Technical-economic characterization of the lulo production system (*Solanum quitoense* Lam.) in the department of Nariño

Caracterización técnico-económica del sistema de producción de lulo (*Solanum quitoense* Lam.) en el departamento de Nariño

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ABSTRACT

Nariño is a significant producer of lulo in Colombia, with the producers of the region found in the northern part of the department. The principal problems for the producers are the low levels of productivity and profit, which have led to increasing abandonment of this crop, losses of manual labor, and a reduction in the standard of living. The general objective of the present study focused on the application of multivariate analysis in order to reveal the characteristics of the production system, such as the elements of decisions. The results of surveys, interviews, and direct observations of the production units were analyzed through principal component and grouping analyses, using the Ward distance criterion. The studied lots were between 1,788 m a.s.l. in the La Florida District of the municipality of Colón and 2,480 m a.s.l. in the Botanilla District of the municipality of Cartago. Yields were low, although the majority of the producers in Colón obtained yields over 7.0 kg/plant with a shared production system. The plantlets used for the establishment of the crops are produced by the farmers, few in number, and rarely bought. Chemical fertilization and phytosanitation predominate, although, in San Lorenzo, only organic fertilizers are applied during sowing; microelements are not applied in any of the municipalities. The harvest is commercialized by agrobusinesses with prices fixed by the venders. The analysis of the economic variables showed that those producers with a high number of plants were more efficient and obtained a profit of 488.4%, higher than the general average which was 202.5%.

Key words: fruits, descriptive analysis, principal component analysis, cluster analysis.

RESUMEN

Nariño es un productor importante de lulo en Colombia, localizándose la región productora en el norte del departamento. El principal problema de los productores se centra en los bajos niveles de productividad y rentabilidad, lo cual ha provocado el abandono progresivo del cultivo, pérdida de mano de obra y reducción de su nivel de vida. El objetivo general del presente estudio se centró en la aplicación del análisis multivariado para el conocimiento de las características de este sistema productivo; como elementos de juicio, se analizaron los resultados de encuestas, entrevistas y observaciones directas de las unidades productivas, mediante un análisis de componentes principales y de agrupamiento utilizando como criterio las distancias de Ward. Los predios investigados se ubicaron entre 1.788 msnm en la vereda La Florida, municipio de Colón y 2.480 msnm en Botanilla, municipio de Cartago. Los rendimientos son bajos, aunque la mayoría de los productores de Colón obtienen rendimientos superiores a 7,0 kg/planta en un sistema de producción compartido. Las plántulas utilizadas para el establecimiento del cultivo, son producidas por los productores y solo unos pocos, las compran en casas especializadas. Predominan los controles fitosanitarios y la fertilización química, aunque en San Lorenzo se aplica solo abono orgánico en la siembra y no se aplican microelementos en ningún municipio; la cosecha se comercializa en la agroempresa con precios fijados por el comercializador. El análisis de las variables económicas mostró que aquellos productores con mayor número de plantas, fueron más eficientes y alcanzaron una rentabilidad de 488,4%, por encima del promedio general que fue de 202,5%.

Palabras clave: frutas, análisis descriptivo, análisis de componentes principales, análisis de agrupamiento.

Introduction

Globalization has made economies more dependent and demands a higher level of competitiveness in order to gain and maintain market share (Arredondo and Hernández, 2012). It has increased competition at the national and international levels; production regions must implement technology and strategies that aim to reach the maximum levels of competitiveness (Encinas *et al*., 2011). This scenario requires knowing the current competiveness level of a product or region to form the baseline for the design of policies and strategies that correct weaknesses or

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strengthen successful situations (Lascano, 2002; Lombana and Rozas, 2008).

Colombia is an agricultural country; however, this sector presents worrying productivity indices, mostly due to conditions of low technology, low innovation abilities, and high production costs, resulting in lacking competiveness for access to national and international specialty markets (Arredondo and Hernández, 2012).

Lulo is considered a promising crop with potential due to its nutritional value and its organoleptic properties that make it desirable in national and international markets (Denis, *et al*., 1985; Lobo and Medina, 2000; Huertas e*t al*., 2011). Colombia is part of the origin center of this fruit and offers optimal environments for the crop; however, the desired degree of development has not been reached due to the difficulty in obtaining materials with desirable characteristics that would allow for exploiting the genetic potential of the fruit and for competition in markets (Heiser, 1985; Tafur, 2006).

