Cultivos Tropicales, 2017, vol. 38, no. 3, pp. 58-63 julio-septiembre

ISSN impreso: 0258-5936
ISSN digital: 1819-4087

Ministerio de Educación Superior. Cuba
Instituto Nacional de Ciencias Agrícolas
http://ediciones.inca.edu.cu

GROWTH AND YIELD OF BLACK BEAN CULTIVARS (*Phaseolus vulgaris* L.) IN LOS PALACIOS TOWN

Crecimiento y rendimiento de cultivares de frijol negro (*Phaseolus vulgaris* L.) en la localidad de los palacios

Lázaro A. Maqueira López✉, Osmany Rojan Herrera, Samuel A. Pérez Mesa and Walfredo Torres de la Noval

ABSTRACT. In the Technological Unit Scientist of Base belonging to the National Institute of Agricultural Sciences of Cuba four black bean cultivar were sowed, in three sowing dates with the objective of analyzing the behavior of its growth and yield. The experimental design was at random of blocks with four repetitions and they were evaluated the agricultural yield, number of grains per sheaths, number of grains per plant, number of sheaths per plant, dry mass of the sheaths, dry mass of the grains, dry mass of the air part, dry mass stem and leaves and the crop index. Among the main results it was found that the highest values of Harvest Index generally correspond with higher yields and that CC-25-9 and Cult-156 cultivars are the best performing in the study conditions. In addition, it stresses that the cultivar "Milagro Villareño" due to high harvest index values despite differences in planting dates, showed greater export capacity of photoassimilates per grains; so it is recommended to use as parent in the breeding program of beans.

Key words: dry matter content, cultivate, grains, crop index

RESUMEN. En la Unidad Científico Tecnológica de Base perteneciente al Instituto Nacional de Ciencias Agrícolas de Cuba se sembraron cuatro cultivares de frijol negro, en tres fechas de siembra con el objetivo de evaluar el comportamiento de su crecimiento y rendimiento en la localidad de Los Palacios. El diseño experimental fue de bloques al azar con cuatro tratamientos y cuatro réplicas. Se evaluó el rendimiento agrícola, el número de granos por vainas, el número de grano por planta, el número de vainas por planta, la masa seca de las vainas, la masa seca de los granos, la masa seca de la parte aérea, la masa seca de los tallos y hojas y el índice de cosecha. Entre los principales resultados se encontró que, los mayores valores de índice de cosecha por lo general se corresponden con los rendimientos más elevados y que los cultivares CC-25-9 y Cult 156 son los de mejor comportamiento en las condiciones de estudio. Además, se destaca que el cultivar Milagro Villareño debido a los altos valores de índice de cosecha a pesar de las diferencias en cuanto a fechas de siembra, mostró mayor capacidad de exportación de fotoasimilados hacia los granos; por lo que se recomienda utilizarlo como progenitor en el programa de mejoramiento genético del frijol.

Palabras clave: contenido de materia seca, cultivar, granos, índice de cosecha

INTRODUCTION

The common bean (*Phaseolus vulgaris* L.) is an annual legume, intensely cultivated from the tropics to the temperate zones (1,2). It occupies more than 80 % of the area planted annually (15 million hectares) of legumes, which contains 2,5 times more protein than cereals and in this lies its nutritional priority (2).

Beans such as corn are an adequate food supplement, and therefore represent a staple food for Latin America. The largest producers in the region are Mexico, which grows 1,6 million hectares with 1,2 million tons and Brazil 3,9 million hectares planted and 3,3 million tons. However, the best yields are obtained in Canada and the United States with 1,9 and Argentina with 1,3 t ha^{-1} (3).

In Cuba, around 100 000 ha per year are planted for dry consumption with an average yield of 1,1 t ha^{-1}. The annual per capita regulated for distribution to the population is 6,9 kg, without taking into account the consumption of institutional dining rooms (3).

