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ANALYSIS OF THE AMARANTH PRODUCTION SYSTEM IN HUIXCAZDHÁ, HIDALGO, MEXICO

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ABSTRACT

This research was designed to analyze the amaranth production system in the community of Huixcazdhá, Hidalgo, Mexico, while also identifying the role played by this crop in the daily life of producers. A survey was composed and applied to 20 producers, out of a total of 25, who live in the community. Their age ranged from 30 to 58 years, with an average of 44 years. Of the total number of interviewees, 66% were male of whom all defined themselves as heads of household; 34% were female of whom only a few were heads of household. The interviewees commented that they grow amaranth, maize and beans on their own land and on land lent by the organizations: "San Miguel de Proyectos Agropecuarios, S.P.R. de R.S" and "Asociación Civil Utopía Huixcazdhá". The maximum area loaned is two hectares and they are committed to planting at least half an acre of amaranth and selling the harvest to these companies. These companies encourage the continued production of amaranth in the community. The crop was found to have a negative profit margin, however the producers have not considered ceasing to plant it, as they would lose the opportunity to plant the two hectares that are loaned to them; instead they have opted to increase innovations in the production, marketing and consumption system of the grain.

Keywords: production, profitability, marketing.

INTRODUCTION

Amaranth (*Amaranthus* spp.) is one of the oldest crops in Mesoamerica; it is claimed that it was the staple food of the Aztecs, Incas, Mayans and hunter-gatherer communities. The first data on this plant date back ten thousand years and its role in the diet was as important as maize and beans (Corona *et al*., 2019). This crop was used by pre-Hispanic cultures, both for human consumption and in religious contexts. Because of this, the plant was extensively cultivated under the intensive chinampa system, which the Aztecs developed in the lake area of the Valley of Mexico (Sauer, 1993). When the Spanish arrived in America, amaranth or huautli was one of the grains most highly valued by the Aztecs. Their production was estimated at 15,000 to 20,000 tons per year.

With the arrival of Europeans in America, an intense exchange of crops began, resulting in some gaining greater importance, while others almost disappeared. Fortunately, customs in communities had significant roots and the cultivation and consumption of amaranth has continued for centuries, thanks to the action of small farmers who preserve the tradition of its cultivation, although on a small scale, especially in Morelos, Tlaxcala and the Federal District (Huerta and Barba, 2012). Many consider that the importance of amaranth should be reinstated, as it is a strategic crop in the diet of Mexicans, given its nutritional value concerning both the quantity and quality of its protein, as it surpasses commonly consumed cereals such as wheat, rice, oats and maize (Morales *et al*., 2009).

Amaranth has a protein content ranging from 13 to 18% when dry and presents a good balance of amino acids, with high levels of lysine and adequate levels of tryptophan and sulfur amino acids. Its protein quality is comparable to casein and is the highest among known plant species. Its consumption has been associated with a decrease in osteoporosis and harmful cholesterol; due to tocopherol content it has antioxidant power and helps reduce digestive disorders, fatigue and is also recommended for women who are breastfeeding (Paredes and Valverde, 2006, Morales *et al*., 2009). Amaranth has also been attributed with inhibitory properties against cancer cell proliferation, as it represents a source of bioactive peptides and a series of phytochemical compounds with beneficial properties for human health and potential for biotechnological development (Huerta *et al*., 2012).

The crop has a series of uses similar to those of basic crops, mainly maize, ranging from artisanal sweets such as granola, whole grain flours, extruded foods, baked goods, pastas, to more sophisticated products such as edible oils, baby food, protein concentrates, energy bars and nutritional as well as foods that function to improve human health (Matías *et al*., 2018). Cookies and breads with additional amaranth flour provide hypoallergenic food for those who suffer from gluten intolerance and cannot consume goods baked using wheat flour (Santa Cruz, 2011).

The main and best-known use of amaranth is for human consumption: the grain is mainly used for the artisanal production of the sweet known as "alegría". Matías *et al*. (2018), state that due to its properties, in recent years interest in the consumption of this grain has grown at an international level, indicating a significant potential market, and the possiblity of expanding to other agricultural regions of the world.

