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Potential Areas for Growing *Cyamopsis tetragonoloba* (L.) under Rainfed Conditions in Mexico

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Abstract

Cyamopsis tetragonoloba (L.) Taub., commonly known as guar gum, is a legume of great industrial importance due to the multiple uses which can be given by galactomannans contained in the seed's endosperm. Keeping in mind the acquiring relevance of this crop, it was considered of great importance to characterize the physical environment and the natural factors in order to locate the most suitable cultivation areas under rainfed conditions. The software Arc/View version 3.3 was used to process and analyze the information. The optimal agroclimatic requirements of guar gum were identified and each variable factor was matched with those found at ground level. A cartographic mapping was carried out to regionalize and locate the optimal and suboptimal zones. It was determined that in Mexico there is a great potential for its cultivation since it was found the existence of 900 thousand hectares with high or optimal potential and more than 200 thousand hectares of medium and sub-optimal potential where crop can be well established under rainfed conditions.

Keywords

Regionalization, Legume, Agroindustrial Cultivation

1. Introduction

Cyamopsis tetragonoloba (L.) Taub., known as guar gum, is a legume that is grown mainly in semi-arid and arid regions of the world, especially in countries such as: India, Pakistan, Brazil, South Africa and the United States [1]. This legume is grown mainly for industrial purposes and also as an ingredient for animal feed, due to its high protein content [2].

C. tetragonoloba is an annual crop that has an excellent drought tolerance [1]. It is fast-growing and profitable [3]. Its importance lies in its multiple utilities. Guar Gum is a high molecular weight carbohydrate. Industrially processed, it is a cream-colored powder that is used as a thickening agent. It has a high capacity to adhere to water, so at low concentrations it produces high viscosity solutions. In the food industry it is used for the stabilization of ice cream [1], in processed cheeses, cake mixes, meat products, dressings and sauces.

Douglas (2005) [4], reports its use as a forage plant, green manure, for human consumption (green pods) and industrial applications. Its seed is widely used in many industries, including food processing, papermaking, textile printing, pharmaceuticals, mining explosives, cosmetics and oil and gas exploration [5] [6]. In addition to commercial importance, this leguminous crop species can fix atmospheric nitrogen and improve soil fertility [7].

The most important application of this species lies in the production of galactomannans, called gums, contained in the endosperm of its seed [8] [9], which are long-branched polymers of mannose and galactose, which are used as thickener, gelling agent and suspending agent, viscosifier and emulsion stabilizer [10], and is used in a variety of fields such as: textiles, paper, paint, operations oil, drilling, civil engineering [11] [12] [13]. Guar gum is better suited to tropical and subtropical regions. Although official international statistical data for guar are lacking, today it is mainly grown in: India (80%), Pakistan (15%) and USA (Texas and Oklahoma) (5%) [14]. In Europe, it was cultivated, in the past, in Sicily Italy. Although it is no longer cultivated in this region, details about late planting have been reported [15]. The largest consumer of guar gum is the USA [16], it is used during the extraction of natural gas in its oil wells. Approximately 9 tons of guar gum is required to fracture a single well. About 80 acres of cultivation is required to obtain the necessary production per well [17].

Due to the increasing demand for *C. tetragonoloba*, the improvement of prices at international level and the low availability of raw material in Mexico, raise the need to increase the cultivation area, especially when there is an aroused interest among producers and industrialists of the country.

Given the international relevance acquired by the cultivation of guar gum, it was considered a priority to characterize the agroecological areas of the Mexican Republic in order to define different productive potentials zones.

2. Materials and Methods

The study was carried out at the laboratory of Geographic Information Systems (GIS) from INIFAP Southeast Regional Research Center, throughout the Program for Tropical Development headquarters in Merida, Yucatan, Mexico, which has among its objectives: 1) to gather, synthesize and analyze outstanding information related to technology, economy, markets and environment relevant for tropics development; 2) monitoring the state of agriculture in the tropics in order to identify areas of opportunity for sustainable development at regional level.

