ISSN print: 0258-5936
ISSN online: 1819-4087

Ministry of Higher Education. Cuba
National Institute of Agricultural Sciences
http://ediciones.inca.edu.cu

SCIENTIFIC PRODUCTION ABOUT BIOFERTILIZER IN CUBA IN THE 2008-2012 PERIOD: A BIBLIOMETRIC ANALYSIS OF CUBAN JOURNAL

La producción científica sobre biofertilizantes en Cuba en el período 2008-2012: un análisis bibliometrico de las revistas cubanas

Maida D. Peña Borrego[1]✉, María R. de Zayas Pérez[2] and Rosa M. Rodríguez Fernández[1]

ABSTRACT. The study aims at characterizing the process of the scientific research about biofertilizers in scientific magazines of Cuba during the period 2008-2012, by means of the analysis of bibliometric indicators, in order to determine the regularities of the scientific production by authors and institutions, as well as, the collaboration between provinces, institutions and other nations, in addition to the microorganisms and the crops more often investigated in this subject. As source of information, the author consulted the published in 14 scientific magazines certified by CITMA, as scientific and technological publications. For the analysis of the data Excel, ToolInf and Ucinet 6,0 were used. The year 2008 resulted to be the most productive; thought there was a decrease on the issue of articles about biofertilizers in this period. The Cuban provinces of Mayabeque, Havana and Villa Clara, are the productive centre of these researches. And the most active institutions were: INCA, INIFAT and the Faculty of Biology in the University of Havana, establishing strong collaboration links toward the western region of the country. Concerning international collaboration, Brazil and Mexico, were the countries which contributed the most to the scientific results with Cuban institutions through national publications. Sorghum (*Sorghum bicolor* and *Sorghum vulgare*), rice (*Oryza sativa*), cabbage (*Brassica oleracea*), tomato (*Solanum lycopersicum*), sugar-cane (*Saccharum officinarum*), maize (*Zea mays*), papaya (*Carica papaya*) and canavalia (*Canavalia ensiformis*) were the main agricultural farmings in which a greater number of biofertilizing microorganisms were evaluated; among which, the genus most frequently studied are: *Glomus, Rhizobium, Bradyrhizobium, Azotobacter, Gluconoacetobacter and Pseudomonas.*

Key words: biofertilizers, journal, scientific production

RESUMEN. El estudio tiene como objetivo caracterizar el comportamiento de la investigación científica sobre biofertilizantes en revistas científicas de Cuba durante el período 2008-2012, mediante el análisis de indicadores bibliométricos para determinar las regularidades de la producción científica por autores e instituciones, así como la colaboración entre provincias, instituciones y otras naciones, además de los microorganismos y cultivos agrícolas más trabajados en la temática. Se tomó como fuente de información los artículos publicados en 14 revistas científicas certificadas por el CITMA como publicaciones científicas y tecnológicas. Para el análisis de los datos, se empleó el Excel, ToolInf y Ucinet 6.0. Resultó que el año 2008 fue el más productivo, aunque se manifestó un decrecimiento de los artículos sobre biofertilizantes en el período. Las provincias Mayabeque, La Habana y Villa Clara, constituyen el nicho productivo de estas investigaciones. Las instituciones de mayor actividad científica fueron INCA, INIFAT y la Facultad de Biología de la Universidad de la Habana, estableciéndose fuertes lazos de colaboración en el país hacia la región occidental. Respecto a la colaboración internacional, fueron los países de Brasil y México, los que más contribuyeron a resultados de investigación con entidades cubanas a través de publicaciones nacionales. El sorgo (*Sorghum bicolor y Sorghum vulgare*), arroz (*Oryza sativa*), col (*Brassica oleracea*), tomate (*Solanum lycopersicum*), caña (*Saccharum officinarum*), maíz (*Zea mays*), papaya (*Carica papaya*) y canavalia (*Canavalia ensiformis*) fueron los principales cultivos agrícolas en los cuales se evaluaron un mayor número de microorganismos biofertilizantes, que entre los géneros de mayor nivel de estudio se encuentran *Glomus*, *Rhizobium*, *Bradyrhizobium*, *Azotobacter*, *Gluconoacetobacter* y *Pseudomonas.*

Palabras clave: biofertilizantes, revistas, productividad científica

[1] Centro de Estudios para Agroecosistemas Áridos, Universidad "Oscar Lucero Moya", Avenida XX Aniversario, Vía Guardalavaca, Piedra Blanca, Holguín, Cuba.

[2] Centro de Información y Gestión Tecnológica de Holguín, calle 18 S/N, entre 1ra y Maceo, Reparto El Llano, Holguín, CP 80100, Cuba.

✉ mpborrego@facing.uho.edu.cu; mrosa@ciget.holguin.inf.cu; rmargarita@ict.uho.edu.cu

INTRODUCTION

Biofertilizers are preparations that contain beneficial microorganisms used in agriculture to be applied to seeds, plants, and soil in order to increase productive yield (1).

The use of biofertilizers in Cuba dates back to early XX century with the inoculation of Rhizobium extracted from US isolates to grow leguminous plants at the then Central Agronomical Station of Cuba, the current National Institute of Fundamental Research on Tropical Agriculture (INIFAT), where the application of biofertilizers in Cuba has been widely dealt with (2).

In the eighties, research studies on this topic gained momentum with the creation of the National Biological Front and the development of other scientific institutions in Cuba. Since the emergence of these research line, different paradigms have been assumed, from simple inoculants (3), mixed inoculants (4, 5), both marked by the biotechnological industry, and more recently the artisan production of biofertilizers (6), where grower can prepare these formulations from resources provided by the ecosystem.

Different Cuban authors have studied the potential of biofertilizers (1, 2, 7, 8, 9, 10, 11, 12, and 13). However, the results from science and innovation on biofertilizers are not widely applied by Cuban growers, neither in most of the underdeveloped countries (14, 15). This situation led to the creation in Cuba of the Government Program for Biofertilizers, Biopesticides and Biostimulants, in order to increase research, production and availability of these products at the service of an agriculture on sustainable basis through the accumulated capacities in the country since the creation and development of production network of biofertilizers and bioestimulants in the nineties (13). Hence, the importance of knowing how scientific production on biofertilizers is going on in the country so that strategies can be devised to increase the visibility and distribution of magazines that promote knowledge on this issue and strengthen research towards crops of economic interest in some regions of the country.