Instituto Nacional de Ciencias Agrícolas, Gaveta postal No.1, San José de las Lajas. Mayabeque, Cuba. CP 32700

✉ lalberto@inca.edu.cu

The strategic projection for the cultivation in the country is based on the increase of the sowing areas. As of 2010, it is expected to reach some 135,964 ha and obtain a production of 190,350 t with a yield of 1,4 t ha^{-1}, which represents a great challenge for the country's economy (4).

However, the response of bean cultivars to different environmental conditions is an aspect to be considered in the choice of cultivars with greater adaptation to production zones and in the adjustment of crop management practices. In this sense, the sowing date creates in the crops defined environmental conditions such as water, light, temperature and nutrients that positively or negatively affect the development of the cultivars, as they modify the environment and alter the production of dry matter, the yield of grain and its components, number of plants harvested, pods per plant, grains per pod and grain weight among others (5,6).

Therefore, to achieve stable yields over time or increase them, it is necessary to analyze which are the main factors that contribute to determine the final yield of the crop. Knowing the influence of these and carrying out an adequate management of them.

It is for all of the above that it is of utmost importance to study the performance behavior of different bean cultivars at a local scale, since in most cases the physiological factors that limit yield and its relationship with other crops are not taken into account the behavior of the climate, so this work was developed with the objective of evaluating the growth and yield of four black bean cultivars in the town of Los Palacios.

MATERIALS AND METHODS

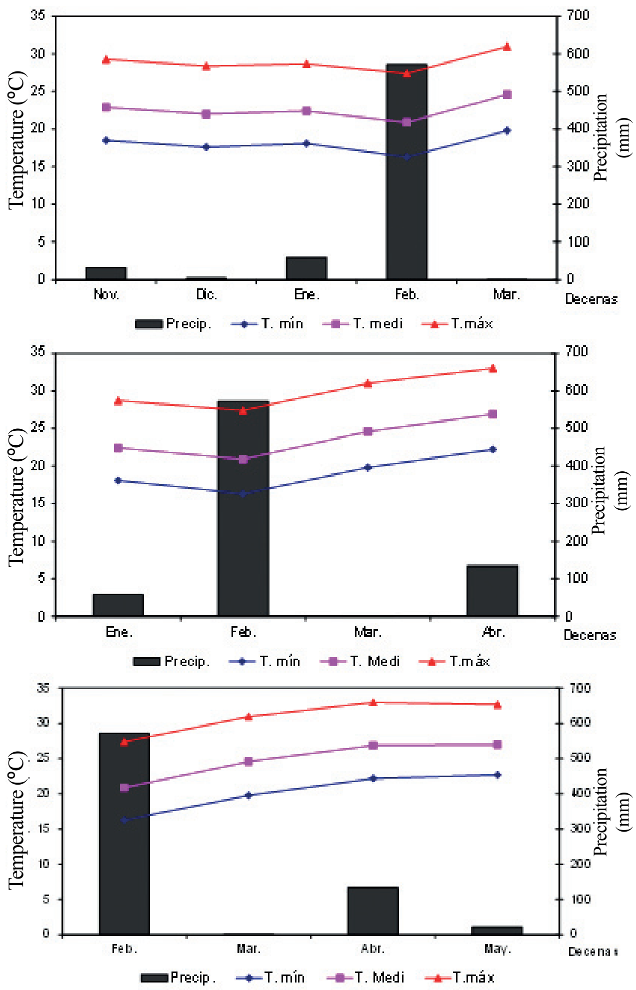
The work was carried out in areas of the Base Scientific Science Unit, Los Palacios (UCTB Los Palacios), Pinar del Río, Cuba, belonging to the National Institute of Agricultural Sciences. To do this, four bean cultivars (CC-25-9, Cult 156, Milagro Villareño, Cufig 48) that are part of the germplasm bank of the Cuban Grain Research Institute were used. These materials were sown on different dates (November 2014, January 2015, and February 2015), corresponding to the cold season, on a Gleysol Nodular Ferruginous Petroferric soil (7). Some of the characteristics of the soil appear in Table I.

