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KNOWLEDGE MANAGEMENT ON THE USE OF BIOFERTILIZERS AT LOCAL LEVEL: CASE STUDY IN CALIXTO GARCIA MUNICIPALITY, CUBA

Gestión del conocimiento sobre biofertilizantes a nivel local: Estudio de caso municipio Calixto García, Cuba

Maida D. Peña-Borrego[1]✉, Rosa M. Rodríguez Fernández[1], Nelvis A. Almaguer Pérez[2], Yuri F. Peña Rueda[2] and Sebastián Zayas Infante[3]

ABSTRACT. One of the main causes for the scarce use of biofertilizers for the improvement of soils and the increase of productivity, is the insufficient knowledge of farmers about the advantages of its usage at Calixto Garcia municipality, located southwest of Holguin Province. Thus, the objective of this research was to elaborate a program for the knowledge management on biofertilizers, in which synergy and participation, facilitated innovation at a local level for a sustainable farming development, through semi-structured interview with 35 farmers in the CCS (Cooperative of credit and service) "Juan Manuel Romero" and the participative observation for three years of the systematic work in this farm. The synergy and participative program for the knowledge management on the use of biofertilizers was obtained and it contains four stages-: elaboration, planning, execution and control and adjustment; with fifteen phases: understanding of necessities and knowledge opportunities, construction, organization, distribution, application and exploitation of this knowledge by the farmer. The needs of knowledge and the typology of producers were identified, comprised by four groups for the recommendation of activities on agrarian extension. A knowledge map about biofertilizers for the municipality with the main knowledge sources and actors with influence upon the thematic was obtained.

Key words: farmers, sustainable agriculture, training, inoculation, social participation

RESUMEN. Una de las causas del escaso empleo de biofertilizantes para la mejora de los suelos y el incremento de los rendimientos productivos en el municipio Calixto García, ubicado al suroeste de la provincia Holguín, es el insuficiente conocimiento del productor agropecuario respecto a las ventajas de su uso. De ahí que, el objetivo de la investigación fue elaborar un programa de gestión del conocimiento sobre biofertilizantes, en el cual la sinergia y la participación facilitan la innovación a nivel local para un desarrollo agropecuario sostenible. Se aplicó una entrevista semi-estructurada a 35 agricultores de la CCS Juan Manuel Romero y la observación participativa durante tres años de trabajo sistemático en esa unidad productiva. Se elaboró un programa sinérgico y participativo de gestión del conocimiento sobre biofertilizantes en unidades agro productivas, que contempla cuatro etapas: elaboración, planificación, ejecución y ajuste y control, con 15 fases, contemplando el entendimiento de las necesidades y oportunidades de conocimiento, la construcción, organización, distribución, aplicación y explotación del conocimiento para el productor agropecuario. Se identificaron las necesidades de conocimiento y se obtuvo la tipología de los productores agropecuarios, constituida en cuatro grupos para la recomendación de actividades de extensión agraria. Se obtuvo un mapa de conocimientos sobre biofertilizantes para el municipio con las principales fuentes de conocimiento y actores de influencia en la temática.

Palabras clave: agricultores, agricultura sostenible, capacitación, inoculación, participación social

[1]Universidad de Holguín sede Oscar Lucero Moya. Ave. XX Aniversario, Vía Guardalavaca, Piedra Blanca, Holguín, Cuba
[2]Universidad de Holguín sede José de la Luz y Caballero. Ave. de Los Libertadores #287, Holguín, Cuba
[3]CUM Ernesto Guevara. Universidad de Holguín. Plaza de la Revolución # 6, Buenaventura
✉ maida@uho.edu.cu

INTRODUCTION

Biofertilizers are one of the alternatives for the productivity of crops, the tolerance of plants and the improvement of soils, being in some countries

contemplated for the certification of organic productions (1-3), however, their use does not it is restricted to this way of doing agriculture (4).

The application of biofertilizers in Cuba has spread more to the west of the country, where the main research centers that have developed the same reside (5). The application of these bioproducts has been less favored in the eastern region of the country, despite the significant efforts made by the Institute of Soils, as well as other research institutions for the production and introduction of this technology, which currently present Limited production capacities (6).