Bibliometric indicators of agricultural research in Cuba have been evaluated by different authors (16, 17, 18, 19, and 20).

These studies have made possible the evaluation of the scientific productivity of Cuban researchers and the main magazines being published; however, they do not deal with the behavior of the studies on biofertilizers.

A bibliometric analysis made by the magazine Pastos y Forrajes (Pastures and Fodders) from 1978 to 2000, mention biofertilizers, though research was oriented to the change of paradigm in cattle raising (21). This study showed that biofertilizers were one of the knowledge areas with the highest annual historical average of articles in such magazine during the evaluated period and the first article, published in 1982, dealt with the inoculation of seven isolates of Rhizobium in Leucaena.

Nevertheless, these studies did not deepen on the behaviour of research about fertilizers in agricultural and livestock science. Hence, a first approach to current scientific production in Cuba on biofertilizers is done through a bibliometric studty in Cuban scientific magazines from 2008 to 2012. The selected study period allowed determining existing knowledge from the most recent scientific literature, greatly used to transfer knowledge to the agricultural and livestock community and manage projects on this topic.

MATERIALS AND METHODS

As a unit of analysis a magazine was selected and the information on biofertilizer articles was processed from 2008 to 2012 in 14 certified scientific magazines (Table I) as scientific and technological publications of the Ministry of Science, Technology, and Environment in Cuba (CITMA) (22). A total of 112 scientific articles on biofertilizers were found in each number published in scientific magazines related to biofertilizers, as those of agricultural, livestock and biological sciences. Though it is known that several researches on this topic are published in magazines far distant from this nature, it is understood as a limiting factor for this study.

Bibliometric analysis

Data compilation and processing was made with Microsoft Excel and ToolInf, an analytical tool developed by BioMundy Consultancy in Cuba that permits homogeneizing and counting data as well as matrix preparation (23, 24).

Information was structured in two fields: Title of the article, authors, institution, province, international collaboration, magazine, publishing year, beneficial microorganisms, and agricultural crop.

Finally, the resulting files were taken to Ucinet and within it, NetDraw (http://www. analytictech.com/ucinet/trial.htm) was used, to obtain matrix of co-ocurrence between two variables which allowed mapping, editing and analyzing social matrix and make them visual.

The indicators used in the study were: productivity per year, productivity per magazine, authoring productivity, relationship among authors and magazine, institutional productity, relationship among national institutions, productivity per province, main collaborating countries, main microorganisms, and main agricultural crops.

Table I. List of scientific magazines certified by CITMA as scientific and technological magazines consulted and the institutions in charge of their publication

Scientific magazine	Institution
Cultivos Tropicales	National Institute of Agricultural Sciences (INCA)
Revista Cubana de Ciencias Agrícolas	Institute of Animal Science (ICA)
ICIDCA. Sobre los derivados de la caña de azúcar	Cuban Research Institute on Sugarcane Byproducts (ICIDCA)
Pastos y Forrajes	Experimental Station of Pastures and Fodder "Indio Hatuey" (EEPF)
Agrotecnia de Cuba	Fundamental Research Institute on Tropical Agriculture "Alejandro de Humboldt" (INIFAT)
Revista Cubana de Plantas Medicinales	Higher Institute of Medical Science (Havana) (UCMH)
Revista de Protección Vegetal	National Center of Animal Health (CENSA)
Fitosanidad	Plant Protection Research Institute (INISAV)
Revista Cubana del Arroz	Rice Research Institute (IIA)
Biotecnología Aplicada	Genetic Engineering and Biotechnology Institute (CIGB)
Centro Agrícola	Agricultural Research Center of the Central University of Villa Clara (UCLV)
Ciencia y Tecnología Ganadera	Research Center for Animal Breeding in Tropical Livestock Tropical (CIMAGT)
Revista CENIC. Ciencias biológicas	National Scientific Research Center (CENIC)
Acta Botánica Cubana	Ecology and systematic Institute (IES)
Revista Ciencias Técnicas Agropecuarias	Agrarian University of Havana (UNAH)

RESULTS AND DISCUSSION

Productivity per year

The distribution of the 112 scientific articles on biofertilizers analyzed in the 2008-2012 period allowed evaluating the recent behavior of research on this topic (Figure 1). There is a decrease of articles on biofertilizers in the studied magazines; the highest quantity was attained in 2008 and 2010; "Cultivos Tropicales" was the magazine that most published articles on the topic in both years.

A study on the visibility of Cuban agricultural sciences from 2000 to 2008, showed an ongoing reduction of the number of national publications in this sector (25). This trend constrasts with the quantity of agricultural Cuban magazines now; it reflects the policy of the Cuban government to foster scientific publications and the academic dialogue in this field.

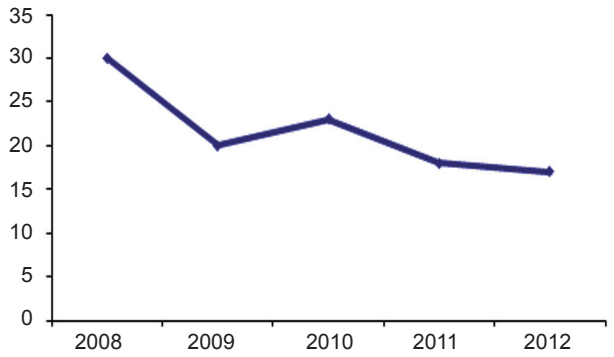


Figure 1. Quantity of articles on biofertilizers published by year from 2008 to 2012

Productivity by magazine

The main Cuban magazines that published results on biofertilizer investigations from 2008 to 2012 belong to the Ministry of Higher Education (MES) and were "Cultivos Tropicales" with 52 articles, "Centro Agrícola" with 14 articles and "Pastos y Forrajes" with 12. It matches those of highest frequency in agricultural sciences since their foundation in the seventies (19).

The fact that major Cuban magazines publishing articles on biofertilizers belong to the Ministry of Higher Education, is due to the intensive research from institutions of this Ministry that has meant to take into account this topic with the increase of research in this knowledge area. For example, the magazine "CultivosTropicales" around 1997, considered biofertilizers as one of the topic lines and it became the most productive one within MES from 1989 to 1998, with an average of 39,7 articles per year (19).