Amaranth is now distributed worldwide and is cultivated on all five continents. The principal countries that produce amaranth grain are China, India, Kenya, Mexico, Nepal, Peru, the United States, Bolivia, Pakistan, Nepal, Argentina and Russia (Bale and Kauffman, 1992; Morales *et al*., 2009).

According to SADER (2020), in Mexico, the State of Puebla was the largest producer of amaranth with 61% of national production. Tlaxcala follows with 22%, the State of Mexico with 13%, Mexico City with 3%, Oaxaca with 2% and Morelos with less than 1%. This crop is present in several states, but is usually concentrated in particular communities, as producers are completely unaware of its possible benefits and there is lack of dissemination of this information. One of the cases is the State of Hidalgo, where most of the producers are located in the town of Huixcazdhá, pertaining to the municipality of Huichapan.

The adverse production conditions in some areas where amaranth is grown result in low yields, as it is generally a rainfed crop requiring intense labor; nor is there adequate nutritional management for using the highly nourishing seeds, limited or no use of machinery and lack of inputs to enable exploiting the crop's potential and increasing production per hectare, as application of technology has been adequate (Parra *et al*., 2012; Ayala *et al*., 2012; Escalante Escoffié, 2011).

In the town of Huixcazdhá, production and processing of amaranth represents the main economic activity, however there is no analysis of the factors that limit its production or information concerning the specific conditions under which this crop is produced in the town.

This research intended to describe the amaranth production system in the community of Huixcazdha, Huichapan, as well as to identify the role played by this crop in the daily lives of producers.

Huixcazdhá is a rural community that suffers from a certain degree of marginalization, located in the municipality of Huichapan, in the State of Hidalgo, whose main economic activity is subsistence agriculture, in an area with a difficult climate.

THEORETICAL FRAMEWORK

Production system

According to Slack *et al*., (1999), a production system is a set of resources, processes and activities that are combined to create goods or services. Similarly, Gaither and Frazier (2000) comment that a production system receives inputs in the form of materials, personnel, capital, services and information. These inputs are transformed within a subsystem of conversion into the desired products and services, known as products. A portion of the resulting product is monitored by the control subsystem to determine whether this is acceptable in terms of quantity, cost and quality. If the result is acceptable, no changes are required in the system, but if not, then corrective administrative action is required.

FAO (2017) defines agricultural production systems as sets of individual farms with generally similar basic resources, business models, family livelihoods and

limitations, to which similar development strategies and interventions would correspond. In this study, we take up what was proposed by Caicedo *et al.* (2020), who mention that agricultural production systems are sets of individual farms with generally similar basic resources, family livelihoods and limitations; to which similar development strategies and interventions would correspond; each production unit has specific characteristics, which are derived from the existing diversity, in relation to the provision of resources and family circumstances. The entire agricultural household, its resources and the flows and interactions that occur at this level are known as the production system.

The characterization of the main agricultural production systems provides a framework within which both agricultural development strategies and appropriate interventions can be defined.

The system's characteristics

The biophysical, socioeconomic and human characeristics of a farm are interdependent, meaning farms can be analysed as systems from various points of view (Hall, 2001). According to Hall (2001), in agriculture, small production units are intended for the subsistence of farmers; this production unit presents a variety of natural resources available to farming families. These resources normally include different types of land, varied water sources and access to common property resources, including ponds, grazing areas and forests. Besides these basic natural resources, there are factors of climate and biodiversity, as well as human, social and financial capital; agricultural production systems are necessary to enable the crop to adapt to this context.

Type of cultivation

Amaranth (*Amaranthus* spp.) is a high-yield and versatile seed, capable of thriving in adverse conditions (Espitia *et al*., 2021). It stands out for its exceptional nutritional value, in terms of both quantity and quality (Morales *et al*., 2009), clearly indicating its potential as a source of healthy food in rural communities and an alternative reconversion crop, to address the problems afflicting society.

