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Multivariate Statistical Analysis For The Grouping Of Jalapeño Producers In Quintana Roo, Mexico

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Abstract:
The study was conducted in the state of Quintana Roo, Mexico, through interviews with jalapeño pepper producers. Based on information provided directly by the producers, five groups were formed according to their similar characteristics. This study identified deficiencies in crop management, mainly in terms of the timing of applications and the optimal quantities of inputs. This had a negative impact on production, resulting in low yields, and therefore actions and strategies need to be implemented to promote more sustainable production and short-chain marketing of the product.

Background*: Mexico is one of the leading producers of jalapeño peppers, and the state of Quintana Roo is located in a strategic area for their production. It is one of the most widely cultivated alternatives due to its diversity of uses and nutritional and industrial value. For this reason, with the aim of strengthening the jalapeño value chain and with funding from the Mixed Funds of the National Council for Science and Technology in Mexico, a research project is being carried out to propose a comprehensive strategy and productive innovation to boost the productivity of jalapeño cultivation in the state of Quintana Roo.*

Materials and Methods*: From a list of 115 jalapeño pepper producers, a sample size with a confidence level of 95% and a precision of 10% was obtained. A total of 52 questionnaires were administered to jalapeño producers to obtain sociodemographic information as well as information on crop management and marketing. The agglomerative hierarchical method was used for cluster analysis, and Ward's method was used for linking. Three metric variables were selected for sample segmentation (producer age, number of family members, and experience). Distances were calculated using the Euclidean distance equation. Finally, a multiple discriminant analysis was performed to verify that the classification had been carried out correctly.*

Results*: 98.1% of the original clustered cases were correctly classified into five groups: 1) adults with young family households and beginners in jalapeño cultivation, 2) adults with young family households and intermediate level of cultivation, 3) adults and extended family households and intermediate level of cultivation, 4) adults with family households and advanced cultivation skills, and 5) older adults with family households and expert cultivation skills.*

Conclusion: *Cluster analysis identified groups with different sociodemographic characteristics but with very similar problems in terms of the production and marketing of their product. In this region, actions are needed to disseminate the technology available to increase yields, promote more sustainable production of jalapeño peppers, and develop agribusiness.*

Key Word: *Cluster analysis; discriminant analysis; jalapeño pepper.*

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I. Introduction

The jalapeño pepper (Capsicum annuum L.) belongs to the Capsicum genus, which is the most widely cultivated in Mexico. Its origin is attributed to the municipality of Jalapa, Veracruz, and since the 1980s, it has been one of the main producers of jalapeños in the dry season, and the state of Chihuahua in the rainy season[1]. The largest area planted with jalapeño peppers is concentrated in Chihuahua, Sinaloa, Michoacán, Chiapas, and Jalisco, which together account for 67.1% of the national area of 27,763.8 ha[2]. However, the largest share of

national production (55.9%, or 799,388.3 t) comes from Chihuahua and Sinaloa, with average yields of 35.7 t ha^{-1} [2].

The socioeconomic importance of jalapeño cultivation lies in its profitability and the jobs it generates in the agricultural sector[3]. However, in the last few years (2010-2020), the area under cultivation decreased by 11.2%[4]. Several factors have contributed to this decline, including inefficient pest and disease management[5], adverse weather conditions[6], producers' disregard for consumer preferences regarding jalapeño attributes, and the disconnect between the primary link and end consumers[4], which has led to a decrease in the physical volume index and the current value of production[7].

[8]Found that consumer-purchasing behavior varies by region and that understanding this pattern could help propose differentiated strategies for jalapeño production and marketing. While it is essential to know consumers tastes and preferences, it is also important to know the characteristics of jalapeño producers in order to develop differentiated strategies. That is why this research aims to group producers who are most similar to each other based on their experience in cultivation, the size of their households, and their age.

II. Material And Methods

The information was obtained through a structured survey with multiple-choice questions administered to jalapeño producers, including information on the geographical coordinates of their plots[9]. The sample size was obtained using the maximum variance equation p=50% (p=0.5) and q=50% (q=0.5)[10].

$$n = \frac{\frac{Z^2 p_n\, q}{d^2}}{1 + \frac{Z^2 p_n\, q}{N\, d^2}}$$

Where: Z=95% confidence level (1.96), d=10% precision level (0.10), p_n=proportion of the population belonging to the group of interest, q = (1-p_n), N =population size (115 producers), and n=sample size (52 producers).