Besides, scientific magazines from MES are registered like the ones with more articles on agricultural sciences (25), despite the quantity of agricultural mags of the Ministry of Agriculture and MES are similar.

Out of the 14 analyzed magazines, SCOPUS: Cuban Journal of Agricultural Science, Biotecnología Aplicada and Revista Cubana de Plantas Medicinales, may be found. Their ranking was established with the support of indexes from SCImago Journal Rank (SJR) and index H (Table II). The results of Cuban magazines are not significant as compared to those of the German magazine Biology and Fertility of Soils that account for SJR values of 1,108 and 69 of index H and published 11 scientific articles on biofertilizers between 2008 and 2012.

Table II. Cuban scientific magazines published on biofertilizers and indexed on the Scopus Data Base

Publication	Quantity of articles on biofertilizers 2008-2012	SJR	Index H
Biotecnología Aplicada	1	0,118	8
Cuban Journal of Agricultural Science	3	0,110	7
Revista Cubana de Plantas Medicinales	1	0,102	5

Source: SCImago Journal (SJR) & Country Rank from Scopus data

Authors' productivity

A total of 268 researchers were involved in trials on biofertilizers. Among the twelve most productive authors with more than seven articles (Figure 2), the first four were deeply studied: Ramón Rivera Espinosa, from INCA, is the most productive author of the period; his main line is on mycorrhizal biofertilizers. The productivity of this author is due to the high level of co-authorship maintained for collaborating with other researchers. The main national magazine in which he published his articles was "Cultivos Tropicales".

Bernardo Dibut Álvarez, author from INIFAT, published articles on the soil-plant relationship and on the endophyte *Gluconoacetobacter diazotrophicus*, mainly in the magazines "Agrotecnia de Cuba" and "Cultivos Tropicales". He outstands for the number of authorship, out of the eleven articles published in this period, six belong to him.

María C. Nápoles García, works at INCA, she published articles on biological nitrogen fixation, particularly with the study of Bradyrhizobium and nodulation factors, the results of the research were mainly published in "Cultivos Tropicales" and "Pastos y Forrajes".

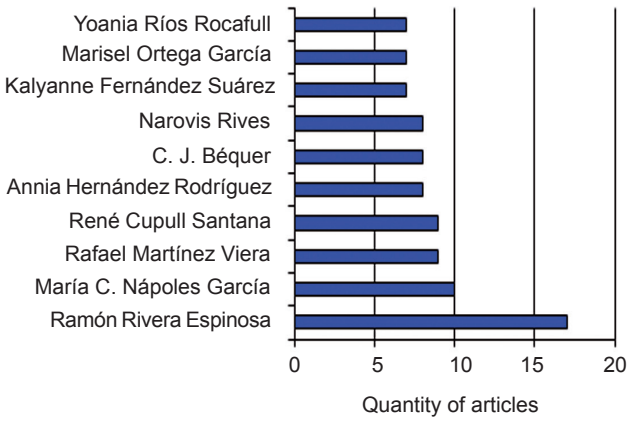


Figure 2. Distribution of cuban scientific articles on biofertilizers (2008-2012) by main authors

Rafael Martínez-Viera (†), author from INIFAT, co-studied with Bernardo Dibut the soil-plant relationships by endophyte bacteria like Gluconoacetobacter diazotrophicus and published the results in "Agrotecnia de Cuba" and "Cultivos Tropicales". This author was awarded within the XXIV Latin American Meeting on Rhizobiology (RELAR) and the I Iberoamerican Conference on beneficial interactions of microorganisms-plant-environment "IBEMPA", for his outstanding participation in the study of biofertilization in Cuba and the international dissemination of this topic (26).

On the other hand, on the visibility of Cuban agricultural sciences seen at the Cubaciencia database from 2000 to 2008, the most productive authors had between 16 and 37 scientific articles (25); however, any of the researchers on biofertilizers was included among the 22 most productive authors of agricultural and livestock sciences of Cuba in that period. If such a study would have been made from 2008 to 2012, only Ramón Rivera Espinosa, with 19 articles would be among the most productive ones because of collaboration and co-authorship links.

Relationship between authors and magazine

Figure 3 shows the relationship among authors with more than three articles and the magazines in which they publish their results; it also shows that most of them are published in more than one magazine and the existence of a network as a result of the alliance level among authors from different institutions.

The magazine in which most authors publish their articles is "Cultivos Tropicales", which coincides with that of more articles per year on biofertilizers due to the acceptance of the magazine within the scientific community of the agricultural and livestock sector (19, 25).

However, magazines with less publications (less than three articles) on biofertilizers from 2008 to 2012, were "Ciencia y Tecnología Ganadera", "Revista Ciencias Técnicas Agropecuarias", "Acta Botánica Cubana", "Revista Cubana de Plantas Medicinales", "Biotecnología Aplicada" and "Ciencias biológicas". It coincides with their topic spectrum, either by their specialization level within agricultural and livestock sciences or because they tribute to medical and biological sciences.

