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Original article

Innovation factors and domains of recommendations in local rice (*Oryza sativa* L.) production systems

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ABSTRACT

The scientific analysis of farming systems by homogeneous groups or recommendation domains contributes to the planning of differentiated actions for the adoption of technological innovations in local rice production systems. For this reason, this research was carried out with the objective of identifying the main factors that influence the adoption of technological innovations as well as to determine and characterize groups of farms or recommendation domains. A questionnaire was applied to a sample of 44 farmers who produce rice in the Credit and Service Cooperatives of Madruga municipality (Mayabeque province) and information was obtained on socio-cultural, economic, environmental and technological variables. The descriptive analysis showed that variables with the greatest discriminating capacity for the analysis of farm differentiation were: *(i)* the Purchase of Seed, *(ii)* the Cultural Method in Pest Management and *(iii)* the Harvesting Method. Through the use of multivariate analysis, six innovation factors were identified that determine 67.63 % of the total variability and four farm groups or recommendation domains were characterized, with a percentage participation of 45.4, 25, 18.2 and 11.4%, respectively. It was possible to identify the quantitative and qualitative variables included in the technological aspects, the most relevant innovation factor, where Domain I showed the best practices in rice crop management.

Key words: multivariate analysis, statistical methods, sustainability, typology.

INTRODUCTION

In the last decade, studies on the adoption of technological innovations in agriculture have been a topic of growing interest for researchers. In this sense, factors that influence innovation and the scientific analysis of peasant systems by homogeneous groups or domains of recommendations are jointly approached from different disciplines and productive scenarios (1–5).

On the other hand, one of the forms of the rice production system in Cuba is the so-called non-specialized or popular production, which is characterized by its small and medium scale, with low use of external inputs, the use of varieties adapted to the different agroecosystems and extensive use of animal traction and manual labor (6). In this context, the Credit and Service Cooperatives (CCS) contribute more than 50 % of the national production, in a heterogeneous environment in terms of socio-cultural, economic, environmental and technological circumstances, which affect the sustainability of rice agroecosystems.

In this regard, Mayabeque province presents a large number of associates belonging to the CCS that participate in popular rice production and adopt different agroecological practices in this crop. However, both at provincial and national level, there are few studies with the application of multivariate methods for factor identification that determine innovation and the analysis of local rice production systems by domains of recommendations.

Therefore, this research was carried out with the objective of identifying the main factors that influence the adoption of technological innovations in rice (*Oryza sativa* L) production, as well as to determine and characterize the groups of farms or recommendation domains, according to their needs and technological constraints.

MATERIALS AND METHODS

The research was developed during the years 2008-2015 in Madruga municipality, located in the northeast of Mayabeque province. It has a surface area of 465.6 km^2 which represents 12.4 % of the territory of this province. Its center point is located at 22°55' north latitude and 81°52' west longitude (7). The climate is tropical savannah (8) with an average annual temperature of 23.9 °C, relative humidity of 79 % and average annual rainfall of 1954 mm. From the productive point of view, the territory has 14 CCS (9), there is a tradition of small and medium-scale rice production with 4 % share of the regional production volume, and the agricultural yield is 3.17 t ha^{-1}, which corresponds to 3.20 t ha^{-1}, the national average.

This research had an exploratory-descriptive scope where theoretical (induction-deduction, analysis-synthesis, historical-logical) and empirical (non-experimental cross-sectional design) methods were used. The survey was used as a method for the collection of data from 43 qualitative and quantitative variables. The instrument consisted of a questionnaire with open and closed questions, which consisted of five sections that responded to: *(i)* farmer's general information, *(ii)* his technological situation, *(ii)* natural resources and agroecological practices, *(iii)* access to external inputs and their impact on production results, and *(iv)*, institutional relations and knowledge-related aspects.

The universe or population was represented by the total number of farmers engaged in rice production and belonging to the CCS. This figure reached a value of N = 354, according to ANAP's (National Association of Rural Farmers) Municipal Registry of Associates. The formula was used to calculate the sample size required for an estimate with a predetermined maximum error using expression 1 (10).

$$n = \left(\frac{\sigma Z_{1-\frac{\alpha}{2}}}{d}\right)^2 \qquad (1)$$

where:

n is the desired sample size

σ is the standard deviation

1-α is the confidence level which is set by the researcher and a confidence level of 0.95 was assumed.