The delimitation of the production potential is based upon the search for agroecological requirements and their respective spatial query on existing maps, taking into account the climatic, topographic and soil variables, in addition to their intersections. This information was based on consulting crop experts, databases from Ecocrop of FAO and existing textbooks and articles of the studied species.

2.1. Agro-Ecological Requirements Determination

Crops distribution is currently marginalized by climate limits worldwide, either by default or by an excess of the vital needs for the individuals within different biotypes. Right from the moment the planting is performed, the plants are submitted to the climate components asynchronous variations, having those turned into the most determinant factors for the success of any given crop [18] [19] [20] [21] [22].

The particular needs and requirements of such crops are most commonly described in ranges, being usually reported by species or even genotype. The result of the diagnosis shall rely on the intervals taken into account; as a result, if optimal values are considered, the resultant potential areas may indeed provide a better yield and cultivation profitability.

The following criteria were considered to determine the rainfed potential areas for *Cyamopsis tetragonoloba*: 1) those where all of the appropriate variables interacting with each other were considered as the most suitable for an optimal development; 2) those where the correct climatic and soil characteristics interaction prevailed, despite some restrictions, were considered as suboptimal; 3) finally, those considered as inadequate for the mechanical settlement of Guar cultivations were reported, too. Potential areas were determined taking into account only those opened for cultivation. Altitude, soil, temperature and annual rainfall levels were also taken into account in addition to climate, in order to define the optimal, suboptimal and inadequate *Cyamopsis tetragonoloba* cultivation areas (**Table 1**).

2.2. Identification or Regionalization of Potential *Cyamopsis tetragonoloba* (L.) Cultivation Areas

The Arc/View version 3.3., software—developed by the American company ESRI—was the program used for data process and analysis. Geo-referenced data can be represented with it, as well as the analysis of characteristics and distribution patterns for such data, looking forward to have it reported, afterwards [23]. All of the Arc/View activity took place within the project parameters, which were a collection of related documents controlled during the Arc/View session.

Table 1. Agroecological requirements for Goma guarunder rainfed conditions.

Variable	Unit	Optimal	Suboptimal	No suitable
Climate	Types*	Bs, Aw, Cf, Cs, Cw		
Average annual temperature	˚C	25 - 30	11 - 25 30 - 40	<11 >40
Altitude	*m*	0 - 600	600 - 1000	>1000
Average annual precipitation	*mm*	600 to 1200	400 to 600 1200 to 1500	<400 >1500
Soil	Types	- Fluvisols - Luvisols - Nitisols - Regosol	- Cambisols	- Solonchaks - Flooding Gleysols - Flooding Vertisols - Leptosols - Acrisols - Planosols - Histisols - Calcaric Regosol - Kastañozems - Andosols
Soil texture	Types	Light and medium	Medium	Heavyand very light
Soil depth	m	<1	1 to 0.20	<0.20
Soil pH	Indicator	7.0 to 8.5	5.5 to 7.0 8.5 to 9.0	<5.5 >9.0
Drainage	Types	Good	Good	Deficient

***Types of climates:** Aw = Tropical savanna climate; Cw = Humid subtropical climate; Cf = Warm oceanic climate; Bs = Warm semi-arid climate; Cs = Warm Mediterranean climate. **Source:** Own elaboration based on consultation of experts and different sources of information.

Projects may contain as many as five different views, tables, charts, layouts (or printouts) and scripts. The names of all of the documents contained in an Arc/View project were displayed through the Project window; then, a project had the status of all of these documents properly organized and stored; next, the project decided how and where such documents were meant displayed, keeping the document selection active and with the appearance of the application window defined, which is the same as making a quick picture of the Arc/View status at the moment of saving it. The project information was further stored in an ASCII format file, always with an *. Apr. Extension, Arc/View, which was mainly a maps vector generator.