Direct sowing technology was used at distances of 0,70 m between rows and 0,05 m between plants, with a standard of 50 kg ha^{-1} of seeds. It was deposited about 24 seeds per linear meter to ensure at least 45 plants per square meter.

Table I. Some properties of the arable layer (0-20 cm) that characterize the fertility of the soil where the experiments were carried out

pH (H_2O)	Ca^{++}	Mg^{+}	Na^{++}	K^{+}	P_2O_5	MO
	Cmol kg^{-1} Suelo				Mg 100 g^{-1} de suelo	%
6,29	6,80	2,91	0,18	0,20	19,77	2,96

The phytotechnical activities were developed as recommended by the Technical Instructions for Bean Cultivation (3). The experimental design was of random blocks with four treatments (the cultivars) and four replicas, with experimental plots of 50 m^2. The behavior of the local climate during the period that the experiments lasted at each planting date appears in Figure 1. These data were informed by the San Diego Paso Real Agrometeorological Station in Los Palacios.



Data taken from the San Diego Paso Real Agrometeorological Station

Figure 1. Temperatures (maximum, average, minimum) and precipitations during the period that the experiments in the field lasted

At the time of harvest, in each experimental plot the agricultural yield (t ha^{-1}) was determined at 14 % moisture of the grain (Yld P). In addition, ten representative plants were taken at random, the edge area was always taken into account and in each plant the following variables were evaluated:

- Dry mass of the pods (M Pods)
- Dry mass of grains (M Grains)
- Total dry mass of the aerial part (total M)
- Dry mass of stems and leaves (M Stems and leaves)
- Number of grains per pod (No Gr.Vai)
- Number of grains per plant (No Grains)
- Number of pods per plant (No Pods)
- Mass of 100 grains (M mil)
- Harvest Index (HI)

To determine the agricultural yield, 9 m^2 of the center were harvested in each plot, the plants were threshed and the grains dried up to 14 % humidity. Regarding the number of grains and number of pods, the value of each variable per plant was counted, and for the amount of grains per pod, the total of grains was divided among the total pods per plant. For the dry mass of the parts of the plant (M pods, M grains, M stems and leaf), each of the parts were separated and kept in an oven for 72 hours at a temperature of 70 ºC until constant weight (8).

The total mass (total M), was calculated by summation of the dry mass of each individual organ. The HI was determined as the quotient of the dry mass of grains between the dry mass of the aerial part of the plant at the time of harvest (dry mass of stems and dry leaves, dry mass of pods) (9). For the same sowing date, each variable was analyzed for variance and the significant differences between the means of the different treatments (cultivars) were verified by the Tukey test at 95 % (10). For the case of yield and its components and the harvest index, the confidence interval was determined taking into account the experimental error of the analysis of variance and the statistical package Statgraphics 5.1 (11) was used.

RESULTS AND DISCUSSION

The behavior of agricultural yield appears in Figure 2. In general, these values varied among cultivars for the same planting date and between dates.

February 2015, is the date in which lower values of this variable were reached, while the highest values were observed in November 2014, although only for cultivars CC 25-9 and Cult 156. This variability may be related to the response of the cultivars before the behavior of meteorological variables such as temperatures and rainfall, which play a fundamental role in the productivity of the crop. As of November 2014, temperatures generally remained more stable during most of the cycle and with values lower than those observed on February 2015, where they were higher (Figure 1).

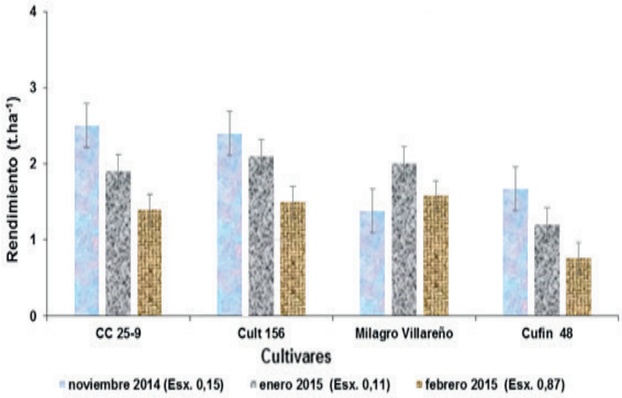


Figure 2. Agricultural yield (t ha^{-1}) at 14 % of grain moisture of bean (*Phaseolus vulgaris* L.) cultivars