Among the causes that some decision makers and farmers have not joined the use of these inputs resulting from science and innovation, are the lack of policies and distribution of bioproducts and programs for knowledge management aimed at decision makers and extension agents. These issues are aggravated by the lack of help from the functioning of the market for the acquisition of bioproducts and the agroecological demands of the population (7).

In the 90s of the last century, laboratories for soil and fertilizers were created in most of the Cuban provinces, beginning in them, the production on a handmade scale of inoculants based on *Rhizobium* sp. with the capacity to benefit the crops of peanuts (*Arachis hypogaea*), beans (*Phaseolus* sp.), beans (*Vigna* sp.) and forage legumes. In addition, investigations of the fundamental type-applied in other microorganisms used as biofertilizers (*Azotobacter*, *Azospirillum*, *Pseudomonas*, *Bacillus* and arbuscular mycorrhizal fungi) were consolidated (8).

In Holguín province, around 2006, investigations were halted and the production of biofertilizers was limited, due to multiple factors, among which, the organizational aspects of the activity, were the main cause of extinction of that service (9); Although the application of rhizobia in the cold and spring bean planting campaigns has not stopped in the Holguín province, the use of biofertilizers does not meet the real needs and training of agricultural producers and other actors is scarce conservation and management of them, and their integration with chemical and organic fertilizers (4,10).

Calixto García municipality, in Holguín province, produces appreciable volumes of meat, milk and viands, even though the effects of scarce rainfall and soil degradation, specifically salinization, cause insufficient agricultural yields. However, it is not common among farmers to apply biological products, which could reverse part of this problem by increasing the availability of nutrients to crops (11), among other causes, due to logistical issues due to the distance of the manufacturer and the farmer, in addition to the fact that the information on biofertilizers that the social actors possess is insufficient, and the local learning networks are wasted (12-14).

Although there is agrarian extensionism in Cuba, with diversity in its approaches, its capacity to respond, it does not solve the problems that arise in the productive sector based on its requirements (15). On the other hand, knowledge management involves the identification, acquisition, development, sharing and distribution, use, retention and measurement of knowledge, as strategic processes of its management (16). In addition, the creation, identification, acquisition, storage, sharing and application of knowledge are important processes for the management of local development, by fostering collaboration in the identification of local problems, identification of people or organizations that provide knowledge and construction of nexuses and networks (17).

In the country, through the process of universalization of higher education opportunities are offered to social development based on knowledge; development strongly supported in social learning and promoter of a broad process of social appropriation of knowledge and at the local level there is a relevant actor of knowledge and innovation: the Municipal University Centers (CUM) (18). However, there have been some obstacles to local development that hinder the university management of knowledge and innovation in the territorial context, one of them is precisely the insufficient introduction of results of science, technology and innovation, disarticulation and sectoralism at work of institutions and projects, making suggestions for the application of university management policy aimed at local development (19,20).

This research aims to develop a synergistic and participatory program of knowledge management on biofertilizers that encourages the use of this alternative, strengthening the network of social actors, providing the farmer with useful information for its application and management, as well as improvement measures and conservation of soils from the use of these bioproducts.

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MATERIALS AND METHODS

The Calixto García municipality, Holguín province (Cuba) was selected in 2012 for its study as a local context where a program of knowledge management on biofertilizers was applied, as it is the scenario with a strong farming culture, where they have been detected Problems related to the fertilization of crops for both human and animal food.

The development of the knowledge management program on biofertilizers in the municipality of Calixto García was structured in four stages: preparation, planning, execution and adjustment-control in 15 phases; The conception of knowledge management phases was based on Nagles (21): understanding knowledge needs and opportunities, constructing, systematizing, distributing, applying and exploiting knowledge (Table 1).

Table 1. Procedure and tools for the implementation of the Knowledge Management Program on biofertilizers in Calixto García municipality