Cultivated areas are located in hillside zones between 1,200 and 2,800 m a.s.l., offering an alternative with potential for diversifying the production systems of the coffee-growing zone or in those zones with illicit crops (Franco *et al*., 2002). Profitability is closely linked to the use of familial manual labor and crop yields vary between 3 and 18 t ha^{-1}, due to factors such as the climatic characteristics of the cultivation zone, soil fertility, technology level, and the limited offering of genetically superior cultivars (Lobo, 2004; Angulo, 2008; Huertas *et al*., 2011).

Lulo cultivation is an area of great importance to the municipalities of northern Nariño due to the fact that it generates employment, provides income, and improves the standard of living for the producers. However, multiple problems of a technological, phytosanitary, and commercial nature threaten its sustainability (CIAT, 2007). According to Agronet (2012), between the years 2010 and 2012, Nariño presented a decreased annual lulo production rate of 16.71%, decreased harvested area (18.70%) and a slight increase in yield (1.99%). The low profitability of the producers is a consequence of the low productivity, deficient quality, and disorganization of the production and the producers, which make them vulnerable to the intermediaries with whom they do not have the ability to negotiate (Muñoz *et al*., 2013).

In Colombia, there are 7,559 ha cultivated with lulo (2012) and, for the year 2025, it is estimated that there will be a need for another 10,000 ha (Tafur, 2006). According to Agronet (2012), if the average production of 5.3 t ha^{-1} of Nariño, the average national production of 8.9 t ha^{-1} and the 27 t ha^{-1} fresh fruit production potential of the species are taken into account, the technological gap is around 18.1 t ha^{-1}; that is to say, between 27 and 45 million Colombian pesos are lost out on per hectare by the farmers.

Agricultural production can be understood as the ability to achieve higher production with the desired quality at a low cost in order to increase customer satisfaction and profitability (Lascano, 2002). When production is higher, it benefits the community through the creation of new jobs and taxes. If the concept of sustainability over time is added to this definition, it is possible to speak about the competitiveness of agricultural businesses (Pannell *et al*., 2013; Escudero, 2002). Competiveness in this context must be understood as the ability of lulo producers to remain in the market in the long-term through the continuous improvement of technology in order to offer quality products at a reasonable price for the consumer. In the current conditions, the low level of technology among the lulo producers of the municipalities of northern Nariño impedes competiveness at the national and international levels, which could result in the disappearance of these cultivated areas in the immediate future (Huertas *et al*., 2011).

This study of the production system allowed for the identification of the activities from the start of production until harvest and commercialization; it also revealed the strengths and weaknesses that can be found within a determined production system (Huertas *et al*., 2011). According to Pedraza *et al*. (2011), a system is composed of interactive components, such as the agricultural production of a country, a region, or even small levels such as farms. Agrobusinesses are systems with different types of resources, processes and production components that the farmers, individually or collectively, combine to form subsystems; at the same time, they convert the resources into products and the products into resources through the systematic action of the resources, the systematic collection of the products and systematic exchange of both within the socioeconomic context of the system in a manner that sustains all (Homolka and Bubeníková, 2013; Tang, 2013).

The role of agrobusinesses as socioeconomic systems is limited by the broadness of the decisions permitted to the producers by the social system, by the value assigned by the economic system to the resources and products, by the availability of land, manual labor, and technology,

and the information on how to combine the components available in the agrobusinesses (De Groote *et al*., 2010; Asfaw *et al*., 2012).

With these considerations, this study aimed to use Multivariate Analysis techniques in the technical-economic characterization of the lulo production system (*Solanum quitoense* Lam.) in the municipalities of Cartago, Colón and San Lorenzo in the department of Nariño in order to identify the factors with more influence on the system's competitiveness.

Materials and methods

The present study employed a descriptive-type non-experimental methodological design that was carried out in the municipalities of Cartago, Colón and San Lorenzo, located in the northern section of the department of Nariño, where 45% (307 ha) of the cultivated area for lulo for this department is located (MADR, 2010).

The municipality of Cartago is located at 01°55'25'' N and 77°07'55'' W, at a distance of 84 km from the department's capital, with an altitude of 2,000 m a.s.l. and average temperature of 18ºC. The municipality of Colón is located at 01°38'12'' N and 76°58'0'' W, 127 km from the town of Pasto, at 1,750 m a.s.l., with an average temperature of 17ºC; the municipality of San Lorenzo is located at 1°44'32'' N and 77°19'51'' W, 104 km from the town of Pasto, at 2,150 m a.s.l., with an average temperature of 16ºC.

The economy of these municipalities is principally based on agriculture and the principal products are coffee, mora, lulo, corn, cane and fique. The agriculture is carried out by families on a small scale for self-consumption and the excess is sold in local, departmental and national markets (Departamento de Nariño, 2011).