The literature highlights that the variability of yields is closely related in recent years to the role played by meteorological conditions in the definition of yield for a particular cultivar, an aspect that explains how some cultivars respond better than others to soil and climatic conditions of a certain location. Also results of research developed indicate the influence of high temperatures (higher than 30 °C) in the decrease of the yields of some species of grains, specifically rice, soybeans and beans (3,12). The results in this paper show that despite the variability in climate, the response of a particular cultivar can be positive in certain prevailing local conditions; that is why it is important to select these by location.

Regarding the result of the components of the yield (Table II), it is possible to highlight that a behavior similar to that observed in the agricultural yield is seen in the mass of the grains, where in general, it is in November 2014 where the crops are concentrated greater values. Some authors relate the good behavior of this variable with higher moisture content in the soil during flowering and the filling stage of the grains (13). Although these authors do not highlight the percentage of soil moisture, they refer to the relationship between the highest values of the mass of the grains and the amount of rainfall that existed during the reproductive stage in the area of the mounted experiments, which exceed the 200 mm.

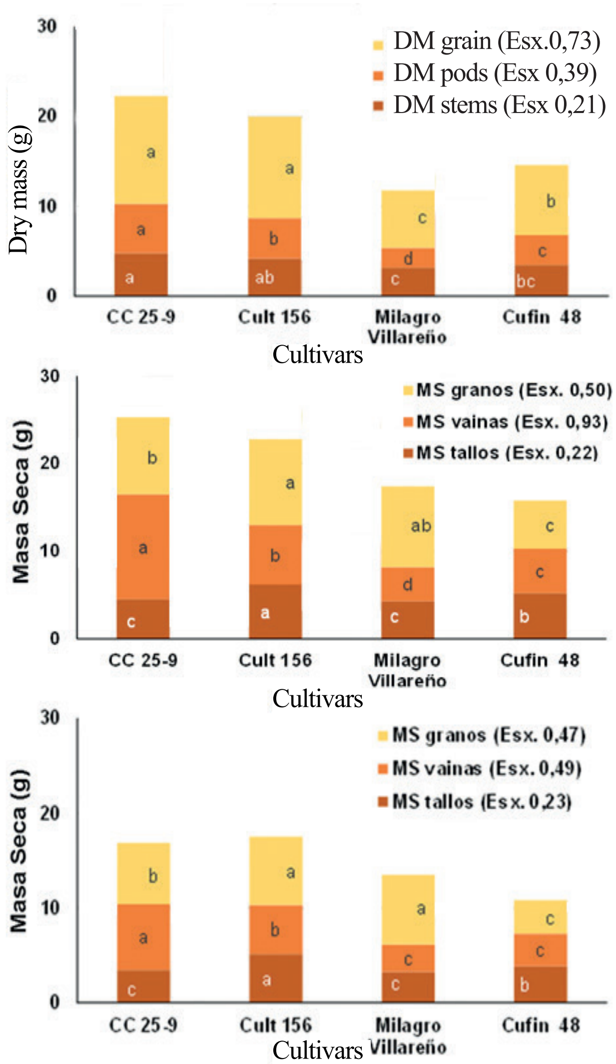
In this sense, for the conditions in which this work was carried out, it is in November 2014 that the greatest amount of rainfall occurred in the period of the reproductive phase (greater than 600 mm), Figure 1. However, as regards to the number of grains per pod the lowest values are on this date. This variability that exists in the cultivars, which present higher values of one component and lower values in the other for the same planting date, could be due to the compensatory character that is established between the components of yield in crops, where it is important The characteristics of the cultivar are linked to the culture conditions, elements that have also been highlighted by other authors (14,15).