Procedures of the program		Tools
Stage 1. Preparation of the program		
Phase 1.1	Determination of priorities to which the program responds	Documentary review
Phase 1.2	Conception of program objectives	Meeting of multi-actor work team
Phase 1.3	Approval of the program objectives by the actors	Presentation of the proposal before the decision-making bodies involved
Stage 2. Planification		
Phase 2.1	Determination of activities	Workshop
Phase 2.2	Programming activities	The moments and frequency in which these activities are carried out are established.
Phase 2.3	Inclusion of actions in financing methods	Evaluation of calls for national and international financiers
Stage 3. Execution		
Phase 3.1	A. Understanding knowledge needs and opportunities	Workshops, meetings and exchange visits between multi-actors
Phase 3.2	B. Build knowledge	Semi-structured interview, diagnosis of the productive unit, typology of producers and bibliometric analysis on biofertilizers
Phase 3.3	C. Systematize knowledge	Map of knowledge about biofertilizers of the municipality
Phase 3.4	D. Distribution of knowledge	Visits to the producers, participation in assembly of associates of the CCS, broadcast of communications on the radio and the provincial television, realization of activities for the farmer together with the municipal library
Phase 3.5	E. Application of knowledge	Practical demonstration of handicraft production of biofertilizers and observation of the efficiency of biological nitrogen fixation from nodulation, practices of multiplication of mycorrhizae in the soil and biofertilizer fairs for human and animal food: EcoMic®
Phase 3.6	F. Exploitation of knowledge	Peasant experimentation, monitoring of the GCE and of professors and / or researchers associated with the different types of projects recognized in Cuba
Stage 4. Adjustment and Control		
Phase 4.1	Follow-up to the agro-productive unit	Visits to the farms and the board of directors of the productive unit, observation and interviews
Phase 4.2	Partial evaluations	Review of the projects that are taxed, writing a partial report
Phase 4.3	Final evaluation	Review of the final reports of the projects that are taxed and final report writing

The data collected corresponded to 26 variables evaluated in each productive unit and with them a main components analysis was elaborated. The smallest number of components was selected with which a high percentage of the experimental variance was explained (≥ 75 %) and in these, the variables that presented correlation coefficients ≥0.7. The variable quantity of soil was included because it had a high statistical significance in the Pearson correlation.

The CCS "Juan Manuel Romero" was taken as a case study to implement the program based on the awareness to participate in the actions of the President of the cooperative and its board of directors. Systematic and participatory observation was used for three years to identify the needs of knowledge and approach to the context and municipal actors. It was coordinated with the board of directors of the CCS and information on the general operation of the productive unit, available resources and knowledge needs was captured through a semi-structured interview (22), applied to a sample of 35 producers (24% of the universe of associates to the cooperative), with the participation of 13 interviewers (eight professors and five students), who were prepared in advance for the application of the interview. The six selected variables were standardized and the hierarchical conglomerate was made by the Ward method, through the Euclidean square distance to group the different productive units according to the variables. The definition of the types was made graphically by tracing a vertical cut line for 70 % of the maximum distance between cases (Figure 1).

The soil quality variable was based on farmers' perception of the farm's soil, for which they were asked, in addition, what aspects they take into consideration to establish soil quality.

In addition, the availability of knowledge, recognized from works published in national sources, was studied, carrying out two previous bibliometric analyzes (5,23) and a part of the biofertilizer knowledge map was constructed from these data. The map highlights each source of knowledge and information through a symbology in: knowledge distributor, lost link of knowledge, knowledge springs and knowledge sinks (24).

Peasant experimentation was carried out in three farms of CCS partners, where the biofertilizers were applied: efficient microorganisms in the culture of tomato (*Solanum lycopersicum*) and beans (*Phaseolus vulgaris*), mycorrhizal inoculants (EcoMic®) in cassava (*Manihot esculenta*), maize (*Zea mays*) and pumpkin (*Cucurbita* sp.) and inoculation of rhizobia in beans (*Phaseolus vulgaris*). The variables used to evaluate the application of biofertilizers perceived by farmers were collected.

RESULTS AND DISCUSSION

The Knowledge Management Program on biofertilizers in Calixto García municipality (Table 1) began when a demand was identified for the agro-productive unit by the Faculty of Agricultural Sciences of the University of Holguin, but this procedure could also be triggered by the demand of others actors, such as the municipal extension of the UEICAH, the ANAP of the municipality, as well as a need detected by the CUM.

