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Amaranth production in Tulyehualco Xochimilco, Mexico City

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ABSTRACT

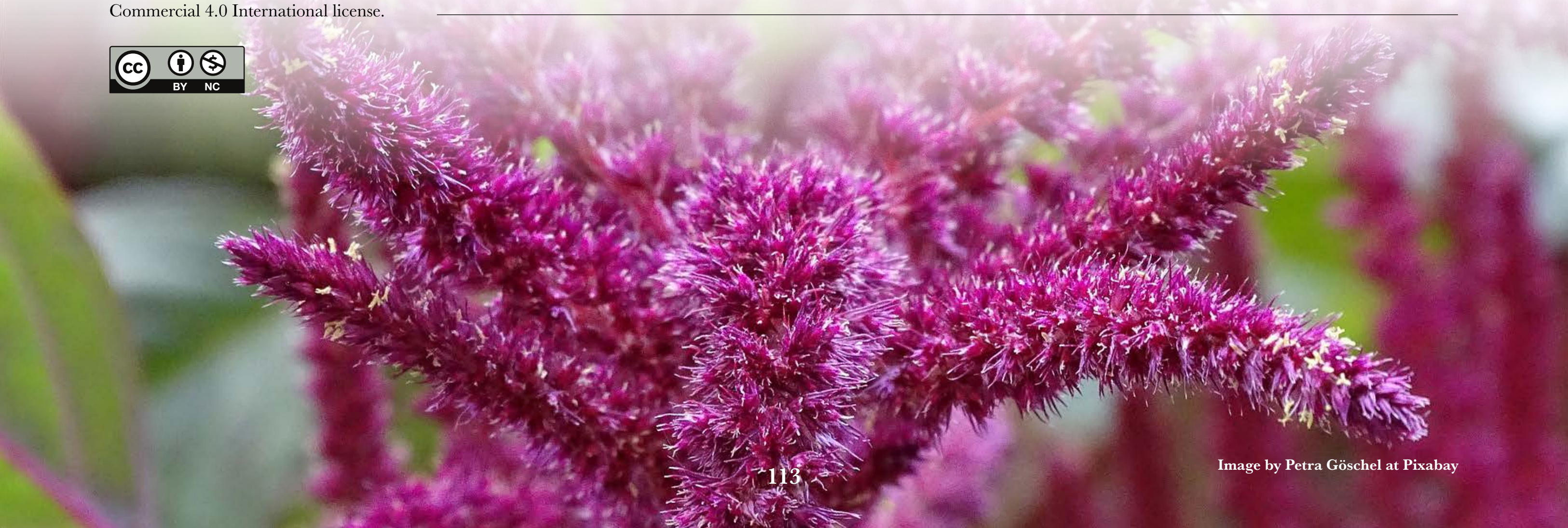
Objective: To know the form of production and commercialization of amaranth in Tulyehualco, Xochimilco, to identify and propose improvement actions.

Methodology: During 2010-2019, amaranth was cultivated in at least 11 states in Mexico, while in Mexico City it is grown in the municipalities of Xochimilco, Milpa Alta and Tláhuac. Xochimilco stands out due to harvested area and production, with 82.9 ha and 91.7 t which represents 60.4% and 55.6% respectively. The information was obtained through the application of a survey through non-probability sampling for convenience, with the selection criterion of individuals who were willing to be surveyed, and the survey was applied from September to December 2019, to n=35 producers, n=3 marketers and n=4 transformers. Amaranth production is carried out in two ways, by means of chapin and directly, and due to its traditional way of producing the crop is ancestral in those areas, so there is a millenary knowledge of the families that are dedicated to planting the crop.

Results: Amaranth production has a positive cost benefit ratio R (B/C) although production is better in direct sowing. Planting with a seedbed (Chapin) has higher costs and yield, however, this does not compensate the producer in profits.

Conclusions: For a potential impact at the level of amaranth production, the adoption of technologies related to density, nutrition and technical recommendations for pest and disease control is necessary.

Keywords: Chapin, production costs, profitability.