The agglomerative hierarchical method was used for cluster analysis, and Ward's method was used for linking, to join groups or clusters with the smallest increase in variance[11].

The following steps were taken to carry out the grouping: three metric variables were used: producer age (years), number of family members, and farming experience (years). The Euclidean distance equation was used to calculate distances in order to select the most similar pair of elements to form a group with the smallest distance GROUP $\rightarrow \min\{d_{ij}\}$:

$$d_{ij} = \left[\sum_{k=1}^{r} \left(x_{jk} - x_{jk}\right)^2\right]^{\frac{1}{2}}$$

Where: d_{ij} is the distance between the profiles of objects i and j, X_{ik} represents characteristic k measured in object i, X_{jk} represents characteristic k measured in object j, and r is the number of characteristics used to evaluate similarity[11]. Subsequently, multiple discriminant analysis was performed to verify whether the producers interviewed were correctly classified using cluster analysis. Statistical analysis was performed using Statistical Package for the Social Sciences (SPSS) version 27.

III. Result And Discussion

Figure 1, shows the dendrogram obtained with the cluster analysis, with the formation of five groups at a Euclidean distance of six.

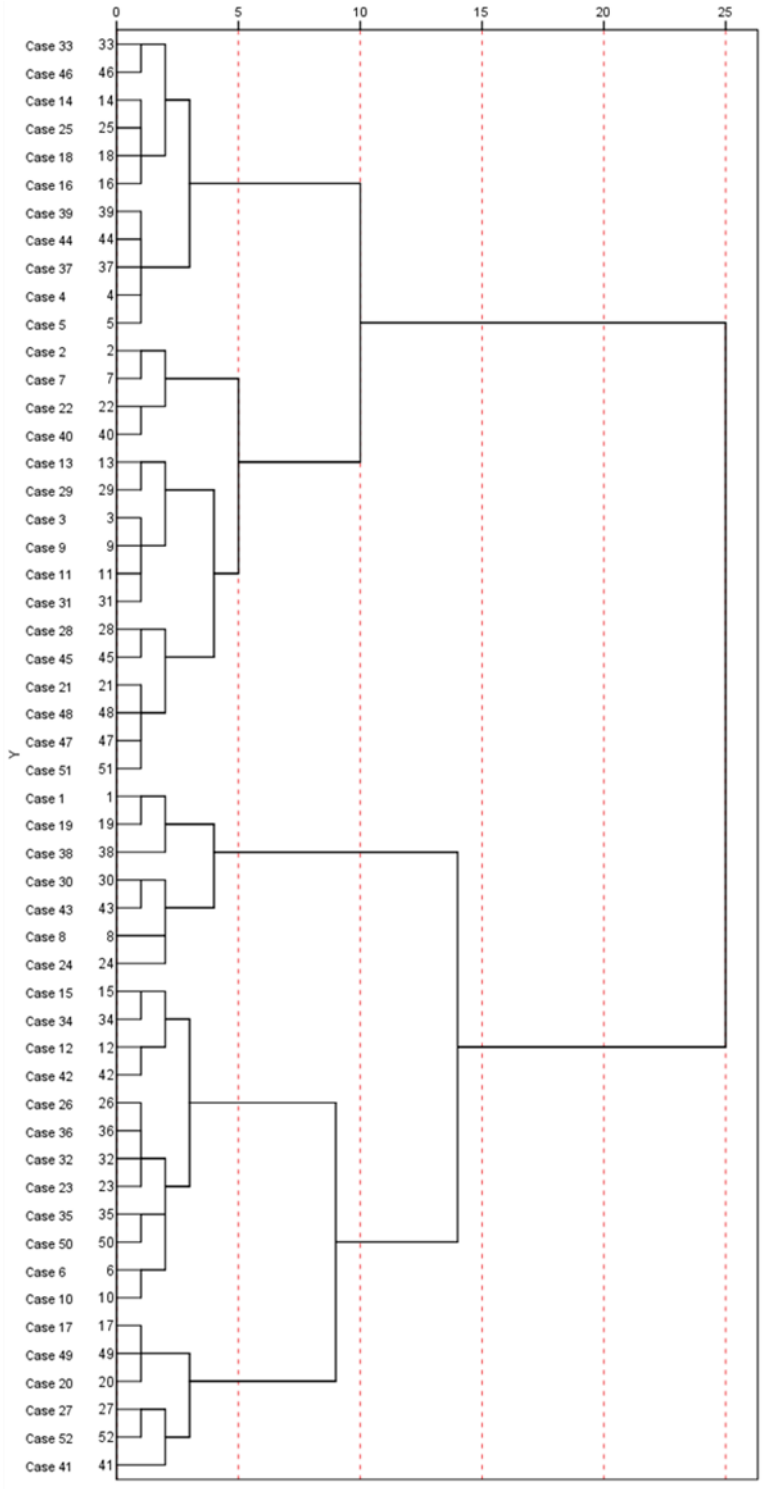

Figure 1: Dendrogram using Ward's linkage