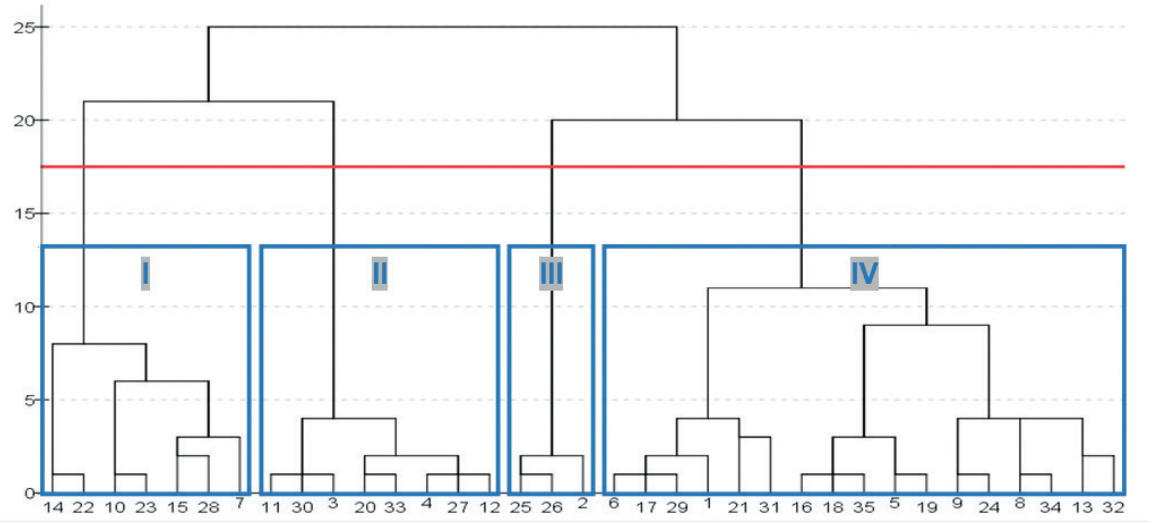


Figure 1. Dendrogram showing the grouping of the producers of the CCS "Juan Manuel Romero"

In stage 1 (Elaboration of the Program), the work team, coordinated by the University of Holguin and integrated by the CCS "Juan Manuel Romero", the CUM, the UEICAH (Unit of Extension, Research and Training of Agriculture in Holguin), the Municipal Office of ANAP, the Municipal Office of Urban Farm, the Municipal Library "Onelio Jorge Cardoso" and the Provincial Training School of MINAG, established (phase 1.1) that the priorities to which the Program responds, are the guidelines 136, of the Science, Technology, Innovation and Environment Policy; and 184 and 187 of the Agro-industrial Policy, both included in the Economic and Social Policy of the Party and the Revolution, in addition to the priorities of the Human and Animal Food Programs (25).

In phase 1.2, the scarce use of biofertilizers was identified as a problem to increase productive yields in degraded agroecosystems of Calixto García municipality, in the face of a situation of not providing nutrients to the crops and the existence of results in the use of different types of biofertilizers in the country in various crops (26-31).

Conceiving as a general objective (phase 1.3): promote the use of biofertilizers in agroecosystems of Calixto García municipality, through the management of knowledge in agricultural producers in a synergistic and participatory manner.

The financing was included in the economic plan in the Science, Technology and Innovation section, both of the University and the productive unit, and stakeholders as part of the Stage 2 (Planning) and proceeded to the evaluation of calls for financiers national and international, achieving insert the CCS in an institutional project, two projects associated with program and VLIR-UOS international project, led to the isolation of rhizobia and mycorrhizal strains adapted to salt stress conditions and drought.

A workshop was held at CCS "Juan Manuel Romero" for the negotiation of actions as part of Stage 3 (Execution), phase 3.1; two meetings with the board of CCS directors for the coordination of activities and systematic exchange visits with the farmers, which allowed to understand the needs and opportunities of knowledge in the CCS and in the municipal context. To construct knowledge (step 3.2) the information generated was used for the semi-structured interview, where it was determined that there are three main components defined as: Supplies[1], Training fertilizantes[2] and Improvement soil[3], which together determine the 73.69 % of the total variance explained (Table 2).

In Figure 1 it can be seen that below the cut line four groups are formed, and whose characteristics are described below and are summarized in Table 3.
Group I: mainly agricultural producers, with little land extension (approximately 3 ha), with irrigation systems, good soil quality, do not apply organic matter and if chemical fertilizers, they want to be trained in soil fertilization.
Group II: mainly livestock producers, owners of approximately 9 ha of land, without irrigation, with regular soil quality, apply organic matter and do not use chemical fertilizers; has no interest in being trained in topics of soil fertilization, but in raising animals and rainfed crops, and livestock technologies.