This crop has been grown in Mexico for more than 4,000 years, however, it has been little developed throughout the country (Casas *et al.*, 2001). Contrary to its importance as part of the national identity and as an economic alternative for agriculture, the amaranth value chain is poorly integrated in terms of its marketing and production system, economies of scale are absent, making it a deficient agroindustry with poorly organized trade of products; this coupled with competition from crops that can be more easily mechanized, as well as the low sale price of the product, has resulted in reduced income for producers (Ayala *et al*., 2014).

Ayala *et al*. (2014) mention that amaranth cultivation can be developed in small communities under conditions that lack, both natural resources such as water, but also technology for production and transformation, as it adapts easily to fragile environments (Das, 2016).

One of the limitations, according to Ayala *et al*. (2016), is lack of mechanization. The only tasks carried out with a tractor and corresponding implements are fallowing, tracking and furrowing; all other activities are undertaken manually. This is because not all producers have the purchasing power to buy the necessary machinery.

METHODOLOGY

This study was carried out in the town of Huixcazdhá, also known as "La Manga", located in the municipality of Huichapan, in the State of Hidalgo.

The community is located in the geographic region of the Mezquital Valley. The geographical coordinates are 20° 20′ 42.109″ north latitude and 99° 47′ 20.711″ west longitude, with an altitude of 2,288 meters above sea level. Figure 1 shows a map of the location.

The climate in this area is mostly temperate-cold, with an average annual temperature of 16°C. Average annual rainfall is estimated at 437 mm per year, with a rainy period in the months from May to September (Government of Hidalgo State, 2010).

Interview procedure

The methodology used in this study was based on field work; the individuals in the study were agricultural producers and key informants. Two types of surveys were designed; one for producers and one for key informants. The directed survey is used in various disciplines, both social and in other conexts to carry out exploratory studies, as it makes it possible to capture abundant and basic information regarding a problem (Rojas, 2002). The total number of surveys applied to producers was 20, during the months from March to July 2023. The study population comprises 25 producers. The survey for key community informants was applied to 4 people (Production Technician for the Field Schools of the Bienestar program, 2 leading producers representing the ejido and a representative from the agroindustry). The surveys were designed to include qualitative questions, which were transformed into quantitative data for a detailed analysis. The results were captured in a database and analyzed using descriptive statistics.

Profitability (B/C ratio)

To determine profitability, algebraic equations were applied, based on economic theory (Krugman and Wells, 2006; Samuelson and Nordhaus, 2009):

Source: Google Maps, 2024.
Figure 1. Study zone of Huixcazdhá, Huichapan, Hidalgo, México.

$$CT = P_X X \quad (1)$$

where CT: Total cost of production; P_X: Price of input or activity; X: Activity or input.

Total income per hectare is obtained by multiplying the crop yield by its market price. Expressed algebraically as:

$$IT = P_Y Y \quad (2)$$

where IT: Total income (\$ ha^{-1}); P_Y: Market price of crop Y (\$ t^{-1}); Y: Crop yield (t ha^{-1}).

The market price used to calculate income was the average rural price reported in the previous cycle (SIAP, 2022).

A benefit-cost analysis (B/C) was carried out in order to assess profitability. According to the B/C analysis, the project will be profitable if the B/C ratio exceeds the unit. B/C > 1 → the project is profitable.

RESULTS

Community characteristics

Originally, Huixcazdhá was an Otomi community located in the municipality of Huichapan, Hidalgo. Currently, it is a mestizo community, where the main economic activity is subsistence agriculture in an area with hostile climate.

In Huixcazdhá, Benito Manrique de Lara sought to contribute to the community through the creation of the company: San Miguel de Proyectos Agropecuarios S.P.R. de R.S. (SMPA), a company dedicated to producing derivatives of amaranth seed since 1986. Before the arrival of the company San Miguel de Proyectos Agropecuarios, the community did not have either electricity or drinking water. After the creation of this company, resources were developed to provide some services such as drinking water, drainage, electricity and cobbled streets. Doctor Benito Manrique de Lara, also introduced the cultivation of amaranth in the community of Huixcazdhá.