Table 1 shows the classification results based on the discriminant function obtained. In this case, it can be seen that 98.1% of the producers interviewed were correctly classified.

Table 1: Producer ranking results

		Predicted group membership					
	Group	1	2	3	4	5	Total
Recount	1	11	0	0	0	0	11
	2	0	15	0	1	0	16
	3	0	0	7	0	0	7
	4	0	0	0	12	0	12

	5	0	0	0	0	6	6
%	1	100	0	0	0	0	100
	2	0	93.75	0	6.25	0	100
	3	0	0	100	0	0	100
	4	0	0	0	100	0	100
	5	0	0	0	0	100	100
a. 98,1% of correctly classified original clustered cases.							

Figure 2 shows each of the observations on the factorial axes, confirming that the observations are correctly discriminated on the factorial axes obtained from the initial explanatory variables. Likewise, the average value of the centroids of each group shows that they do not mix.

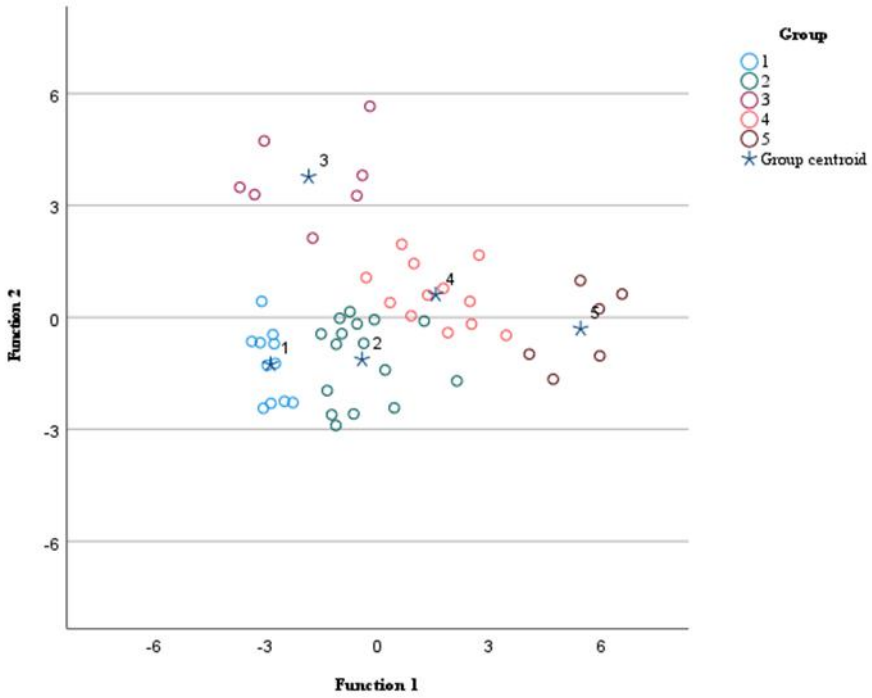

Figure 2: Canonical discriminant functions

The following describes the identified groups and the percentage of the sample: 1 (21.6%) adults with young families and beginners in jalapeño cultivation, 2 (31.4%) adults with young families and intermediate level of cultivation, 3 (13.5%) adults and extended family households with an intermediate level of cultivation, 4 (23.1%) adults with family households and advanced cultivation skills, and 5 (11.5%) older adults with family households and expert cultivation skills (Table 2).