$Z_{1-\alpha/2}$ is the value of the Z Table, according to the level of confidence

1-α and d corresponds to the margin of error

A maximum admissible error of 30 % (0.30) of the standard deviation was considered according to the range established (0.25>σ<0.50) by studies on this subject (11,12).

From the total number, a sample of n=44 (12.4% of the population) was selected by simple random sampling and with compliance with eligibility criteria, which was made up of farmers from nine CCS (64 % of the total number of entities of this type in the municipality), who declared their intention to collaborate.

Based on the data provided in the questionnaires, the analysis and statistical processing was carried out using SPSS version 21 on Windows. To identify factors influencing the adoption of technological innovations, quantitative and qualitative ordinal variables were chosen and those with discriminatory capacity were determined by means of descriptive statistics (CV≥50 %), discarding redundant information. Principal component analysis was performed for mixed variables (13) with the criterion of eigenvalue greater than or equal to unity (λ≥1) and the use of orthogonal rotation (Varimax method).

The determination of recommendation domains was performed with hierarchical cluster analysis according to Ward's method and with the squared Euclidean distance interval measure (13). The graphic technique of the dendrogram was used in the representation of the groups and the cut-off that induced the arrest of the fusion process of the different groups was made at a distance (rescaled value) of 3%.

RESULTS AND DISCUSSION

In the characterization of the local rice production systems of Madruga municipality, it was detected that not all variables contribute equally to the classification of farms. The descriptive analysis showed that, of the 43 initial variables, only 17 presented CV values equal to or higher than 50 %. Therefore, these variables contributed to the identification of the innovation factors and constituted the points of differentiation between groups or domains of recommendations, due to their discriminatory capacity (Table 1).

The variable Seed Purchase reached the highest value of the variation coefficient (Table 1) and this was due to the low number of farmers who declared this way of acquiring seed. This situation corroborates the fact that farmers do not use seed from the formal system, which indicates the importance of having a local seed production system. In this sense, some authors affirm that the sustainable operation of certified seed production on a local scale is one of the imperative needs for the development of programs aimed at guaranteeing in a stable manner the availability and access to high quality seed, in order to maintain the purity of cultivars (14,15).

Table 1. Descriptive statistics of the variables with discriminatory capacity

Variables	Mean	SD	CV
Cultivation Experience	27.36	13.81	50.47
Seed Purchase	0.05	0.21	**422.00**
Seed Selection	0.73	0.45	61.78
Sowing Standard	27.78	14.91	53.67
Cultural Attentions to the Seedbed	0.30	0.46	154.00
Transplanted area of a producer	3.09	5.59	181.08
Planting time	1.43	0.90	62.94
Mineral Nutrition	0.55	0.50	91.64
Organic manure as fertilizer	0.45	0.50	112.00
Phytosanitary Problems	0.45	0.50	112.00
Use of manual knapsack as phytosanitary equipment	0.30	0.46	154.00
Cultural Method in Pest Management	0.20	0.41	**204.00**
Harvesting Method	0.20	0.38	**185.07**
Drying Method	0.34	0.26	76.00
Soil Improvement and Conservation Measures	0.75	0.44	58.40
Variety Knowledge	0.59	0.50	84.24
Training Frequency	0.48	0.41	85.89

SD: Standard Deviation CV: Coefficient of variation

The variables Cultural Method in Pest Management and Harvesting Method showed the relevance of crop phytotechnology as a differentiating aspect among farmers. These variables show points of coincidence with what is stated in the literature about the management of weeds and harvesting in popular rice production. This production scenario is characterized by its heterogeneity, in terms of the use of agroecological practices to reduce the harmful effects of inter-specific competition with rice and the use of artisanal or industrial techniques for harvesting and processing rice [6].

In the identification of innovation factors, the principal component analysis revealed the selection of six components with an eigenvalue greater than unity, which explain 67.63 % of the total variability among the agroecosystems studied (Table 2).