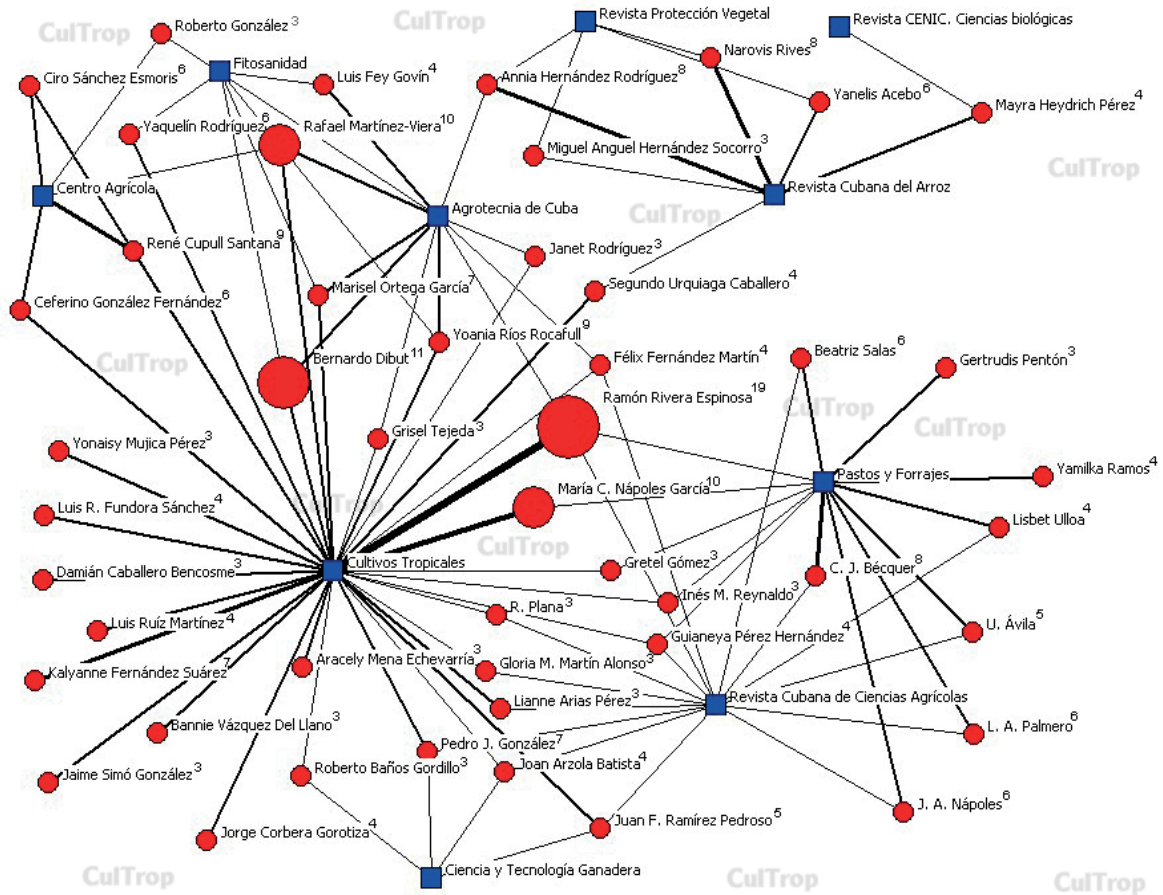


Figure 3. Relationship among Cuban researchers on biofertilizers, quantity of articles and scientific magazines from 2008 to 2012

Institutional productivity

The analysis of the most productive institutions (Figure 4) showed that 74 % of the publications related to this topic belong to Research Institutes. INCA runs first with 47 %, then universities with 20 %, the University of Havana stands out and the rest 6 % pertains to Experimental Stations of Pastures and Fodders in Sancti Spíritus and "Indio Hatuey" in Matanzas.

The main institutions that research on biofertilizers enjoy a great prestige because of their tradition, the quality of human resources and the technological capacity according to the interest of the Government in the scientific development of the country, especially in INCA. This institution was founded in March 1970 by Commander in Chief Fidel Castro Ruz, it has a Nutrition and Biofertilization Department, a mycorrhizal lab and a plant to produce ECOMIC. Since 1977, INCA is a postgraduate center in Cuba and as such, develops PhD courses, master courses, specialties, diploma courses and training on this topic for which a highly qualified staff is an essential support.

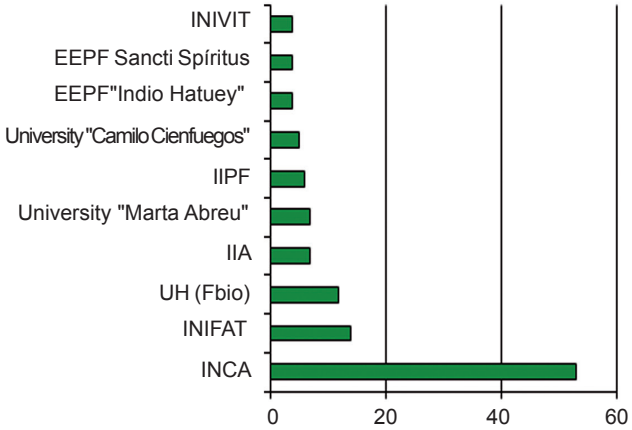


Figure 4. Distribution of articles on biofertilizers (2008-2012) in the main institutions of the country

INIFAT as the oldest Agronomical Experiment Station, was pioneer in the studies of biofertilizers in the country since 1904; nontheless, after the triumph of the Revolution in 1959, such studies were taken up back again by the Soil Institute and University of Havana.

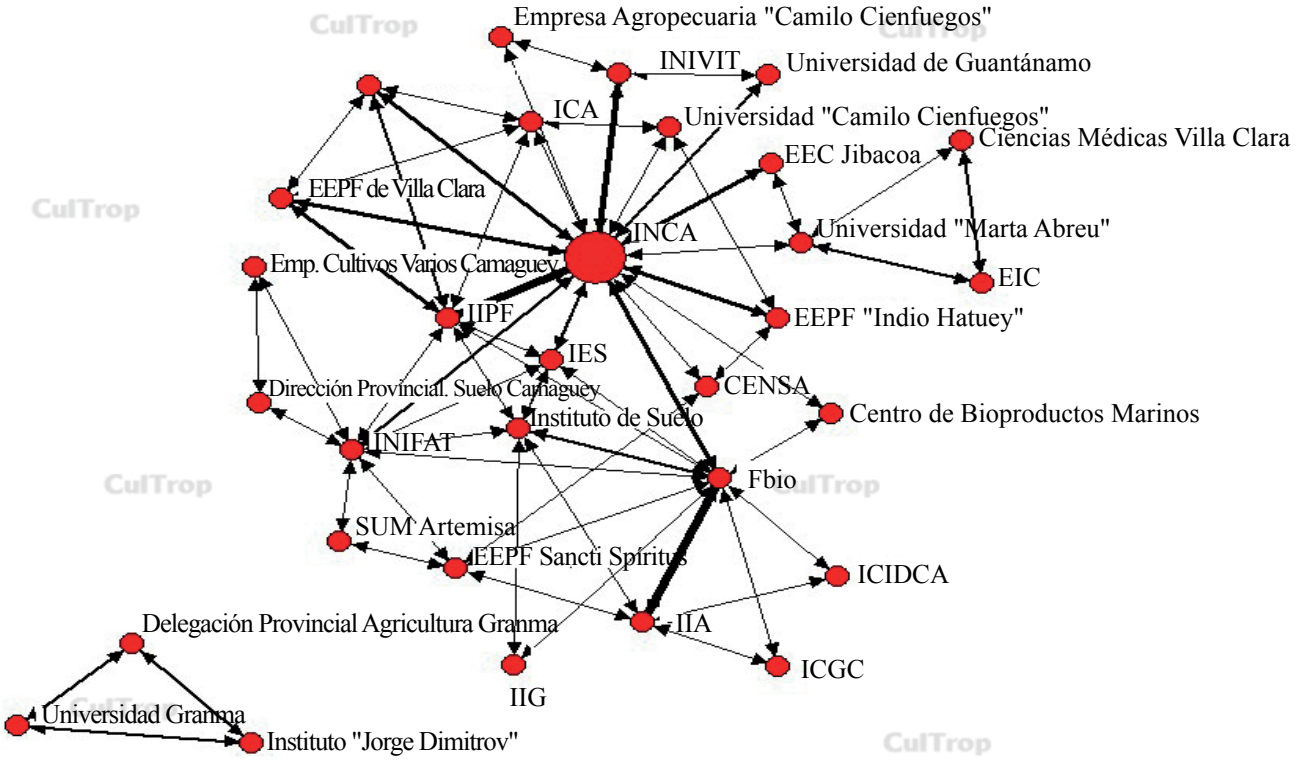
At present, INIFAT has a Topic Group on Biofertilizers that has developed manufacturing technologies of biofertilizers and biostimulants from Azotobacter and other microorganisms.