Table 2. Matrix of main components obtained from the factorial analysis on fertilization of soils by producers of the CCS "Juan Manuel Romero"

	Components					
	1		2		3	
Amount of land	0,520	**	-0,614	**	-0,001	
Soil quality	-0,436	**	0,343	*	0,709	**
Chemical fertilization	0,780	**	0,319		-0,040	
Training in fertilizers	0,033		0,826	**	-0,064	
Irrigation	0,767	**	0,389	*	0,016	
Organic manure	0,436	**	-0,245		-0,757	**
Autovalue	1,848		1,491		1,082	
Variance	30,805		24,853		18,030	

Statistical significance is denoted by * for p≥0.05 and with ** for p≥0.01

Table 3. Table of variables of greatest interest used to characterize the types of producers of the CCS "Juan Manuel Romero"

Groups	#	Amount of land	Soil quality	Chemical fertilizer	Training in fertilizers	Irrigation	Organic manure
1	7	3,57±4,47	Buena	Sí	Sí	No	No
2	8	9,5±7,8	Regular	No	No	No	Sí
3	3	41,33±2,31	Buena	Sí	No	Sí	Sí
4	17	6,18±5,46	Regular	No	Sí	Sí	Sí

Group III: basically cattle producers, with more than 40 ha of land, with irrigation, good quality soils, apply organic matter and chemical fertilizers and do not request training in soil fertilization, if on topics such as animal feed technologies and livestock.

Group IV: Producers with 6 ha of land, with irrigation, regular quality soils, apply organic matter and not chemical fertilizers and if they require training on soil fertilization.

In general, the producers of the CCS under study do not know or use the term biofertilizers on a daily basis, since they associate the term with the use of organic fertilizers and have little knowledge of it, only one of the producers surveyed reported applying Rhizobium, since specializes in bean planting. The small amounts of producers who know about these bioproducts agree with what was previously reported in the country for the Pinar del Río province (12). Similar results were obtained in a study conducted in India, where less than 30 % of the respondents answered that they have knowledge about biofertilizers, being one of the countries in which these bioproducts are most applied (32), among the causes is reported, the insufficient access to these inputs and insufficient knowledge of farmers (33).

For the CCS "Juan Manuel Romero" it is recommended to initiate the extension activities with the groups IV and I, which are the groups of producers demanding the training on biofertilizers, having to register in these groups the results that are produced regarding the use of biofertilizers and the soil fertility management.