The agroindustry of San Miguel de Proyectos Agropecuarios, S.P.R. de R.S., primarily intended to prevent the construction of a housing estate in the ejido and to disseminate knowledge about amaranth cultivation and various value-adding processes, which this association began to promote among producers. Since its founding, the association has supported agricultural producers in the community with land loans in order to maintain the production and consumption of amaranth. The above information was obtained through field work, from surveys of both key informants and producers.

Socioeconomic characteristics

Producers in Huixcazdhá have the following socioeconomic characteristics: age ranging from 30 to 58 years, with an average age of 44.

Of the total number of respondents, 66% were male and all said they were heads of household; 34% were female and also heads of household.

Regarding educational level, 28% had only completed primary school, 57% had completed secondary school, only 8% had university studies and 7% had no education.

Importantly the Huixcazdhá Civil Association Utopía intends to reinstate women's participation in the industry related to this crop by promoting transformation and consumption for the benefit of families. They also mentioned that the Huixcazdhá Civil Association Utopía has given them access to knowledge about the crop and various transformation processes. In economic terms, for producers, agriculture represents the main source of income; on average 50%.

Organization

The Huixcazdhá Civil Association Utopía was established in 2011, on the initiative of Benito Manrique de Lara, a doctor who came to the community intending to support the inhabitants. The association consisted of 25 members, most of the participants were natives and inhabitants of the community, some others were from nearby communities. The organization originally intended to avoid the transformation of their ejido into a housing estate. Subsequently, strategies have been devised to contribute to the development of the community and the region, promoting projects for sustainable development at a human level in the community of Huixcazdhá in its geographical and social environment; having as its main objective, respect for the values of the community, while contemplating the participation of women.

Producers commented that the organization has introduced them to knowledge about amaranth crop production, post-harvest management and different transformation processes, benefitting producers in terms of production, while promoting consumption of the crop. The main benefit has been the promotion of the use and consumption of amaranth among children and the elderly.

The organization is important for the support it provides to its members, offering them a range of services, in particular, access to productive inputs, transformation, marketing opportunities, information and communication. It has also facilitated access to resources and enabled participation in decision-making that influences policies (FAO, 2012). Likewise, it enables more effective communication with other key actors affecting progress, such as government entities, educational institutions, research centers and related companies, among others (Ayala *et al*., 2016).

Productive activities

The interviewees commented that the main productive activity in the town is agriculture for self-consumption. The crops planted include amaranth, maize and beans. We should recognise the role played by the agroindustry San Miguel de Proyectos Agropecuarios, S.P.R. de R.S, in terms of job generation; as the amaranth producers work in this company in the transformation of the crop, for which they have been trained; over time they have learned how this product can be used.

Production units

According to the interviewees, the average production area is 2 ha. They mentioned that the company "San Miguel de Proyectos Agropecuarios, S.P.R. de R.S" supports them with a loan of up to 2 ha per person for cultivation. This loan is made under the conditions that at least part of the land is used

for amaranth planting and that all production is sold directly to the company. On the 2 borrowed ha, they plant at least 0.5 ha of amaranth and divide the rest between maize and beans for their own consumption; they use their communal lands to supplement their income. The producers have rights to communal land totalling 2 ha.

Characteristics of the production system

90% of those surveyed said that they do not have any government or financial support, so all the money they invest is from their own resources. They also stated that they do not have agricultural insurance, as they lack necessary information or advice on the subject, and nor do they have the resources necessary to acquire it.

Means of Production

According to the producers surveyed, only 10% have their own agricultural machinery; the rest rely on day laborers or unpaid family labor. The main activities for which day laborers are employed are those of sowing and harvesting. 90% said that they rent machinery to be able to carry out some agricultural activities; mainly for fallowing, tracing and furrowing.

The use of agricultural machinery in amaranth production has been increasing and only 14% of respondents continue to use the yoke tillage method. For grain cleaning, respondents mentioned that the company San Miguel de Proyectos Agropecuarios, S.P.R. de R.S., provides its workers with machinery for cleaning and quality testing of amaranth.