Table II. Interval of yield components of bean (*Phaseolus vulgaris L.*) cultivars

Cultivars	Number of pods	Number of grains per pod	Mass of 100 grains
november 2014			
CC 25-9	15,7-22,1	3,3-3,7	17,2-18,8
CUL 156	20,4-26,8	2,4-2,8	17,6-19,2
Milagro Villareño	7,3-13,7	3,1-3,5	18,2-19,8
Cufig 48	8,4-14,8	3,1-3,5	19,9-21,5
Esx	1,6*	0,11*	0,39*
january 2015			
CC 25-9	11,7-14,5	4,0-5,0	14,4-15,6
CUL 156	14,0-16,8	4,0-5,0	13,7-14,9
Milagro Villareño	9,3-12,1	5,0-6,0	15,3-16,5
Cufig 48	8,3-11,1	2,9-3,9	16,2-17,4
Esx	0,70*	0,23*	0,32*
february 2015			
CC 25-9	8,3-10,0	4,0-4,6	15,2-18,6
CUL 156	10,9-12,6	3,1-3,7	16,6-20,0
Milagro Villareño	7,7-9,3	4,1-4,7	18,7-22,1
Cufig 48	7,6-9,2	2,9-3,5	11,6-15,0
Esx	0,42*	0,16*	0,87*

Confidence interval at 95 % probability calculated from the mean taking into account the experimental error of the analysis of variance

Figure 3 shows the dry mass of stems, pods and grains at the time of harvest. In general, an influence of the sowing date was found on the values of dry mass reached by the cultivars, since it is in January 2015 that the highest values of this variable can be appreciated in comparison with the rest of the sowing dates studied. It should be noted that in the three sowing dates the cultivars CC 25-9 and Cult 156 reached the highest values of dry pod mass; In addition, in most cases, a similar behavior is observed in the dry mass of grains for both cultivars. In this sense it should be noted that the cultivar ¨Milagro Villareño ¨also shows a pattern of behavior similar in terms of the dry mass of the grains to the two cultivars previously mentioned, since it is only on a sowing date (November 2014) where lower values of this variable are appreciated.



At each sowing date and for each variable of dry mass, equal letters between cultivars, do not differ statistically for p≤0.05

Figure 3. Dry mass (g plant-1) of stems, pods and grains at the time of harvest of bean plants on three planting dates

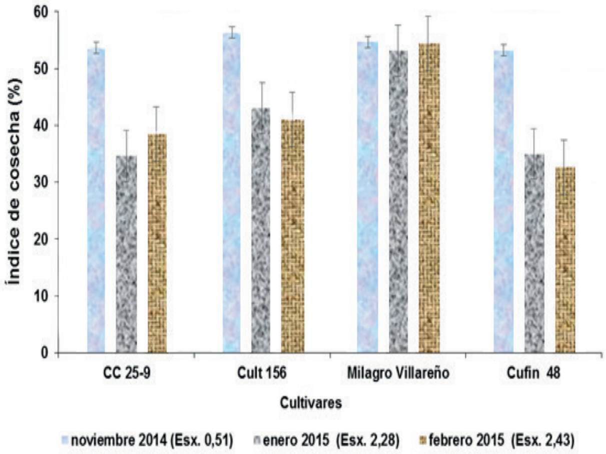
This behavior of cultivar ¨Milagro Villareño¨ may be related to the high amount of rainfall that occurred on this planting date during the stage of filling the grain compared to the two remaining dates under study, which was highlighted earlier in this work. Therefore, the amount of rainfall during the stages in which the grains are filled can be an element to consider for the sowing of this cultivar in conditions where a high probability of rain is predicted. In this sense, some authors stand out (16), that although for the cultivation of beans, irrigation is very important to achieve yield increases, it is necessary that the final stages of growth do not coincide with periods of high rainfall to avoid damage to seeds excess moisture (3).

All the previous evidence once again that the differences that are appreciated between cultivars in the sowing dates can be related to the characteristics of each cultivar, especially for the growth of the plants under different climatic conditions. There are cultivars that in the cold season or under certain circumstances, reach a smaller size, their leaves are smaller among other characteristics (12). These elements, together with a low photosynthetic activity can bring with it a lower production of dry mass in both vegetative and reproductive organs (17).