The Faculty of Biology of the University of Havana, founded in 1976, has a Department of Soil Microbiology with a staff of 29 professors and researchers, out of whom 11 are PhD and 10 are Masters in Science. This department coordinates a master course of Microbiology and also teaches pre and postgraduate courses closely related to biofertilization, soil microbiology, microbiology of fermentation processes and microbial ecology.

Relationship among national institutions

Looking at the relationship among Cuban institutions (Figure 5), a network stands out with prominent communication centers like INCA, INIFAT, and the University of Havana. INCA maintains strong links with IIPF, ININIT, "Indio Hatuey" Experiment Station on Pastures and Fodders and the University of Havana.

INCA's strong position is marked by the training services on biofertilizers, postgraduate courses, master and PhD courses, among them. Institutions from Granma province are not included in this network and do not collaborate with other institutions out of the province.



INCA: Instituto Nacional de Ciencias Agrícolas
INIFAT: Instituto Nacional de Investigaciones Fundamentales de Agricultura Tropical
Fbio: Facultad de Biología de la Universidad de la Habana
IIPF: Instituto de Investigación de Pastos y Forrajes
EEPF: Estación Experimental de Pastos y Forrajes
ININIT: Instituto Nacional de Investigaciones de Viandas Tropicales
EEC: Estación de Investigaciones del Café
EIC: Estación de Investigaciones del Café
EPG: Empresa Pecuaria Genética
CENSA: Centro Nacional de Sanidad Agropecuaria
EET: Estación Experimental del Tabaco
ICA: Instituto de Ciencia Animal
ICIDCA: Instituto Cubano de Investigaciones de los Derivados de la Caña de Azúcar
IES: Instituto de Ecología y Sistemática
IIA: Instituto de Investigaciones del Arroz
IIG: Instituto de Investigaciones de Granos
SUM: Sede Universitaria Municipal
ICGC: Instituto Cubano de Geodesia y Cartografía

Figure 5. Relationship among Cuban institutions involved in research on biofertilizers from 2008 to 2012

Among the universities with more participation in the network of institutions are the University of Havana, the University of Villa Clara, the University of Guantánamo, the University of Matanzas and the University of Granma. However, there are not relations among them, but it does with other institutions at the province level.

Productivity by province

Among the most outstanding provinces in research on biofertilizers from 2008 to 2012 are: Mayabeque, Havana and Villa Clara (Figura 6), that also collaborate among them; however, only in the first two a little more than 50 % was found.

Opposite to the high levels of scientific production related to this topic in the Western part of the country, low levels can be found in the Eastern part with only six articles in provinces like Granma, Santiago de Cuba and Guantánamo that account for 5 % of all publications. Provinces like las provincias de Ciego de Ávila, Las Tunas and Holguín did not show activity in this regard.

Main collaborating countries

There are several countries in the world that research or use biofertilizers like North America, Brazil, South Cone countries, Russia, Asia, Africa, China, among others (27).

During 2008-2012 countries like Brazil, Mexico, Spain, Colombia, Canada, Argentina, France, Ecuador, Belgium, and Angola collaborated with Cuba in the publication of articles on biofertilizers.

Brazil, applies from 60 000 to 70 000 t of biofertilizers every year according Dr. Luís Prochnow and Dr. Valter Casarin representatives of the IPNI Program in Brazil. This country, through the Centro de Pesquisa de Agrobiología (EMBRAPA), held relations with INCA and with the Coffee Experimental Station of Jibacoa (Villa Clara) for the inoculation of arbuscular mycorrhizal fungi in coffee (*Coffea arabica*).

On the other hand, it interacted with the Soil Institute and with the Rice Research Institute to study the nitrogen biological fixation with Azospirillum, Pseudomonas and Azotobacter in rice (*Oryza sativa*). In Mexico, the Research and Advanced Study Center (CINVESTAV) worked with INCA on the use of arbuscular mycorrhizal fungi in potato (*Solanum tuberosum*) and sorghum (*Sorghum vulgare*).

The Faculty of Biology of the University of Havana prepared an inoculant from *Burkholderia* sp. For rice (*Oryza sativa*) and corn (*Zea mays*) and the Autonomous University of Mexico (UNAM) and the Faculty of Biology previously mentioned, conducted environmental research on this topic focused on studying the diversity of rhizospheric bacteria associated to plants of Typha dominguensis in wetlands of the Almendares river in Havana.