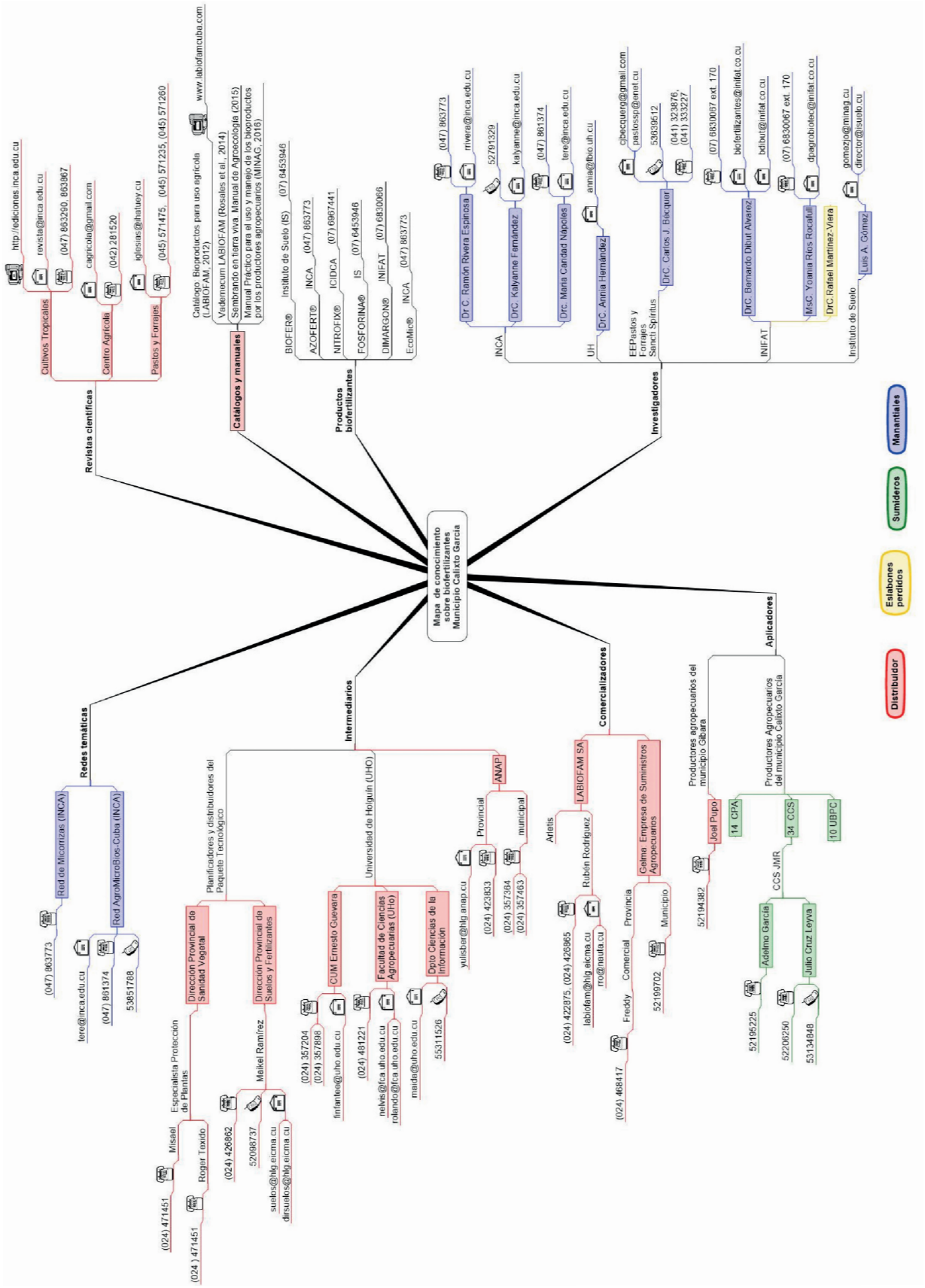
The fact that the agricultural producers of groups II and III do not demand training on soil fertilization, could be explained by their fundamental dedication to livestock, appreciating a lower culture of the use of fertilizers in animal feed crops. The existence of differences between groups of agricultural producers supports the principles of agrarian extension, stating that farmers may prefer not to be trained on certain issues and not listen to extension agents, producers do not learn if they do not feel that the things learned they will allow to satisfy their needs and desires (34), for which reason it has been recommended to study the motivational factors in the process of dissemination and adoption of new technologies in the productive sector, from the first time they heard about the technology until its adoption (35).

Regarding the variable quality of the soil, the producers take into account the following aspects to perceive the quality of the soil: results achieved in the production, quality of the crops, presence of vegetal layer, texture, presence of salts, years of exploitation of the soil, plant growth easily, type of crops planted, plant development, color and relief. This diversity of variables that farmers have agrees with that reported by Kissing *et al*. (12); nevertheless, in the CCS "Juan Manuel Romero" surprises that the producers do not consider as variable the water retention capacity for the soil, since they are affected by the drought. In another more recent study in Zimbabwe (36), on the indicators of soil degradation obtained from farmers, it was obtained that they mainly consider weeds, crop performance and physical attributes of the soil, categorizing the arable land in four productivity classes: productive, moderately productive, degraded and severely degraded.

In phase 3.3 of the program, knowledge was organized through systematization. Based on the information obtained in the semi-structured interview, the diagnosis, the typology and the bibliometric analysis, the knowledge map on biofertilizers was drawn up in Calixto García municipality (Figure 2). This map was distributed (phase 3.4) to the producer through the extension agent, the representative of urban and suburban agriculture, the MINAG trainer, the CUM, the municipal library, the municipal Radio, Youth Radio and the television program "A buen Tiempo", for being of great acceptance among the agricultural producers of the area, as well as the television program "Espiral", in which, in addition, the way of preparation of the bioproduct efficient microorganisms was made known. The importance of determining and strengthening the multiactoral knowledge network can be reflected in the knowledge map (16), where different actors with different types of knowledge converge in the farmer, positioning him or her in a key actor that integrates the knowledge of both formal and informal networks and generates new knowledge in close relation with local knowledge (34). Recent studies confirm the use of knowledge maps in case studies, especially in the technique known as *Knowledge flow map* (37).