In this sense, it is worth noting that the accumulation of dry mass in a crop is given by the balance of carbon metabolism, considering that beans are a C_3 plant type where there are losses by respiration and photorespiration mainly in the stages of cultivation where the air temperature increases; however, other meteorological variables, such as solar radiation and relative humidity, also affect it (18). In addition, although the production of total dry mass (biological productivity) of the plant is important, it is also necessary to guarantee that part of that total production is destined to the economically useful part of the plant (agricultural productivity) where the HI is a variable which indicates the difference between these two productions.

When analyzing the HI (Figure 4) it can be seen that in general there are differences between cultivars. It is valid to highlight how the cultivar ¨Milagro Villareño ¨ in all sowing dates maintained values close to 50; in addition, the other three cultivars on the sowing date of November 2014 also reached values similar to the one previously mentioned, an aspect that generally coincides for this sowing date with the highest yields. The values for the bean of the HI are normally between a range of 50 and 60. Lower indices indicate a poor formation of the pods or seeds in relation to the development of the crop (19).

Therefore, cultivars CC 25-9, Cult 156 and Cufin 48 at the sowing dates of January and February 2015 reached a deficient agricultural productivity in correspondence with that reported in the literature, since the HC values are found in the highest of cases close to 40.



The bars represent confidence intervals at p≤0.05

Figure 4. Harvest of bean cultivars on three planting dates

These results show how there can be a low efficiency in the conversion of economically useful dry mass in bean cultivars according to the sowing dates. This may be related to the genetic characteristics and the response of the cultivar to the prevailing conditions during its development.

In the literature, it is suggested that HC values may vary between sowing dates for the same cultivar and it also emphasizes that sowing density and prevailing climatic conditions may influence the different stages of crop development (14). It also highlights the importance of HC to have a measure of the efficiency of the plant in certain weather conditions especially in the use of light, water and nutrients in terms of producing grains (20). In studies carried out in the bean crop, the differences found between cultivars in the HC are evidenced and generally, where the highest value of this variable was reached, the highest yields were found (21).

CONCLUSIONS

- Based on the foregoing, it is possible to conclude that the highest values of harvest index correspond to the highest yields; although, it depends to a great extent on the cultivar and the conditions under which it is developed. Cultivars CC 25-9 and Cult 156 are those with the best performance in terms of growth and yield under the study conditions.

- ♦ The cultivar ¨Milagro Villareño¨ due to the high values of the harvest index, despite the prevailing conditions, showed greater export capacity of photoassimilates to the grains. Taking into account this element, it is recommended to use this cultivar as parent in the breeding program of beans.