This technical-economic study of the lulo production system of the mentioned municipalities started with information from the directors of Umatas to determine the name of the producer, the number of plants per productive unit, and the location of the farm; 215 productive units were identified, distributed as follows: Cartago (103), Colón (42) and San Lorenzo (70). The number of plants was stratified as follows: less than 1,000 plants, between 1,000 and 2,000 plants, and productive units with more than 2,000 plants. Stratified random sampling was carried out with allocation for the municipalities and the size of the productive units according to the number of plants. The number of farm units to survey was calculated using the formula proposed by Scheaffer *et al*. (2007) and Ríos *et al*. (2004), resulting in 59 farms that were distributed according to the participation of each municipality in the number and size of crops. Furthermore, information was gathered with interviews, visits to the farms, and official statistics and reports from the Ministerio de Agricultura, Secretaría de Agricultura de Nariño and developmental plans of the municipalities.

The obtained information was evaluated with the SPAD v5.6 software through a principal component analysis (PCA) and a cluster analysis using Ward distances as a classification criterion (Ríos *et al*., 2004; Chávez *et al*., 2010).

Results and discussion

The analysis of the information obtained with the surveys established that 55.9% of the crops are located above 2,000 m a.s.l., 23.7% are between 2,000 and 1,900 m a.s.l., and 20.3% are below 1,900 m a.s.l., a condition that is highly related to the time required from sowing to harvesting of the product, according to Medina *et al*. (2009). Small crops predominate, with less than 2,000 plants (86.4%), resulting in high heterogeneity in the production and quality which causes disadvantages in the ability to negotiate in the commercialization process (Aubron *et al*., 2009). The majority of the productive units are owned (81.4%), 5.1% are rented and 13.5% are used by companies.

A 42.3% of the sowing of the crops coincides with the rainy season, 47.5% do not use any programming type, and only 10.2% use interval sowing which allows for production year-round; resulting in the vast majority of the producers being at risk due to variations from climatic changes and the lack of adapted cultivars, as expressed by Brown and Funk (2008).

Due to its treatment as a crop that does not allow for direct sowing, the quality of the plants is of great importance to the future performance of farms; however, 89.8% of the producers carry out their own seeding and only 10.2% buy plants produced by specialized companies in La Unión and Popayán. The preparation of the soil is usually (84.7%) done by only tilling the sowing site, which improves soil behavior in terms of erosive factors, principally by water; 15.3% prefer to prepare all of the land.

In terms of crop management, high variability was observed in the aspects related to density, fertilization, irrigation, and sanitation management, which made it difficult to standardize the technical norms and, in general, presented heterogeneity in all the aspects related

to production. 47.5% of the surveyed producers use sowing densities below 2,000 plants/ha, 32.2% use densities between 2,000 and 3,000 plants/ha, and 20.3% use high sowing densities (>3,000 plants/ha); resulting in different degrees of susceptibility to phytosanitary problems because high densities facilitate humidity levels that lead to the development of diseases (Santos *et al*., 2010), such late blight (*Phytophthora infestans*), white mold (*Sclerotinia sclerotiorum*) and black spot disease (*Colletotrichum* sp.), thereby limiting production (ICA, 2011). The sowing of the plants is done with the application of just organic fertilizers (50.8%), only chemical fertilizers (30.5%) or with a mixture of both (18.6%).

A 54.2% use spray irrigation, 30.5% use localized irrigation with conventional hoses and 15.3% do not use irrigation. 30.5% apply fertilizers every month, 64.4% do so every two months, and 5.1% do it every four months. 74.6% only apply chemical fertilizers and 25.4% use a mixture of organic and chemical fertilizers. The majority of these fertilizers are compound (50.8%), 8.5% simple, or the indiscriminate use of compound and simple fertilizers (40.7%). The application quantities vary and depend on the age of the crop: in the adult stage, 81.4% apply 100 g/plant, 8.5% apply 150 g/plant, and 10.1% apply 200 g/plant. The vast majority of lulo producers of this zone do not apply microelements (78.0%), leading to the supposition that, during growth, the lulo presents nutritional deficits that affect productivity because, according to Moreno *et al*. (2011), the use of only macroelements leads to misbalances in the chemicals of the cultivated soil, directly affecting productivity.

For pests and diseases controls, it was found that 30.5% carry out weed management with mechanical methods, 18.6% with manual methods, and 50.8% with integrated methods. The use of mowers predominates, with occasional combinations with chemical products, practices that are favorable for avoiding the erosive deterioration of the soil (Romero and Díaz, 2011). In terms of phytosanitation controls, chemical controls predominate (76.3%), followed by methods that combine chemicals with traps in the case of pests (23.7%). Biological controls and resistant varieties are not used conscientiously.