The procedure was performed in Arc/View 3.3 (**Figure 1**) to take the variables intersection process into consideration in order to generate optimal, suboptimal and unsuitable potential areas. The maps were generated through cartographic intersections between polygons and potential classes were described and maintained in each process of intersection in vector processing; as a result, the final map provided information on all of the variables that were intercepted. These

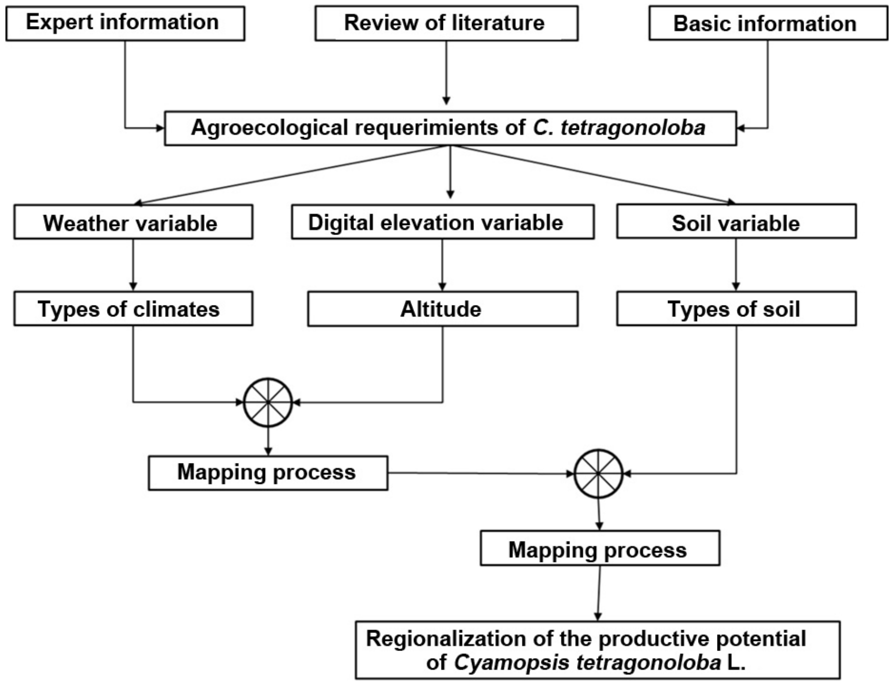

Figure 1. Methodologicalmodel used to determine the production potential.

maps were more representative vector models as they were more accurate to generate estimates of a given area, due to the fact that the maps involved in the processes were polygonal. Crop requirements were identified, and those suitable for the cultivation with regards to each variable that were analyzed in the study hereby; then, the performance of the mapping features were selected intersections.

Based on the agroecological requirements of *C. tetragonoloba*, the following criteria were considered to determine the potential areas under rainfed conditions: 1) high potential areas where all variables of climate, digital elevation and soil behave as optimal conditions for the crop; 2) medium potential areas where the above mentioned variables are suboptimal; and 3) no suitable areas where all variables are limiting factors for crop development.

3. Results and Discussion

3.1. Potential Areas for *Cyamopsis tetragonoloba* under Rainfed Conditions in Mexico

According to results, Mexico has a total of 1,125,803 hectares to be cultivated under rainfed conditions; 901,138 hectares have a high potential and 224,665 hectares have a medium or suboptimal potential (Table 2). The areas of high potential are mainly distributed in the Pacific states such as: Sinaloa, Nayarit, Jalisco, Michoacan, Guerrero, Oaxaca and Chiapas; however, there are some important areas in the central region (the State of Mexico and Morelos) and in the Gulf of Mexico region (Veracruz and Tamaulipas) as well as the Yucatan Peninsula (Figure 2). The middle or suboptimal zones were found in the states of

Table 2. Potential areas for *Cyamopsis tetragonoloba* (L.) Taub. under rainfed conditions in Mexico.