Table 2. Matrix of correlations between the rotated components and the variables

Variables	Component					
	CP1	CP2	CP3	CP4	CP5	CP6
Planting time	0.84					
Cultural method of pest management	0.78					
Transplanted area of a producer	0.58					
Organic manure as fertilizer	0.46					
Cultural attentions to the seedbed	0.45					
Mineral nutrition		0.82				
Drying method		0.74				
Seed selection		0.55				
Harvesting method		0.52				
Seed purchase			0.65			
Soil improvement and conservation measures			0.48			
Phytosanitary problems				0.87		
Backpack as a phytosanitary equipment				0.85		
Crop experience					0.68	
Planting standards						0.74
Frequency of training						0.67
Variance explained %	17.46	14.32	11.01	9.96	7.76	7.12
Accumulated variance %	17.46	31.78	42.79	52.75	60.51	67.63

Fulfillment of the first premise for the this multivariate method application provided that the variables measured represent 94 % of the variables with discriminatory capacity and their factor loadings reached values greater than 0.40 in each component or factor extracted (Table 2). Therefore, the degree of correlation is adequate [16,17]; this allows the identification of the associated variables in each component, the interpretation from the empirical point of view and their denomination.

In the first principal component (CP1), variables with the highest preponderance were Planting time, Cultural method in pest management and Transplanted area of a producer, which explained 17, 46 % of the variance. This could be due to the type of agriculture carried out in local rice production systems, in which agro-technical methods have great relevance in crop management [6]. For this reason, this factor represents the *spatio-temporal arrangement and cultural method* and it is the main differentiating point between groups of farmers. This result coincides with studies conducted in Panama and Sierra Leone, where it was shown that the adoption level of agroecological practices is conditioned by the socioeconomic environment in which the main actors in the agricultural sector are immersed. Thus, farmers with financial constraints and limited access to external inputs are more likely to adopt practices with an agroecological approach in economically important crops [(1,3)].

Variables related to Mineral nutrition and drying method were the most relevant in CP2, which explained 14.32 % of the variance. Also, this component included Seed selection and Harvesting method, activities that are part of the cultural attentions in rice cultivation. This factor was denominated *Management of mineral nutrition and post-harvest*. On this topic, the analysis of questionnaires revealed the existence of different alternatives in nutrition management and 30 % of respondents stated that they use mineral fertilizers in small doses. The predominance of manual methods in harvesting was found, as well as the handmade drying of rice grains, and 84 % of farmers select the seed with water.

These results indicate the low access of farmers to external inputs, an issue that affects the sustainability of their agroecosystems [(18)]. On the other hand, studies of agricultural typologies in irrigated rice ecosystems show that the adoption of technological packages with mineral fertilizers, improved seeds and infrastructure for industrial rice processing is an attractive proposal from the economic point of view of farmers, due to the higher income obtained for family sustenance [(19)].

The third component (CP3), called *Acquisition of seed and soil resource*, supported 11.01 % of the total variance of the agroecosystems studied and the variable with the greatest contribution to this factor was the purchase of seed. In this regard, farmers did not identify the lack of certified seed as a high priority indicator and this may be due to the fact that more than 90 % of respondents stated that they produce their own seed. This aspect is an essential point for the intervention of Participatory Plant Breeding, in accordance with experiences developed in popular rice production, which focus on the dissemination of cultivars [(20)].

Soil Improvement and Conservation Measures is another variable that contributed, to a lesser extent, to CP3. On this topic, the exploratory study showed that crop rotation is used by 86.4 % of farmers and the predominant rotations were: rice-cattle grazing, rice-fallow, rice-beans and rice-sunflower. If it is taken into account that the purpose of rice production in small areas is self-consumption, then farmers adopt this agroecological practice in order to satisfy other food needs and at the same time, contribute to sustainable soil management [(6,21)].

The fourth component (CP4) presented a high correlation with Phytosanitary problems and the necessary means to face these problems, therefore it was called *Management for pest handling* and explains 9.96 % of the variance (Table 2). Like Seed Purchase, phytosanitary problems did not constitute a first order issue and this is due to the low perception of farmers about the incidence of pests, although 14 and 11 % of the respondents declared the presence of rice mite (*Steneotarsonemus spinki* Smiley) and rice blight (*Pyricularia griseae* Sacc), respectively. In addition, it was found that the majority (70.5 %) do not have phytosanitary equipment and only 36.4 % use different pest management methods.