Table 2: Main grouping characteristics

Group	Age (average years)	Household size (Median number of members)	Experience (Median in years)
1	37	3	5
2	52	3	15
3	51	8	20
4	58	4	28
5	70	3	45
Aveage	52	4	20

28.8% of respondents indicated that they spoke a native language such as Maya, Ch'ol, Chinanteca, Tseltal, and Zoque, which coincides with the linguistic diversity of the state[12]. The highest proportion was concentrated in groups 2 and 4. The size of jalapeño pepper producer households in Quintana Roo was above the state average of 3.5 [13]. Both the level of education (incomplete primary education) and the average age of producers (52 years) were consistent with other studies conducted in the region, in the municipality of Othón P. Blanco, where producers have four years of schooling and are 42 years old[14].

On the other hand, 63.5% of producers stated that their father was also a jalapeño pepper producer, with the highest frequency identified in groups 1, 2, and 4. For the vast majority of producers, 92.3%, jalapeño cultivation is their main source of income under the ejido regime with rights of use and exploitation. With regard to crop management, it was found that 51.9% of producers plant at the optimal times (May 15 to July 15)[15]. Table 3 describes the jalapeño pepper crop management practices carried out by each group of producers on the plot.

Table 3: Technological and handling features

Characteristics	Group				
	1	2	3	4	5
Varieties	54.5% native and 45.5% commercial	43.8% native, 12.5% Don Benito, 43.8% commercial	42.9% native y 57.1% commercial	66.7% native, 8.3% Don Benito y 25.0% commercial	50.0% native, 9.6% Don Benito y 40.4% commercial
Other crops	corn, squash, beans, watermelon, cucumber, sweet potato, and lemon	corn, squash, beans, melon, cucumber, peanuts, and lemon	corn, squash, beans, melon, watermelon, cucumber, jicama, and lemon	corn, squash, beans, melon, watermelon, peanuts, tomatoes, and lemons	corn, squash, beans, watermelon, habanero peppers, and tomatoes
Applied technology	90.9% under rainfed conditions, 9.1% backpack irrigation and manual harvesting.	87.5% under rainfed conditions, 6.3% backpack irrigation, 6.3% sprinkler irrigation, and manual harvesting.	100% under rainfed conditions y 85.7% manual harvesting	75.5% under rainfed conditions, 25.0% sprinkler irrigation and manual harvesting	83.3% under rainfed conditions, 16.7% sprinkler irrigation and manual harvesting
Fertilization (average kg ha^{-1})	Nitrogen (52.8), Pentaphosphate (64.0), and Potassium (57.0)	Nitrogen (35.5), Pentaphosphate (51.7), and Potassium (26.0)	Nitrogen (41.3), Pentaphosphate (46.1) y Potassium (20.3)	Nitrogen (72.0) y Pentaphosphate (57.5)	Nitrogen (49.5), Pentaphosphate (97.8) y Potassum (8.7)
Tasks	36.4% row planting, 18.2% corn barrier	37.5% row planting, 6.3% fallow and harrowing, 12.5% plowing, furrowing, and corn barrier	28.6% row marking, 14.3% fallow land, plowing, harrowing, and 28.6% corn barrier	16.7% row crop, 8.3% fallow land and corn barrier	50.0% row marking, 33.3% fallow, plowing, harrowing, furrowing, and 16.7% corn barrier

Jalapeño cultivation is carried out on a small scale on areas no larger than 2 ha^{-1}, characteristics that coincide other studies carried out in the state[16]. This study identified a preference for native seeds, with the exception of group 3. This preference is characteristic of the Southeast region[17], mainly in the states of the Gulf of Mexico and Southeast of the country, such as Oaxaca, Chiapas, Veracruz, Tabasco, Campeche, and Quintana Roo, where native materials or open-pollinated materials are used. In Quintana Roo, it is estimated that 36,129 ha are planted with native seeds and 59,136 ha with improved seeds[18]. In this regard, the National Institute of Forestry, Agricultural, and Livestock Research has released three jalapeño pepper varieties, of which Don Benito is one of the most economically significant in our country, with progress being made in the registration of new varieties such as Crótalus, developed especially for chipotle production[19].

Table 4, below describes the socioeconomic and cultural characteristics, highlighting that jalapeño production is mainly geared toward selling the product through different market agents. However, a high percentage of producers market their production through destination wholesalers, who are intermediaries that purchase jalapeños from origin wholesalers and resell them to the retail market.