State	High Potential (ha)	Medium Potential (ha)	Total (ha)
Sonora	1631	**112,750**	114,381
Baja California Sur	0	5549	5549
Nuevo Leon	0	1812	1812
Tamaulipas	11,674	6130	17,804
Sinaloa	**136,150**	19,708	155,858
Durango	2010	2856	4866
San Luis Potosi	107	757	864
Nayarit	**107,272**	18,314	125,586
Jalisco	45,745	18,899	64,644
Veracruz	5192	3422	8614
Yucatan	17,958	0	17,958
Quintana Roo	5634	0	5634
Queretaro	0	15	15
Hidalgo	0	106	106
Puebla	7685	7.88	7693
Campeche	19,091	0	19,091
Michoacan	**170,609**	2644	173,253
State of Mexico	3912	2021	5933
Colima	32,691	319	33,010
Morelos	390	0	390
Guerrero	**229,137**	8606	237,743
Oaxaca	39,876	767	40,643
Chiapas	64,374	19,982	84,356
Total	**901,138**	**224,665**	**1,125,803**

Sonora, Jalisco, Baja California Sur, Durango, Nuevo Leon, Queretaro, Puebla, Hidalgo and Colima (Figure 2).

3.2. Soil and Climate

The optimal soils for the cultivation of guar gum are those with pH from 7.5 to 8.0. It grows very good in well-drained soils with light to medium texture with sandy loam texture [24]. This annual crop is not demanding for very fertile soils; tolerates saline soils and drought [1] [25]. It could be considered as an inter-cropped alternative with cereals and vegetables [26]. In addition, it can enrich soil fertility through the atmospheric fixation of N [7]. Luvisols, Fluvisols, Nitisols and Regosols are being considered optimal whilst Cambisols with good drainage are suboptimal (Table 1). The optimal soils are distributed mainly in the soils located along the Gulf's river basins, The Yucatan Peninsula and all the states that make up the Pacific region (Figure 3).

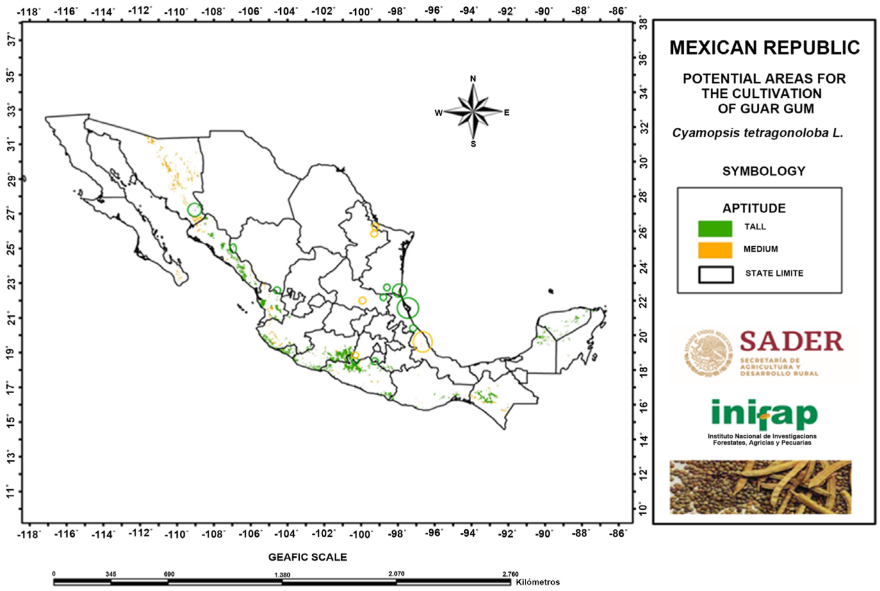

Figure 2. Geographical distribution of potential areas for *Cyamopsis tetragonoloba* in Mexico.