These results agree with a perception study carried out with grain producers in Guanabacoa municipality (Cuba), in which the lack of agricultural implements was recognized as one of the main productive limitations for pest management, as well as the absence of a relationship between farmers' knowledge of main pests associated with crops and the application of control measures (22).

The fifth component (CP5) consisted of a single variable that contributed 7.76 % of the variance and was called *Farmer experience*. In responses to questionnaires, more than half of the farmers considered their experience in rice cultivation as positive and this may be due to the fact that 54.5 % had been in this agricultural activity for more than 20 years. In this sense, the literature consulted indicates that years of experience are determining factors in the adoption of innovations. Farmers with more experience are more likely to adopt innovations due to the reduction of the risk involved in the decision to adopt, as empirical knowledge increases (1,23).

Finally, the sixth component (CP6) had the lowest contribution (7.12 %) and it was made up of the variables *Planting standard and Frequency of training*. The manifestation of these variables in CP6 was due to the fact that more than 70 % of respondents expressed that they comply with the optimum value of the sowing standard (24 kg ha^{-1}) and regarding the training frequency, farmers referred that the monthly activities turn out to be the most profitable, as well as they were able to identify several modalities and resources necessary for their successful development.

The above aspects indicate that there is a propitious framework for the adoption of innovations, corroborating the criteria of different authors when they point out that access to the technological knowledge of a crop lays the foundations for its adequate management to increase production (3,23,24). Therefore, this component was denominated *Compliance with technical instructions and farmer learning*.

In general, these results emphasize crop phytotechnics as the main factor of innovation and differ from those indicated by several authors who give greater importance to the variables that contemplate socio-cultural aspects (2,25,26): educational level and personal attributes of household head, characteristics of the labor force, school-age children and school attendance, economic: sources of income and relations with the market and institutional: perception and participation in farmers' organizations; while the technological aspects referred to the agroecological management of crops occupied a third or fourth position.

In agricultural systems, no two farmers have identical technological needs and, on the other hand, many solutions would be required if each farmer were to be addressed. Given this reality, it is convenient to classify recommendations into domains, in order to identify the sites where technologies are appropriate.

A similar situation occurs with the farmers who produce rice in Madruga municipality, since they do not have homogeneous characteristics and differ among themselves according to the circumstances (socio-cultural, economic, environmental and technological) that affect the sustainability of rice agroecosystems. Therefore, the corresponding technique was applied in order to achieve the grouping of farmers, based on the variables identified above. The results of the cluster analysis were shown in the dendrogram (Figure 1), which represented the formation of four groups or domains of recommendations characterized in Table 3.

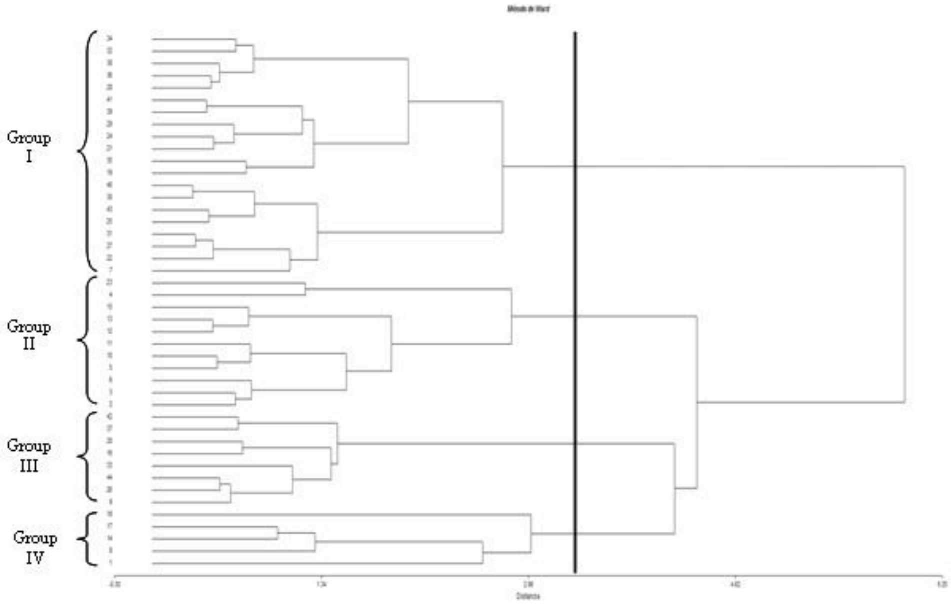

Figura 1. Dendrogram of 44 farms, according to the variables contemplated in the factors that influence the adoption of technological innovations in the local rice production system by the CCS of Madruga municipality

