in Pinar del Rio, but different spatial and temporal arrangements should be studied.
- The contribution of biomass to the soil, the incidence of pests, among other aspects, influence the productivity and sustainability of the crop.

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