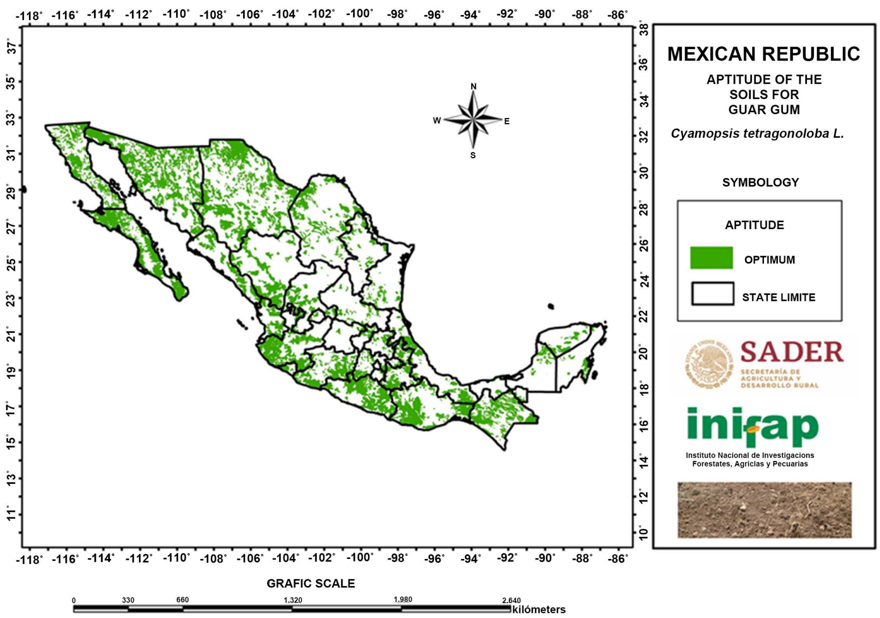

Figure 3. Aptitude of soil types for *Cyamopsis tetragonoloba* in Mexico.

The Rainfall. *Cyamopsis tetragonoloba* in its natural state grows in arid and semi-arid regions with an annual precipitation of 200 - 600 mm [27]. In United States it grows well in areas with 900 mm [28]. However, this crop can be adapted to tropical and subtropical regions [1]. For the Mexican study, 600 to 1200 mm was considered as an optimal condition whereas for suboptimal conditions both ranges: from 400 to 600 mm and from 1200 to 1500 were considered. The extreme conditions of under 400 mm and those over 1500 mm were not eligible (**Figure 4**). However, Liu *et al.*, (2007) [29] indicates that sowing

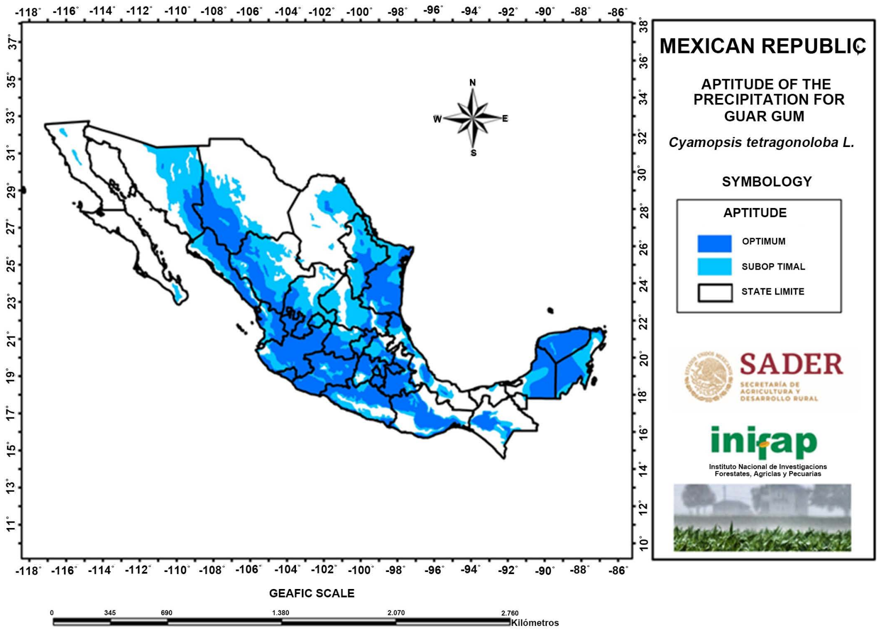

Figure 4. Aptitude for *Cyamopsis tetragonoloba* under rainfed conditions in Mexico.