Table 4: Socioeconomic and cultural characteristics

Characteristics	Group				
	1	2	3	4	5
Purpose of production	90.9% marketing	90.6% marketing	79% marketing	92.0% marketing	98.3% marketing
Type of production	Family members with daily wage contracts for certain activities such as land preparation and harvesting				
Scale of production (ha)	1.3	1.6	1.5	1.9	1.5
Marketing	36.4% destination wholesaler, 45.5% origin wholesaler, and 18.2% retailer	18.8% destination wholesale, 50.0% origin wholesaler y 31.3% retailer	57.1% destination wholesale y 42.9% origin wholesaler	25.0% destination wholesale, 33.3% origin wholesaler y 41.7% retailer	50.0% destination wholesale, 33.3% origin wholesaler y 16.7% retailer
Yield (t ha^{-1})	6.5	7	7.8	6.9	7.3

Although the state of Quintana Roo is considered a strategic region for jalapeño pepper production, the nearest marketing company is located in Chiapas and the industry in Veracruz. The yields obtained in this study are below the national average estimated at 25 t $^{ha-1}$ [20]. Based on the analysis of the characteristics of the producers,

actions and strategies for production and marketing were defined to promote cultivation in the state, as listed in Table 5.

Table 5: Production and comercial actions and strategies

Group	Description	Identified issues	Production actions and strategies	Commercial actions and strategies
1	Adults with young families and beginners in jalapeño cultivation	Low population density, inappropriate use of fertilizers, lack of foliar fertilization, inappropriate use of inputs for pest and disease control, use of own vehicle to market the product, intermediation.	Develop a calendar for the application of inputs. Strengthen technical knowledge on how and when to apply. Encourage the use of improved varieties to increase yields and bio-inputs.	Promote contract farming, use digital platforms for direct communication between buyers and sellers, promote short supply chains, and encourage partnerships between small producers and companies for adequate product transportation.
2	Adults with young families and intermediate level of cultivation	Establishing crops outside the optimal date, low crop density, inappropriate use of fertilizers, lack of foliar fertilization, inappropriate use of inputs for pest and disease control, using their own vehicle to market the product, intermediation, considering their relationship with intermediaries acceptable.	Outreach activities to raise awareness of the appropriate planting dates for crops. Participatory development of a calendar for the application of inputs. Strengthening technical knowledge on how and when to apply inputs. Promoting the use of improved varieties to increase yields and bio-inputs.	Promote contract farming, use digital platforms for direct communication between buyers and sellers, promote short marketing chains, encourage partnerships between small producers and companies for adequate product transportation, and strengthen the link between buyer and seller.
3	Adults and extended family households with an intermediate level of cultivation	Inappropriate use of fertilizers, lack of foliar fertilization, inappropriate use of inputs for pest and disease control, use of their own vehicle to market the product, 70% do not have access to financing, and 42% are not organized for marketing.	Participatory development of a calendar for the application of inputs. Strengthening technical knowledge on how and when to apply. Outreach activities to promote bio-inputs.	romote partnerships between small producers and companies for the proper transportation of products, association and training so that they can offer volume and quality, financial training.
4	Adults with family households and advanced cultivation skills	Low population density, inappropriate use of fertilizers, lack of foliar fertilization, inappropriate use of inputs for pest and disease control, use of their own vehicle to market the product, consider their relationship with intermediaries acceptable, 50% do not have access to financing and are not organized for marketing.	Participatory development of a calendar for applying inputs. Strengthening technical knowledge on how and when to apply them. Outreach activities to promote bio-inputs.	Promote partnerships between small producers and companies for the proper transport of products, strengthening the link between buyer and seller, associativity and training so that they can offer volume and quality, financial training.
5	Alder adults with family households and expert cultivation skills	Low population density, inappropriate use of fertilizers, lack of foliar fertilization, inappropriate use of inputs for pest and disease control, 50% use their own vehicle to market the product, consider their relationship with intermediaries to be acceptable or indifferent, 50% do not have access to financing and are not organized for marketing.	Participatory development of a calendar for applying inputs. Strengthening technical knowledge on how and when to apply them. Outreach activities to promote bio-inputs.	Promote partnerships between small producers and companies for the proper transportation of products, strengthening the link between buyer and seller, associativity and training so that they can offer volume and quality, financial training.

IV. Conclusion

Cluster analysis identified groups with different sociodemographic characteristics but with very similar problems in terms of the production and marketing of their product. In this region, actions are needed to disseminate the technology available to increase yields, promote more sustainable production of jalapeño peppers, and develop agribusiness.

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