BIBLIOGRAPHY

1. Hernández-López VM, Vargas-Vázquez MLP, Muruaga-Martínez JS, Hernández-Delgado S, Mayek-Pérez N. Origen, domesticación y diversificación del frijol común: Avances y perspectivas. Rev Fitotec Mex. 2013;36(2):95–104.
2. Porch TG, Beaver JS, Debouck DG, Jackson SA, Kelly JD, Dempewolf H. Use of Wild Relatives and Closely Related Species to Adapt Common Bean to Climate Change. Agronomy. 2013;3(2):433–61.
3. Faure AB, Benítez GR, Rodríguez AE, Grande MO, Torres MM, Pérez RP. Guía técnica para la producción de frijol común y maíz. 1st ed. La Habana, Cuba: Instituto de Investigaciones en Fruticultura Tropical; 2014. 22 p.
4. Benítez R. Nuevas variedades de frijol común para la producción comercial en Cuba. In La Habana, Cuba; 2011. p. 109–10.
5. Giménez L. Comportamiento fenológico de diferentes grupos de madurez de soja (*Glicine max*) en Uruguay. Ubicación temporal del período crítico. Agrociencia. 2007;11(2):1–9.
6. El-Aal HA, El-Hwat N, El-Hefnawy N, Medany M. Effect of Sowing Dates, Irrigation Levels and Climate Change on Yield of Common Bean (*Phaseolus vulgaris* L.). Am-Eurasian J Agric Environ Sci. 2011;11(1):79–86.
7. Hernández JA, Pérez JJM, Bosch ID, Castro SN. Clasificación de los suelos de Cuba 2015. Mayabeque, Cuba: Ediciones INCA; 2015. 93 p.
8. Maqueira LA, Torres W, González D, Shiraishi M. Evaluación del comportamiento de variables del crecimiento en variedades de arroz de tipo japónica condiciones de secano favorecido. Cultiv Trop. 2014;35(1):43–9.
9. Sabouri H, Sabouri A, Dadras AR. Genetic dissection of biomass production, harvest index and panicle characteristics in *Indica-Indica* crosses of Iranian rice (*Oryza sativa* L.) cultivars. Aust J Crop Sci. 2009;3(3):155–66.
10. Tukey JW. Bias and confidence in not quite large samples. Ann Math Stat. 1958;29(2):614–23.
11. 11. Statistical Graphics Crop. STATGRAPHICS® Plus [Internet]. 2000. (Profesional). Available from: http://www.statgraphics.com/statgraphics/statgraphics.nsf/pd/pdpricing
12. Zonetti P da C, Suzuki LS, Bonini EA, Ferrarese MLL, Ferrarese-Filho O. Altas temperaturas, crecimiento y lignificación de soya transgénica resistente al glifosato. Agrociencia. 2012;46(6):557–65.
13. Rodríguez R, López S, Tosquy V. Componentes del rendimiento de frijol negro en diferentes fechas de siembra durante ciclo otoño-invierno en el norte de Veracruz, México. Rev Biológico Agropecu Tuxpan. 2014;2(3):266–70.
14. Chacón A, Pedraza C, Barreda A, Colás A, Alemán R, Rodríguez G. Caracterización agronómica del crecimiento en el cultivar de soya Incasoy-27 (*Glycine max* (L.) Merr.) en una época de siembra. Cent Agríc. 2011;38(3):29–36.
15. Morejón R, Díaz SH, Hernández JJ. Comportamiento de tres variedades comerciales de arroz en áreas del Complejo Agroindustrial Arrocero «Los Palacios». Cultiv Trop. 2012;33(1):46–9.
16. Boudet A, Boicet T, Radame Oduardo. Rendimiento y sus componentes en variedades de frijol común (*Phaseolus vulgaris* L.) bajo condiciones de sequía en Rio Cauto, Granma. Cent Agríc. 2015;42(3):61–68.
17. Barrios MB, Buján A, Debelis SP, Sokolowski AC, Blasón ÁD, Rodríguez HA, et al. Relación de raíz/biomasa total de Soja (*Glycine max*) en dos sistemas de labranza. Terra Latinoam. 2014;32(3):221–30.
18. 18. Azcón BJ, Talón M. Fundamentos de la Fisiología Vegetal. España: Universidad de Barcelona; 2000. 522 p.
19. CIAT. Informe del Centro Nacional de Agricultura Tropical. Cali, Colombia; 1988 p. 130.
20. 20. Hernández N, Soto F. Influencia de tres fechas de siembra en el crecimiento y rendimiento de especies de cereales cultivadas en condiciones tropicales. Parte II. Cultivo del sorgo (*Sorghum bicolor* l. Moench var. Isiap Dorado). Cultiv Trop. 2012;33(2):50–4.
21. Morales-Rosales EJ, Escalante-Estrada J a. S, López-Sandoval JA. Crecimiento, índice de cosecha y rendimiento de frijol (*Phaseolus vulgaris* L.) en unicultivo y asociado con girasol (*Helianthus annuus* L.). Univ Cienc. 2008;24(1):1–10.

Received: June 3rd, 2016
Accepted: December 22nd, 2016

Revista Cultivos Tropicales
Instituto Nacional de Ciencias Agrícolas