All respondents indicated that they do not use fertilizers, herbicides or insecticides, as their aim is for their product to be natural. The only thing they use is organic fertilizers, such as manure from backyard animals.

Benefit/cost ratio of cultivation

Table 1 shows the investment and profit of interviewed producers, who cultivate amaranth. Taking into account the sale price of the grain, the yield and the cost of production, it was found that the benefit-cost ratio (B/C) was 0.61, that is, for every $1.00 invested, they lose $0.39 cents, indicating that it is not profitable to plant amaranth in the Huixcazdhá area.

Table 1 shows that cultural tasks account for nearly 50% of total production costs, followed by harvesting, because it requires hired labor. Some producers mentioned that in previous years, when rainfall conditions were favorable, the average yield they managed to obtain was 600 kg ha^{-1}.

Producers indicated that their greatest concerns include pressure to convert their ejido into a housing estate, reduced yields and low rainfall. The area suffers from extreme conditions of drought or excessive rainfall, meaning that,

Table 1. Costs for amaranth production in 2023, in Huixcazdhá, Hidalgo.

Labor	Cost ($)
Land preparation ($/ha)	1,400
Sowing ($/ha)	1,700
Cultural tasks ($/ha)	6,400
Harvest ($/ha)	2,066
Inputs ($/ha)	960
Total direct costs ($/ha)	**12,526**
Land rent ($/ha)	0.00
Total indirect costs ($/ha)	**0.00**
Total costs ($/ha)	**12,526**
Profit (kg/ha)	**0.32**
Price per ton ($/ton)	**25,000**
Cost per ton ($/ton)	39,144
Utility ($/t)	-14,144
B/C	0.64

Source: self-elaborated using interview data, 2023.

for more than three cycles, they have not been able to harvest amaranth seed and far from recovering a little of their investment, have lost 100%; this means that, in addition to being a crop with negative profitability, in recent years, the entire harvest has been lost. They comment that they continue to plant amaranth to maintain the companies they established and to prevent their ejido lands from being used for something else.

Transformation and uses of the crop

Producers in this community make a wide variety of amaranth products, ranging from artisanal sweets, granola, whole grain flours, extruded foods, baked goods, pasta, to more sophisticated products, such as edible oils, baby food, protein concentrates, energy bars and special nutritional foods for diabetic or cancer patients (Ayala *et al.*, 2012).

The above is possible because the company San Miguel de Proyectos Agropecuarios, S.P.R. de R.S., rents them an amaranth harvester at low cost, so that they can later transform the harvested product resulting from the sowing of the communal plots, into "alegrías", "calaveritas" and sweets, which can be sold independently.

Trade

Producers point out that most of the amaranth produced is sold to the agroindustry San Miguel de Proyectos Agropecuarios, S.P.R. de R.S.

The agroindustry San Miguel de Proyectos Agropecuarios, S.P.R. de R.S., is the company that carries out the transformation of the product for distribution

at a national level; likewise this company makes it possible for producers to transform their harvest and obtain products so that they can sell them independently.

DISCUSSION

85% of producers do not have high school education and this may affect their interest, or lack thereof, in seeking and implementing new technologies and having administrative control of production units. Ayala *et al.* (2014) found that the age of the producer and the level of education determine the adoption of new agronomic practices, impacting crop yield. Producers in Huixcazdhá have low yields per unit of surface area, compared to those seen in other states, which together with extreme environmental conditions, represent the main problems for amaranth producers. Daya (2021) mentions that climate change is increasing the vulnerability of plants to extreme weather conditions, besides the risk that their lands will be converted into housing estates. Consequently, and despite the fact that producers understand its nutritional value, some have chosen to cease growing amaranth. The Civil Association Utopía Huixcazdhá has managed to promote the production and consumption of the crop in the community and despite the fact that the benefit/cost ratio is less than one, it has been maintained, in order to support the inhabitants of the community. The company San Miguel de Proyectos Agropecuarios, S.P.R. de R.S., offers jobs and represents a source of income. However, it is important to improve productivity and lower production costs. Among other aspects, the use of improved varieties has enabled an increase in productivity; Huitzilin, an early variety (Espitia-Rangel, Eduardo *et al*., 2023), with resistance to extreme climates, is a good option for this area (Valverde *et al*.; 2018). Espinosa *et al*., (2003) mention that, to reach competitive production levels, improved seeds must be used. Also, to maximize yield, it is important to provide complementary technology and training (Ali *et al*., 2020), as well as developing implements that allow cultural practices to be carried out efficiently, because as this is a plant that is too fragile to touch, it does not allow for easy manipulation, so day laborers are employed, who are usually more expensive and take longer than machines.