According to Casierra-Posada *et al*. (2004), the efforts of lulo producers are decreasing due to the losses caused by multiple factors that affect the fruit during the preharvest, harvest and postharvest, with producers of the zone being characterized by harvests every 15 d (50.8%), every 21 d (40.7%), and every 30 d (8.5%). Frequent harvests are an important factor in the definition of the uniformality in the maturation points, which is key for classification. The classification of the lulo in the zone is principally done by size (78%), which is important to take into account when new crops are going to be programmed. Genotypes with a high production of small fruits, such as La Selva lulo, tend to have commercialization problems, principally because the price categories are defined by the size of the fruit.

Fruit presentation is very important for commercialization. However, only 11.9% of the producers wash the fruit, while the rest confirm that the fruit loses quality during the packing and transport process. Similarly, the harvest method helps to determine the quality, with 37.3% using plastic buckets, 11.9% using small baskets, and there is still a high percentage of producers that harvest with sacks (50.8%), increasing the physical damage through squashing. Another aspect that determines the postharvest quality is the type of transport from the harvest site to the point of sale, with 54.2% transporting the lulo in sacks carried on the shoulder, 37.3% use horses, and only 8.5% use mechanical methods.

The producers are aware that this type of postharvest management causes problems for lulo quality and 79.7% consider transport to be the most critical factor, while 13.6% consider sanitation problems to be more critical, and 6.8% attribute quality losses to over-maturation of the plants. Fruit that is rejected by buyers due to low quality has no application in the zone and becomes a contamination problem with 76.3% thrown away at the point of sale and 23.7% buried.

Significant problems that are faced by lulo producers in the north of Nariño are related to economic difficulties and limited access to credit (69.5%). Other notable problems include difficulties in finding manual labor, especially during the coffee harvest (10.2%). The number of workdays is a little-identified variable in the zone because a lot of familial labor is used (producer, wife, children) and it is an aspect that the producers do not consider a cost. The analysis of the survey established that 47.5% use less that 250 workdays/ha per year and 22.0% use more than 300 workdays/ha per year, with the majority of the labor being male (91.5%) and only 8.5% is female. Wages that include room and board are more common than those that do not, 66.1% and 33.9%, respectively. Wages for lulo work are relatively high when considering the average wage in the zone is $10,000 Colombian pesos with room and board; 25.4% of the producers pay less than $10,000, 66.1% pay between $10,000 and $15,000, and 8.5% pay more than $15,000.

The commercialization of lulo in the zone is principally done through intermediaries that transport it to supply centers in Pasto and Cali, principally, with 86.4% of the producers using this method without any ability to negotiate the purchase price. A 5.1% of the producers sell in markets that demand less quality and with a lower ability to negotiate price and 8.5% of the producers transport the product directly to the consumption centers in Pasto and Cali. As a consequence, only 8.5% of the producers consider researching the lulo prices in other regions.

Knowledge and application of modern agricultural production principles, such as Clean Production, Good Agricultural Practices, the NTC standard, and the ISO 14000 standard, are not very significant for lulo producers in the north of Nariño, with 32.2, 11.9, 8.5 and 6.8%, respectively; ignorance and non-application of these rules produce less competitive producers in specialized markets (López and Correa, 2006).

The producers are generally dissatisfied with the support they receive from the financial, institutional, commercial, and private entities. The financial support is considered deficient by 50.8%, the institutional support is considered deficient by 91.5% and the private company support is considered deficient by 61%.

The principal component analysis determined, according to the histogram of the eigen values (Tab. 1), a large contribution of the factors that explained the total variability, with the first three factors sufficiently explaining 96.01% of the total variability. Factor 1 represented 66.14% of the total variability and constituted all of the variables except for Investment/plant (INVPL) and Cost/ton (CTON), with demonstrated low correlation with this factor. The largest contribution to factor 2 came from Cost/ton and the largest contribution to factor 3 came from the investment/plant variable (Tabs. 1 and 2).

The grouping analysis of the surveyed producers resulted in four groups. Group 1 had 13 producers, corresponding to 22.03% of the surveyed population. Of these producers, 92.3% came from the municipality of Cartago and 7.7% from Colón. This group of producers was the least efficient from the point of view of investments and attained profitability (Tab. 3). It presented an investment/plant and a cost/ton higher than the general average but profitability (122.63%) lower than the population average (202.5%).

TABLE 2. Contribution of the quantitative variables to the formation of the first three principal factors for lulo production system in Nariño (Colombia).