Table 3. Characterization of recommendation domains

Groups		Domain I	Domain II	Domain III	Domain IV
Number of farmers		20 (including 2 women)	11	8	5
Proportion of the sample (%)		45,4	25	18,2	11,4
Average age (years)		46	54	46	51
Schooling level		Secondary and Pre-university	Primary and Secondary	Secondary and Pre-university	Primary and Secondary
Experience of farmer (years)		28 - 29	24 - 25	26	29
Spatial-temporal arrangement	Planting time	March - April	April - June	March - June	March - May
	Surface (ha)	< 2	2 - 3	2 - 3	10 - 11
	Cultural attentions to the seedbed	Hand weeding (two farmers)	Hand weeding (seven farmers)	Hand weeding (one farmer)	Hand weeding (three farmers)
	Nutrition management	Mineral nutrition	Mixed (mineral and organic)	Mineral nutrition	Organic nutrition
Crop phytotechnics	Harvest and post-harvest methods	Manual harvesting Hand-drying	Manual harvesting Sun-drying	Manual harvesting Sun and nand drying	Semi-mechanized harvesting handicraft, chemical and cultural drying
	Methods used in pest management	Cultural	Cultural, chemical, mechanical and biological	Chemical and mechanical	
Acquisition of seed		Own production	Exchange and purchase	Purchase	Own production
Source of supply Water resources		Well	River	Well	Well
Agricultural yield (t ha^{-1})		4,67	3,77	4,02	4,60

The heterogeneity existing among the groups, mainly due to differences in the phytotechnical management of rice cultivation, reflects its impact on agricultural yields. This issue should be taken into account when making recommendations, together with the variables that determine sociocultural and environmental factors, so that the adoption of technological innovations responds to the real demands of farmers [27].

Group I was composed of the largest number of farmers with schooling above the ninth grade and with more experience in rice cultivation in small areas. At the same time, they use traditional methods and local resources, which allow them to obtain higher yields compared to remaining groups. These farmers could be considered experienced because they have potential for the promotion of ecological agriculture, due to the fact that their members comply with some of the basic principles of agroecology.

Lower schooling predominated in Group II and less experience. This group develops various nutritional alternatives and different methods of pest management. However, agricultural yields are below 4 t ha^{-1}, due to the phytosanitary problems they face and the lack of knowledge of cultivars. Recommendations to this group are directed towards the adoption of the SICA method, the adoption of cultivars with resistance to harmful organisms and training in agroecological pest management, with emphasis on the use of biological inputs.

Groups III and IV coincided in the high level of schooling, knowledge about rice cultivars and agronomic cultivation techniques. In these groups, the level of experience exceeded 25 years and the average age of the members differed by five years. Despite these similarities, Group III is characterized by rice production with the use of external resources on a small scale (2 to 3 ha) while Group IV is composed of the smallest number of farmers, with a larger cultivation area and extensive use of external resources, which favors yields close to those of Group I. The main common point between Groups III and IV lies in the local rice production system, which responds to the interweaving of the Green Revolution model with the principles of agroecology, at different spatial scales of application.

The recommendations for these groups are oriented towards the introduction of medium and short cycle cultivars with high agricultural and industrial yields, resistant to harmful organisms and with low water and fertilizer requirements. Likewise, they are suggested to adopt technologies of direct sowing in line and in drip with the management of weeds by mechanical methods (use of the rotary weeder) and sowing at the beginning of the rainy season. Their implementation will allow locally adapted agroecological practices to stimulate key processes for the functioning of rice agroecosystems, leading to their resilience [18].

CONCLUSIONS

- In the scenario studied, technological factors are the most important in the adoption of technological innovations. In second and third place are the sociocultural and institutional factors, since the problems exposed as weaknesses in other latitudes are solved in the CCS, which constitutes a strength for the adoption of technological innovations in these productive entities.

- The analysis of four domains of recommendations in the local rice production systems of Madruga municipality, showed the superiority of Domain I in rice phytotechnics, the main technological factor that affects the adoption of technological innovations.

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