Respondents affirmed that the only thing they apply is organic fertilizer, for the development and growth of the crop, as they prefer not to use agrochemicals, because they aim towards organic production. This also helps them to reduce costs, as fertilizer is mainly obtained from backyard animals, and because the planting area is usually less than one hectare, they themselves do the work of applying the product. A study carried out by Ayala *et al*. (2014) shows that the costs of agrochemicals represented 14.84% of the total cost, signifying $2,738 pesos; demonsstrating that agrochemicals increase production costs.

Both San Miguel de Proyectos Agropecuarios, S.P.R. de R.S., and the Civil Association Utopía Huixcazdhá play an important role in the production, transformation and consumption of the crop in the community of Huixcazdhá, and without their support, the producers of the region would not have started to produce it and much less to consume it.

The factors that have contributed to the continuation of cultivation are the support they receive from the company, both moral a**n**d in the form of infrastructure and land, helping arrest the change in use of their communal lands and conserve productive land.

Although family labor is used predominantly for some activities, this is insufficient, so day laborers must be hired or agricultural machinery used. Notably the use of agricultural machinery has increased. However, the design and development of machinery is necessary to carry out each of the activities efficiently and in less time.

We should also emphasize that although producers already have guidance and training regarding cultivation, innovation is necessary, in the form of technological packages that are more appropriate for the environmental conditions of the region, because of the threat of droughts or extreme rains, which do not allow the crop to develop properly. Thus, it ceases to be viable as a source of income for producers.

CONCLUSIONS

The factors that threaten the continuity of amaranth cultivation in Huixcazdhá are the low yields of recent years, droughts and lack of machinery.

Factors influencing producers to continue amaranth producion include support from the company San Miguel de Proyectos Agropecuarios and the fear of losing their land.

The companies San Miguel de Proyectos Agropecuarios, S.P.R. de R.S. and Utopía have encouraged the production and consumption of the crop among the inhabitants of the community and also their labor. This explains why amaranth continues to be produced, despite all the negative factors affecting growth of the crop.

REFERENCES

Ali A, Beshir A, Rahut D. 2020. Adoption and impact of the maize hybrid on livelihood of the maize growers: Some policy insights from Pakistan. Scientifica. 2020(5959868). 1-8. https://doi.org/10.1155/2020/5959868.

Ayala AV, Escobedo D, Cortés L, Espitia E. 2012. El cultivo de amaranto en México, descripción de la cadena, implicaciones y retos. En: Amaranto: Ciencia y Tecnología. Espitia E. Ed. Libro científico núm. 2. Instituto Nacional de Investigaciones Agrícolas y Forestales: México; pp: 315-330.

Ayala AV, Rivas P, Cortés L, De la O M, Escobedo D, Espitia E. 2014. La rentabilidad del cultivo de Amaranto (Amaranthus spp.) en la región centro de México. Ciencia ergo-sum. 21(1). 47-