Main agricultural crops

The total number of crops studied in this period was 36, classified in ornamental plants, roots and tubers, vegetables and pastures. The main agricultural crops (Figure 7), in which a higher number of microorganisms were studied were sorghum (*Sorghum bicolor* and *Sorghum vulgare*), rice (*Oryza sativa*), cabbage (*Brassica oleracea*), tomato (*Solanum lycopersicum*), sugarcane (*Saccharum officinarum*), corn (*Zea mays*), papaya (*Carica papaya*) and canavalia (*Canavalia ensiformis*). These results coincide with Dibut's, who says that in Cuba, over 40 plant species have been favored with the use of biofertilizers and biostimulants. These bioproducts, together with the integrated management, nutrition and the agroecological pest management, among other cultural factors, have permitted to produce foods close to people's demands, though in many items and productive chains planned demand is not met by the authorities regulating the agricultural policy of the country (28).

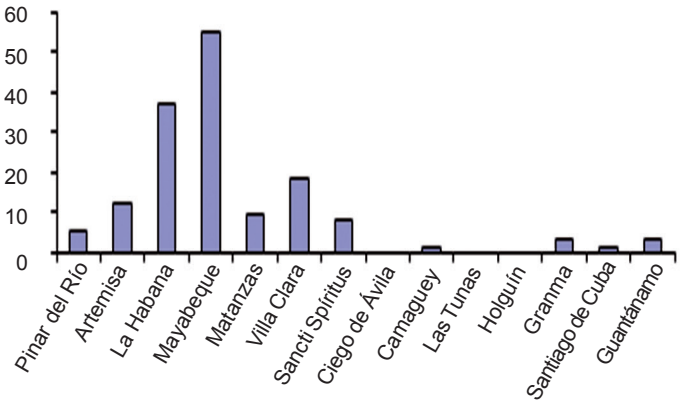


Figure 6. Quantity of articles on biofertilizers by province from 2008 to 2012

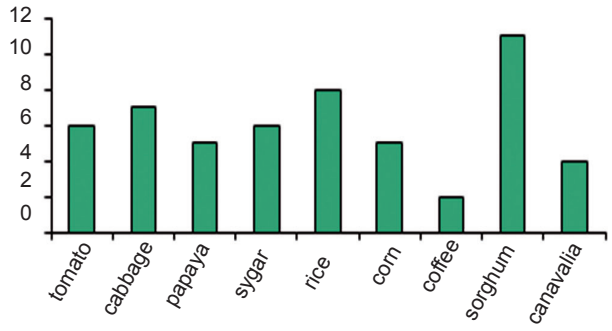


Figure 7. Main crops in which microorganisms biofertilizers were evaluated in Cuba (2008-2012)

Main microorganisms

It has been stated that the most common microorganisms used as biofertilizers are Rhizobium, Azotobacter, Azospirillum and solubilizing microbes of phosphorus like Pseudomonas and Bacillus (29) and those more used in leguminous crops in most of the countries are Rhizobium and Bradyrhizobium (15).

Tabla III shows the genus of microorganisms-biofertilizers that were investigated in the last five years in Cuba, among which are Glomus, Rhizobium, Bradyrhizobium, Azotobacter, Gluconoacetobacter and Pseudomonas.

As for other microorganisms-biofertilizers very little research has been done, it explains the scarce use made by growers in addition to insuficient knowledge, poor infrastructure and the lack of technologies. However, the use of land for agriculture will be increased to meet food demands in the 2008-2017 period, according to the outlook of the Organization for Economic Cooperation and Development (OECD) and the FAO. Therefore, due to the high prices of nitrogen and phosphorus fertilizers, agronomical actions are to be taken to increase nutrients uptake by plants, and the use of microbial inoculants is one of the alternatives that fosters the development of studies on soil microorganisms (30).

In Cuba, the study of fungi of the *Glomus genus* rapidly acquired importance boosted by the wide spectrum of plants that perform mycorrhizal symbiosis and the benefits that provide to the plant as well as the technological advantages its production brings in (Figure 8).

The first micological studies started around 1970 at the Institute of Ecology and Systematics (IES) and from 1988, INCA started research focused on the use and management of mycorrhizal associations. From 1990 to 1994, The Biofertilizers Group of IES, embarked upon a national program to introduce vesicular-arbuscular mycorrhizae in the Cuban agriculture.

Table III. Main agricultural crops in which a higher quantity of microorganisms biofertilizers were studied from 2008 to 2012

	Tomato (*Solanum lycopersicum*)	Cabbage (*Brassica oleracea*)	Papaya (*Carica papaya*)	Sugarcane (*Saccharum officinarum*)	Rice (*Oryza sativa*)	Corn (*Zea mays*)	Coffee (*Coffea* spp.)	Sorghum (*Sorghum* spp.)	Canavalia (*Canavalia ensiformis*)
Glomus	X				X	X	X	X	X
Rhizobium			X	X	X			X	X
Sinorhizobium						X		X	X
Bradyrhizobium						X		X	X
Gluconoacetobacter			X	X					
Azospirillum			X	X	X			X	
Herbaspirillum					X				
Azotobacter	X			X	X	X	X		
Pseudomonas		X	X	X	X			X	
Sphingomonas								X	
Pantoea				X					
Acaulospora	X							X	
Gigaspora	X								
Scutellospora	X								
Bacillus	X	X						X	
Brevibacillus								X	
Paenibacillus								X	
Burkholderia					X	X			
Enterobacter			X		X				
Trichoderma		X							
Aspergillus		X							
Rhizopus		X							
Mucor		X							
Penicillium		X							

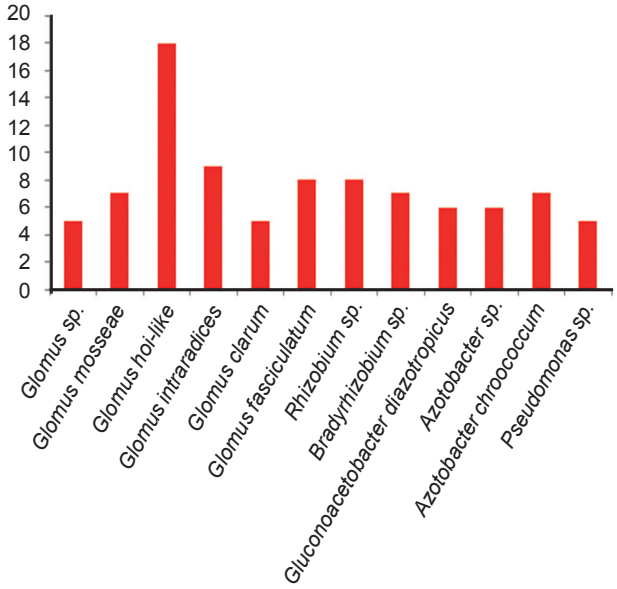


Figure 8. Main microorganisms studied as biofertilizers in Cuba (2008-2012)