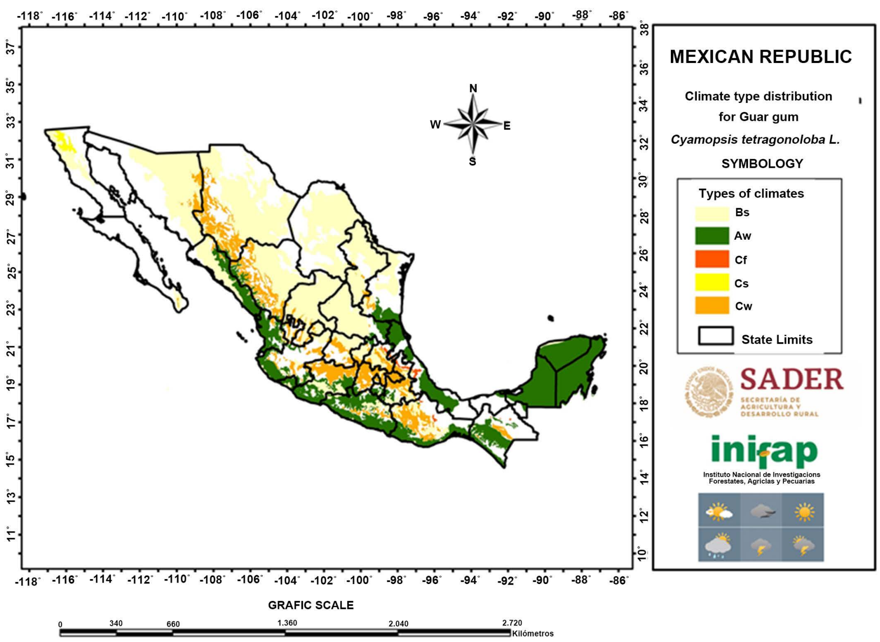

Figure 5. Climate type distribution for Guar gum (*Cyamopsis tetragonoloba*).

dates should be taken into account due to rain effect on seeds blackening which can strongly affect potential yields, seed gum quality and commercial value.

The Climate. Temperature is one of the main environmental factors that affect seed germination [30]. It has to be considered at planting time keeping in mind the crop cycle which can be longer than 160 days in large cycle genotypes [30]. The climates considered as optimal for Mexico were both: the sub-humid zones cataloged as Aw, Bs, Cf and the temperate regions Cs and Cw (**Table 1**) while the optimum temperature was in the range of 25˚C to 30˚C. Suboptimal conditions ranged from both: 11˚C to 25˚C and from 30˚C to 40˚C. Those temperatures under 11˚C and greater than 40˚C were not suitable (**Figure 5**).

4. Conclusion

Mexico has optimal agroecological conditions to produce *Cyamopsis tetragonoloba* under rainfed conditions with high productivity. The most suitable areas to produce guar gum are located in the states of the Gulf of Mexico, the Yucatan Peninsula and in the Pacific region. While the middle or sub-optimal zone was found in the states of Sonora, Jalisco, Baja California Sur, Durango, Nuevo León, Querétaro, Puebla, Hidalgo and Colima. The type of soil, precipitation, temperature and altitude are determining factors to define the optimal and sub-optimal potential areas of this crop. Mexico has more than 900,000 hectares of high potential production and 200,000 hectares of suboptimal ones.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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