54. https://cienciaergosum.uaemex.mx/article/view/7749.
Ayala AV, Espitia E, Rivas P, Almaguer G, Preciado P. 2016. Análisis del sistema productivo de amaranto en Temoac, Morelos, México. Ciencia ergo-sum. 23(1). 49-57. https://cienciaergosum.uaemex.mx/article/view/8113.
Bale JR, Kauffman CS. 1992. Special issue on grain amaranth: New potential for an old crop. Food Reviews International. (8). 1-190. https://www.tandfonline.com/toc/lfri20/8/1.
Caiced JC, Puyol JL, López MC, Ibáñez SS. 2020. Adaptabilidad en el sistema de producción agrícola: Una mirada desde los productos alternativos sostenibles. Revista de Ciencias Sociales. 26(4). 308-327. https://doi.org/10.31876/rcs.v26i4.34665.
Casas A, Valiente-Banuet A, Viveros JL, Caballero J, Cortés L, Dávila P, Lira R, Rodríguez I. 2001. Plant resources of the Tehuacán-Cuicatlán Valley, Mexico. Economic Botany. 55. 129-166. https://doi.org/10.1007/BF02864551.
Corona NA, Jaramillo JL, Manzo F, Cervantes J. 2019. Percepción, opinión y actitud de los productores de amaranto en torno a procesos de agregación de valor en el municipio de Tochimilco, Puebla. Estudios sociales. Revista de Alimentación Contemporánea y Desarrollo Regional. 29 (54). 2-26. https://doi.org/10.24836/es.v29i54.824.
Das S. 2016. Amaranthus: A promising crop of future, 1ª ed.; Springer: Singapore; https://doi.org/10.1007/978-981-10-1469-7. 208 p.
Daya P. 2021. Nuevas variedades de cultivo mejoran el rendimiento del tomate y la soja en Cuba. Organismo Internacional de Energía Atómica (IAEA). https://www.iaea.org/es/newscenter/news/nuevas-variedades-de-cultivo-mejoran-el-rendimiento-del-tomate-y-la-soja-en-cuba
Escalante MC. 2011. Rescate y revaloración del cultivo del amaranto. Instituto Interamericano de Cooperación para la Agricultura (IICA): México. 89 p.
Espinosa A, Sierra M, Gómez N. 2002. Producción y tecnología de semillas mejoradas de maíz por el INIFAP en el escenario sin la PRONASE. Agronomía Mesoamericana. 14(1). 117-121. https://www.researchgate.net/publication/26507417_Produccion_y_tecnologia_de_semillas_mejoradas_de_maiz_por_el_INIFAP_en_el_escenario_sin_la_PRONASE.
Espitia E, Sesma LF, Valverde, MG, González L, Escobedo D, Aguilar MJ. 2021. Tiene el amaranto el potencial agronómico para ser un fenómeno mundial como la quinua. Revista Mexicana De Ciencias Agrícolas. 12(8). 1459-1471. https://doi.org/10.29312/remexca.v12i8.2897.
Espitia E, Lozano A, Aguilar MJ, Valver MG, González L, Martínez E. 2023. Evaluación de la capacidad de reventado de genotipos de amaranto y parámetros genéticos. Revista Mexicana de Ciencias Agrícolas. 14(6). e3429. https://doi.org/10.29312/remexca.v14i6.3429.
FAO (Organización de las Naciones Unidas para la Alimentación y la Agricultura). 2012. El estado mundial de la agricultura y la alimentación. FAO: Roma, Italia; https://www.fao.org/4/i3028s/i3028s.pdf. 179 p.
FAO (Organización de las Naciones Unidas para la Alimentación y la Agricultura). 2017. El estado mundial de la agricultura y la alimentación: Aprovechar los sistemas alimentarios para lograr una transformación rural inclusiva. FAO: Roma, Italia; https://openknowledge.fao.org/server/api/core/bitstreams/eba0d9b5-3dac-4cb0-b6dc-1262dda3e07e/content. 178 p.
Gaither N, Frazier G. 2000. Administration, production and operations, 8ª ed.; Cengage Learning Latin. https://www.academia.edu/31861739/Administracion_de_Produccion_y_Operaciones_Norman_Gaither_y_Greg_Frazier. 846 p.
Gobierno del Estado de Hidalgo. 2010. Enciclopedia de los Municipios del Estado de Hidalgo, Huichapan. Sistema Integral de Información del Estado de Hidalgo. Secretaría de Planeación Desarrollo Regional y Metropolitano: Pachuca de Soto Hidalgo, México; http://docencia.uaeh.edu.mx/estudios-pertinencia/docs/hidalgo-municipios/Huichapan-Enciclopedia-De-Los-Municipios.pdf. 16 p.
Hall M. 2001. Compendio. Sistemas de producción agropecuaria y pobreza: Cómo mejorar los medios de subsistencia de los pequeños agricultores en un mundo cambiante. FAO y Banco Mundial: Roma, Italia; , http://www.fao.org/3/ac349s/AC349s00.htm#TopOfPage
Huerta JA, Barba AP. 2012. Caracterización bioquímica y estructural de las proteínas de reserva del amaranto. *In*: Amaranto: Ciencia y Tecnología, 1ra ed.; Espitia E. Ed. INIFAP/SINAREFI: México; pp: 293-302.
Huerta JA, Maldonado E, Barba RAP. 2012. Amaranto: propiedades benéficas para la salud.