Such program involved 22 scientific institutions and close to 90 researchers in the country. Moreover, they are producing MICOFERT, a certified mycorrhizal inoculant that is being introduced now in agroforestry area. The development of biofertilizers based on arbuscular mycorrhizae and rhizobacteria started in 1995, and in 2002 the patent for ECOMIC was granted. Hence, the development of reserarch in both institutes, the collaboration links and the experience in the application of these products, look at the Glomus genus as the one on which the highest number of investigations have been done in the studied period.

Despite the results attained in Cuba in research, production and application of biofertilizers, publication efforts should be increased both in national and foreign magazines of high scientific and social impact, so feedback among scientists, decision makers and agricultural and livestock growers also increase. On the other hand, science and innovation policies should promote research on biofertilizers in the Eastern region of the country, where the study of native microorganisms adapted to stressing drought and salinity allows encouraging results in the quest of effective inoculants under stressing conditions.

CONCLUSIONS

- There is a reduction of articles on biofertilizers in Cuban scientific magazines from 2008 to 2012 and most of the research is found in the Western and Central regions of the country, with low participation of institutions from the Eastern region.
- The collaboration on this topic with other countries is still limited, Brazil and Mexico were the countries that most collaborated with Cuba in this field in the last five years.
- The agricultural crops where more biofertilizers-microorganisms were studied in the evaluated period were *Sorghum bicolor* and *Sorghum vulgare*, rice (*Oryza sativa*), cabbage (*Brassica oleracea*), tomato (*Solanum lycopersicum*), sugarcane (*Saccharum officinarum*), corn (*Zea mays*), papaya (*Carica papaya*) and canavalia (*Canavalia ensiformis*).
- The biofertilizers-microorganisms of highest level in the studied period were *Glomus*, *Rhizobium*, *Bradyrhizobium*, *Azotobacter*, *Gluconoacetobacter* and *Pseudomonas*.

ACKNOWLEDGEMENT

Authors wishes to thank Dr.C. Judith Licea de Arenas and Dr.C. Francisco Javier Valles Valenzuela from the Autonomous University of Mexico, for their important support and suggestions to improve this article.

BIBLIOGRAPHY

1. Castillo, G.; Gregorí, Bárbara S.; Micheena, Georgina; Díaz de Villegas, M. Elena; Delgado, Grisel; Montano, Ramón; Cejas, Graciela y Gálvez, Luis O. Bioproductos para la agricultura: surgimiento y desarrollo en el ICIDCA. *Rev. ICIDCA. Sobre los derivados de la Caña de Azúcar*, 2007, vol. XLI, no. 3, pp. 42-51. ISSN 0138-6204.
2. Dibut Álvarez, B.; Martínez-Viera, Rafael; Fey Govín, Luis y Ortega García, Marisel. Un siglo de investigaciones y comercialización de biofertilizantes en Cuba. *Agrotecnia de Cuba*, 2006, vol. 30, no. 2, pp. 79-90. ISSN 0538-3114.
3. Viñals, Mabel y Villar, J. Avances en la formulación y aplicación de inoculantes bacterianos de uso agrícola. *Cultivos Tropicales*, 1999, vol. 20, no. 4, pp. 9-17. ISSN 1819-4087.
4. Dibut Álvarez, B.; Martínez-Viera, Rafael; Ortega García, Marisel; Ríos Rocafull, Yohania y Fey Gobín, Luis. Obtención de un biofertilizante mixto de amplio espectro de acción. Efecto sobre el cultivo de la rosa (*Rosa* spp.). *Agrotecnia de Cuba*, 2010, vol. 34, no. 1, pp. 33-43. ISSN 0538-3114.
5. Pentón, G.; Reynaldo, Inés; Medina, R. y Onono, G. Efecto de productos bioactivos combinados con el biopreparado microbiano Azotofos en el crecimiento de *Paspalum salam*. *Pastos y Forrajes*, 2010, vol. 33, no. 4, pp. 1-11. ISSN 2078-8452.
6. Álvarez, J. L., Núñez Sosa, Dania Bárbara; Liriano González, Ramón y Terence Monthy, Gerald. Evaluación de la aplicación de microorganismos eficientes en col de repollo (*Brassica oleracea* L.) en condiciones de organopónico semiprotegido. *Centro Agrícola*, 2012, vol. 39, no. 4, pp. 27-30. ISSN 2072-2001.