Variable	Coordinates		
	1	2	3
PPL	-0.84	-0.34	-0.42
NOPL	-0.80	0.49	0.31
PN	-0.97	0.22	0.04
INVPL	0.10	0.51	-0.84
CT	-0.79	0.56	0.17
CTON	0.65	0.66	-0.02
IN	-0.98	0.13	0.00
PROF	-0.85	-0.49	-0.11

PPL, plant production; NOPL, number of plants; PN, yield; INVPL, plant investment; CT, total cost; CTON, cost/ton; IN, net income; PROF, profitability.

Group 2 had 24 producers, representing 40.7% of the surveyed population. 29.16% came from the municipality of Cartago, 16.66% from the municipality of Colón, and 54.16% from San Lorenzo. It was characterized by having low values for investment/plant ($3287), yield/plant (6.79 kg), and profitability (156.79%), as compared to the average values of the population (Tab. 3).

In contrast, group 3 presented a high profitability (269.74%), high yield/plant (10.26 kg) and a low cost/produced ton ($547167), making it efficient. This group contained 19 producers, representing 32.2% of the surveyed population. 42.10% came from the municipality of Cartago, 31.57% from Colón and 26.31% from San Lorenzo (Tab. 3).

Group 4 had three producers, distributed in three of the studied municipalities, representing 5.1% of the population. This group represented the most efficient producers with the highest economic indices. They possessed a number of plants (4,000 plants) that was higher than the

TABLE 1. Histogram of the eigen values that demonstrated the distribution of the observed variable with the quantitative variables for lulo production system in Nariño (Colombia).

No.	Eigen values	Percentage	Cumulative percentage	Histogram
1	5.952	66.14	66.14	**********
2	1.665	18.51	84.65	**********
3	1.922	11.36	96.01	**********
4	0.303	3.37	99.38	**

TABLE 3. Description of the product groups formed in the grouping analysis based on the quantitative variables.

Test	Probab	Means		Variable
		Class	General	
Class 1 of 4				
5.65	0.000	4692.3	3703.4	INVPL
3.94	0.000	947241.6	725996.9	CTON
-3.14	0.001	122.6	202.5	PROF
Class 2 of 4				
-2.80	0.003	156.76	202.5	PROF
-3.70	0.000	3287.5	3703.4	INVPL
-3.91	0.000	6.79	8.56	PPL
Class 3 of 4				
3.43	0.000	269.74	202.5	PROF
3.14	0.001	10.26	8.56	PPL
-4.13	0.000	547167.1	725996.9	CTON
Class 4 of 4				
6.83	0.000	352.04	42.77	COMTG
6.72	0.000	95922496.6	15797179.39	IN
6.56	0.000	60.0	11.29	PN
5.02	0.000	24077503.4	6785871.45	CT
5.02	0.000	16.67	8.56	PPL
5.02	0.000	4000.0	1194.4	NOPL
4.09	0.000	488.41	202.5	PROF
-2.78	0.003	367958.7	725996.9	CTON

PPL, plant production; NOPL, number of plants; PN, yield; INVPL, plant investment; CT, total cost; CTON, cost/ton; IN, net income; PROF, profitability.

average (1,194 plants), with a yield (16.67 kg/plant) higher than the average of 8.56 kg/plant. They had the highest total costs ($22,077,503 in comparison with the average of $6,785,871) and reached net incomes of $97,922,496, well above the average of $15,797,179. This group was characterized by having the highest profitability with a value of 488.4% in comparison with the general profitability of the surveyed population (202.5%) and a high competitiveness rate (352.04). In addition, the cost/ton ($367958) was lower than the general average ($725996) (Tab. 3).

It is clear that the multivariate analysis identified variables that potentialize the productivity of lulo producers, indicating where efforts should be directed for the improvement of the yield (Ríos *et al*., 2004). In this case, sowing more plants can reduce the cost/ton and the three producers that formed the group with high yields can serve as a model in campaigns to increase lulo yield in the northern zone of the department of Nariño.

Conclusions

In the production system of lulo crops in the northern zone of Nariño, there are problems related to the low technology levels that are typical and characteristic of the rural agricultural subsector, the small size of the lots, the predominance of rudimentary irrigation systems, the absence of soil analysis and the absence of microelement applications.

The low technological level that predominates in the agrobusinesses of lulo production is associated with low productivity levels, high investment per plant, and high cost per ton of produced fruit.

Producers with low costs per ton possess a high number of plants and obtain higher revenue and higher profitability, which make them more competitive.

The grouping analysis identified the producers with more than 3,000 plants as more efficient, with higher profitability and competitiveness (group 4), which only represented 5.1% of the total population.

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