In: Amaranto: ciencia y tecnología, 1ra ed.; Espitia E. Ed. INIFAP/SINAREFI: México; pp: 303-312.

Krugman P, Wells R. 2006. Introducción a la economía: microeconomía. Reverté S.A.: Barcelona, España; 626 p.

Matías G, Hernández BR, Peña V, Torres NG, Espinoza VA, Ramírez L. 2018 Usos actuales y potenciales del Amaranto (Amaranthus spp.). Journal of Negative & No Positive Results. 3(6). 423-436. https://doi.org/10.19230/jonnpr.2410.

Morales JC, Vázquez N, Bressani R. 2009. El amaranto. Características físicas, químicas, toxicológicas y funcionales y aporte nutricional, 1a ed.; Instituto Nacional de Ciencias Médicas y Nutrición: México, D.F. 269 p.

Paredes O, Valverde ME. 2006. Los recursos nutracéuticos y medicinales que Mesoamérica le ha dado al mundo. CINVESTAV. 25(3). 65-73.

Parra FI, Délano JP. 2012. Uso de bacterias promotoras de crecimiento vegetal para aumentar la productividad de amaranto de grano. *In*: Amaranto: ciencia y tecnología, 1ra ed.; Espitia E. Ed. INIFAP/SINAREFI: México; pp: 113-127.

Rojas R. 2002. Guía para realizar investigaciones sociales. Plaza y Valdés: México. 437 p.

SADER (Secretaría de Agricultura y Desarrollo Rural). 2020. Amaranto, un cultivo ancestral y de alto valor nutricional, https://www.gob.mx/agricultura/articulos/amaranto-un-cultivo-ancestral-y-de-alto-valor-nutricional?idiom=es.

Santacruz EE. 2011. El amaranto en el estado de Morelos, México; caracterización de su eslabón primario. Observatorio de la Economía Latinoamericana. 145(1). https://ideas.repec.org/a/erv/observ/y2011i1451.html.

Samuelson PA, Nordhaus WD. 2009. Economía, 19na ed. McGraw-Hill: Madrid, España; https://www.cadep.org.py/uploads/2018/01/economia-con-aplicaciones-a-latinoamerica.pdf. 716 p.

Sauer JD. 1993. Historical geography of crop plants: a select roster. CRC Press: Boca Ratón, FL, USA.; https://doi.org/10.1201/9780203751909. 320 p.

SIAP (Servicio de Información Agroalimentaria y Pesquera). 2022. Estadística de Producción Agrícola. http://infosiap.siap.gob.mx/gobmx/datosAbiertos.php.

Slack SC, Chamber CH, Harrison AH. 1999. Administration de Operations, 1a ed.; Company Editorial Continental: México; 864 p.

Valverde MG, Espitia E, Sesma LF, González L, Rivas P, Escobedo D, Ayala AV. 2018. Evaluación de variedades de amaranto en los valles altos del centro de México. *In*: Primer Congreso Mundial del Amaranto, 10-12 de Octubre, Cholula Puebla, México, pp: 26-29.