7. Martínez-Viera, R. y Dibut Alvarez, B. Utilización de nuevos paradigmas que permitan profundizar los conocimientos sobre las relaciones suelo-planta en condiciones tropicales. *Cultivos Tropicales*, 2009, vol. 30, no. 4, pp. 5-9. ISSN 1819-4087.
8. Hernández, M; Pereira, Madeline y Tang, M. Utilización de los microorganismos biofertilizantes en los cultivos tropicales. *Pastos y Forrajes*, 1994, vol. 17, no. 3, pp. 183-192. ISSN 2078-8452.
9. Rives, N.; Acebo, Yanelis y Hernández, Annia. Bacterias promotoras del crecimiento vegetal en el cultivo del arroz (*Oryza saliva* L.). Perspectivas de su uso en Cuba. *Cultivos Tropicales*, 2007, vol. 28, no. 2, pp. 29-38. ISSN 1819-4087.
10. Dibut Alvarez, B. Los biofertilizantes como complementos en la nutrición de los cultivos en el sistema de agricultura urbana. *Agrotecnia de Cuba*, 2008, vol. 32, no. 2, pp. 1-10. ISSN 0538-3114.
11. Martínez-Viera, R.; Dibut, Bernardo y Ríos, Yoania. Efecto de la integración de aplicaciones agrícolas de biofertilizantes y fertilizantes minerales sobre las relaciones suelo–planta. *Cultivos Tropicales*, 2010, vol. 31, no. 3, pp. 27-31. ISSN 1819-4087.
12. Torrientes, D. Aplicación de bacterias promotoras del crecimiento vegetal en el cultivo de la caña de azúcar. Perspectiva de su uso en Cuba. *Cultivos Tropicales*, 2010, vol. 31, no. 1, pp. 19-26. ISSN 1819-4087.
13. Dibut Álvarez, B.; M-V, Rafael; Hernández Barrueta, Germán; López Gutiérrez, Mirtha; Martínez Cruz, Angélica; Bach Álvarez, Teresa; Rivera Espinosa, Ramón; Hernández Rodríguez, Annia; Fernández Martín, Félix; Medina Basso, Nicolás y Herrera, Ricardo A. Surgimiento y desarrollo en Cuba de la red de producción de biofertilizantes y bioestimuladores. *Agrotecnia de Cuba*, 2011, vol. 35, no. 1, pp. 61-72. ISSN 0538-3114.
14. Kissing, L.; Pimentel, A. y Valido, María. Participatory soil improvement: A cuban case study in fertility managment. *Cultivos Tropicales*, 2009, vol. 30, no. 2, pp. 43-52. ISSN 1819-4087.
15. Martínez-Viera, R. y Dá, Bernardo. Biofertilizantes bacterianos. La Habana: Científico-Técnica. 2012. ISBN 978-959-05-0659-8.
16. Arenas, M.; Dovalina, María Pilar y Licea de Arenas, Judith. La investigación agrícola en América Latina y el Caribe desde una perspectiva bibliométrica. *Anales de Documentación*, 2004, vol. 7, pp. 29-38. ISSN 1697-7904.
17. Licea de Arenas, J.; Valles, Javier y Williams, David. Investigaciones Cubanas en Agricultura: Un enfoque bilbiométrico. *Ciencias de la Información*, 1994, vol. 25, no. 3, pp. 136-141. ISSN 1606-4925.
18. Lozano Díaz, I. A. y Yaniris, R. S. Análisis de los índices H, G y R en el sector agropecuario cubano a través de Scopus, 2005-2009. *Anales de Documentación*, 2012, vol. 15, no. 1, pp. 1-17. ISSN 1697-7904.
19. Mesa, María Elena; Licea de Arenas, Judith y Morales Morejón, Melvin. Análisis cualitativo y cuantitativo de la producción documentaria de los científicos cubanos de la disciplina de las ciencias agropecuarias a través de las revistas científicas editadas por el MES. *Revista de Protección Vegetal*, 2003, vol. 18, no. 2, pp. 133-140. ISSN 2224-4697.
20. Torricela, R. G.; Van Hooydonk, G. V. y Araujo Ruíz, J. A. Citation Análisis of Cuban reserches. Part 1. A case study. *The Cuban Journal of Agricultural Science. Scientometrics*, 2000, vol. 47, no. 2, pp. 413-426. ISSN 1588-2861.
21. Suárez, J.; Armengol, Nayda; Ojeda, Alicia y Hernández, L. La revista Pastos y Forrajes y el cambio de paradigma en la ganadería: un estudio bibliométrico. *Pastos y Forrajes*, 2001, vol. 24, no. 4, pp. 357-369. ISSN 2078-8452.
22. Cuba. Resolución 59/2003 del CITMA: Reglamento sobre el Sistema de Certificación de Publicaciones Seriadas Científico-Tecnológicas. Gaceta Oficial de la República de Cuba, 31 de julio de 2003, vol. 27, pp. 422-424. ISSN 1682-7511.
23. González Guitián, M. V. y De Zayas P., María Rosa. Auditorías de conocimiento. Análisis de dominio en las bases de datos Scopus y Wok. *Revista Interamericana de Bibliotecología*, 2012, vol. 35, no. 1, pp. 17-25. ISSN 0120-0976.
24. Guerra Betancourt, K.; De Zayas P., María Rosa y González Guitián, María Virginia. Análisis bibliométrico de las publicaciones en el tema proyectos de innovación y su gestión en Scopus, en el período 2001-2011. *ACIMED*, 2013, vol. 24, no. 3, pp. 281-294. ISSN 1561-2880.
25. Lozano Díaz, Ivis Anette y Rodríguez Sánchez, Yaniris. Visibilidad Nacional de las Ciencias Agropecuarias Cubanas vistas a través de Cubaciencias, durante el período 2000-2008. *Biblios*, 2009, vol. 36, pp. 1-14. ISSN 1562-4730.
26. Bach Álvarez, Teresa y Ortega Delgado, Eduardo. XXIV Reunión Latinoamericana de Rhizobiología (RELAR) y Primera Conferencia Iberoamericana de Interacciones Beneficiosas Microorganismo-Planta-Ambiente "IBEMPA" 1. *Agricultura Orgánica*, 2009, vol. 2, pp. 20-1.
27. Robert, Terry L. A Summary of the Status of Biofertilizers. EUA: Internacional Plant Nutrition Institute (IPNI). [en línea]. 20011. [Consultado: 2011]. Disponible en: <http://www.ipni.net/ipniweb/portal.nsf/0/94cfd5a0ed0843028525781c0065437e/$FILE/00%20IPNI%20Biofertilizers %20Report%20110125.pdf >.
28. Dibut Álvarez, B. y Rodríguez Manzano, Arlene. Las biotecnologías hechas a la medida: un puente entre la biotecnología y la agroecología. Ejemplo de caso: Los biofertilizantes. *Agricultura Orgánica*, 2010, no. 2, pp. 43-5. ISSN 0717-4829.
29. Motsara, M. R. y Roy, R. N. Biofertilizer assay and production. In: Motsara, M. R. y R., R. N., editor. Guid to laboratory establishmente for plant nutrient analysis. Italia: FAO. 2008. 204 pp.
30. Uribe, D.; S. N., Jimena y Vanegas, Javier. Role of Microbial biofertilizer in the Development of a Sustaineble Agriculture in theTropics. In: Dion, P., editor. *Soil Biology and Agricultural in the Tropic*. Berlin: Springer. 2010. 235 pp.

Received: 1 de septiembre de 2014
Accepted: 6 de noviembre de 2014