In phase 3.5 of application of knowledge, learning was fostered through the strengthening of the network of social actors and the actions carried out, fostering synergy and participation, through the use of existing spaces for the conversion of knowledge.

The monthly space of the Assembly of cooperative associates was used for the practical demonstration of the obtaining of efficient microorganisms, in addition to the space of the Agricultural Fair to carry out an exhibition of cassava varieties for human food and bioproducts.



Own elaboration

Figure 2. Map of knowledge management on biofertilizers for "Calixto García" municipality

In phase 3.6 Exploitation of knowledge, peasant experimentation was carried out with monitoring from the CGE. In the CCS "Juan Manuel Romero" benefited with the application of biofertilizers 13 ha of crops of economic interest. Biofertilizers were applied as mycorrhizal inoculants in cassava (4.5 ha), corn (4.0 ha) and squash (1.0 ha) crops, as well as the efficient microorganism technology in tomato crops (1, 0 ha) and beans (2.5 ha), as well as rhizobia (AZOFERT®) in the beans.

Taking into account the criteria or perception of farmers is essential to adapt the knowledge of the experts to the local context (38). The variables considered by the farmers in the CCS to evaluate the effectiveness of the application of biofertilizers, were the following: pest control, yield, vigor of the plant, palatability according to the time of harvest and size of the fruit. In the three farms, a positive perception was obtained by the experimenting producer of the use of biofertilizers, although they manifested the following limitations of its application in the municipality:

- Efficient microorganisms: difficult to obtain leaf litter, because in the context there are anthropized spaces and high drought.
- Rhizobia: distributed only to farmers who receive the technological package for bean planting, not all farmers.
- Mycorrhizae: there is no mechanism that guarantees this bioproduct in the municipality.

These limitations must be taken into account as situations that inhibit the participation of producers in future experiments (39). In a study conducted in Mexico, the perception of producers is measured through three criteria: technical and economic development, productivity, environmental protection and social development, obtaining a positive perception of the use of biofertilizers, where producers recognize that biofertilizers have more advantages that disadvantages and that these are less risky for producers and soils, than chemical fertilizers (40).

The control of the execution of the Program consisted of:

The partial and final evaluations were carried out through the projects that were submitted to it and they were carried out quarterly, with a report on the execution of the program and a final report in which several social actors participated for the evaluation of the program in the framework of the final workshop.

Follow-up to the productive unit (41): as the program was executed, it participated jointly with the CCS, to provide advice to the producers in the production and application of biofertilizers thus, as in the management of any useful information and promoting the debate in the production unit about the development of the planned actions.

CONCLUSIONS

- A program of knowledge management on biofertilizers was applied at the local level, consisting of four stages and fifteen phases in which the functions of the social actors are used synergistically and participatively, promoting peasant experimentation on commercial biofertilizers EcoMic® and AZOFERT® and the application of efficient microorganisms, the articulation of work between the university and a CCS, and the joint participation of researchers of influence in the subject.
- Four groups of agricultural producers were identified. Group I (20 %) are farmers with irrigation systems, with good soil quality, do not apply organic matter and if chemical fertilizers, they want to be trained in soil fertilization. Group II (23 %) mainly gathers cattle farmers who do not have an irrigation system, with regular soil quality, apply organic matter and do not use chemical fertilizers; has no interest in being trained in topics of soil fertilization, but in animal husbandry, rainfed crops and livestock technologies. Group III (8 %), are farmers with irrigation, good quality soil, apply organic matter and chemical fertilizers and do not want to be trained in soil fertilization, they are interested in livestock issues. Group IV (49 %) is dedicated to both sowing and livestock, with irrigation, soils of regular quality, apply organic matter and not chemical fertilizers and if they require training on soil fertilization.
- A knowledge map on biofertilizers for Calixto García municipality was prepared, finding the main sources of information and knowledge, meaning if they are springs, sinks, distributors or missing links of knowledge, which constitutes a tool for the management of projects and the practical use of the actors with incidence in the subject.

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