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INTRODUCTION

Amaranth (*Amaranthus* spp.) is one of the most ancient crops in Mesoamerica, as the first data of this plant date back to ten thousand years ago and its role in the diet was as important as corn and bean (Corona González *et al.*, 2019). In Mexico, it faces various problems, especially in its production phase regarding a low technological level, native varieties of low yield, and unfavorable agronomic characteristics, such as late maturation, very tall plants, variation in color of plant and seed (Ruiz Hernández *et al.*, 2013), etc. During 2010-2019 amaranth was cultivated in at least 11 states in Mexico, among which Puebla, Tlaxcala, Estado de México, and Mexico City stand out with an average of 2,108 ha, 1,153, 285 and 137 ha of surface harvested annually (Sistema de Información Agroalimentaria y Pesquera, 2020). The contribution of production has been of 50.6% from Puebla with 2,794 t on average, 30.3% Tlaxcala with 1,672 t, 11.10% Estado de México with 613 t, and 2.9% Mexico City with 161 t (SIAP, 2020). Amaranth is cultivated in Mexico City in the mayoralties of Xochimilco, Milpa Alta and Tláhuac, with Xochimilco standing out thanks to its harvested surface and production with 82.9 ha and 91.7 t which represents 60.4 % and 55.6 %, respectively; during 2010-2019 the average annual growth rate (AAGR) of the surface harvested was 0.27% while the AAGR of production was 1.34%; however, the highest yields are from Tláhuac with 1.30 t ha^{-1} (SIAP, 2020), although the AAGR of the surface harvested is −10.8 %.

In Tulyehualco amaranth is transformed artisanal and industrial way for its commercialization (Ramírez Meza *et al.*, 2017). It is consumed as popped grain from which products such as alegrías, cereal, granola, atole, pinole, marzipan, etc., are elaborated. There are also snacks, bread products, cookies, and amaranth flour, which is used in the elaboration of soups, cakes, and breads (Escobedo *et al.*, 2012). De Jesus Contreras *et al.* (2017) mentioned that amaranth production in Tulyehualco is a representative activity of local culture, and they highlight its transcendence as building element of territorial identity and historical depth, with peculiar and traditional agricultural practices characterized by a sustainable management of natural resources. Velarde (2012) points out that in Tulyehualco, amaranth is a historical food product that resulted from the dynamics of a particular territory. Derived from its importance in this region, the objective of study is to understand the form of production and commercialization of amaranth in Tulyehualco, Xochimilco, to identify and suggest improvement actions.

MATERIALS AND METHODS

Xochimilco is located on geographical coordinates 19° 19’ north and 19° 09’ south of latitude North; it represents 7.9% of the surface of Mexico City. It has eight main localities: Tepepan, San Luis Tlaxialmateco, Tulyehualco, Xochimilco, San Gregorio Atlapulco, Santa Cruz Acalpixca, Santa María Nativitas and San Francisco Tlalnepantla. In 60.8% of the territory, there predominates a subhumid temperate climate with summer rains, with medium moisture, followed by subhumid temperate with summer rains, with higher moisture in 26.5% of the territory (Instituto Nacional de Estadística Geografía e Informática, 2014). The study was conducted in the locality of Tulyehualco, where there are a total of 100 producers cultivating amaranth. The information was obtained through the application of a directed survey. The use of this technique is justified when there is not enough informative material about the aspects that there is an interest in researching, or when the information cannot be obtained through other techniques (Rojas Soriano, 2013). A non-probabilistic sample from convenience was carried out, with the selection criterion of individuals who were willing to be surveyed, and it was applied from September to December of 2019, to 35 producers, 3 marketers and 4 transformers. Calculating the profitability was done by obtaining the average production costs on which they incur during the production process. The costs were divided in two parts: direct costs and indirect costs (Swenson & Haugen, 2012). Within the direct costs, the costs of inputs and production means were included, such as seed, fertilizers, workforce, and opportunity cost of the investment. Land rental and general expenditures were included in the indirect costs. To determine the profitability, the following algebraic expressions were used, based on economic theory (Krugman & Wells, 2006; Samuelson & Nordhaus, 2009).

$$TC = PxX$$

Where TC=Total cost, Px=Price of the input or activity, X and X=Activity or input.

The total income per hectare is obtained by multiplying the crop's yield by its market price. The algebraic expression is:

$$TI = PyY$$

Where TI=Total income (\$ ha^{-1}), Py=Price of crop market Y (\$ t^{-1}); Y=Yield of the crop (t ha^{-1}).

Finally, the profitability is calculated with the following formula:

$$Profitability = TI - TC$$

RESULTS AND DISCUSSION

The producers were in an age range of 35 to 79 years, with an average of 57 years, although it was found that the age range among amaranth producers was 20 to 79 years, with average age of 48 in the study conducted in the states of Puebla, Tlaxcala, Morelos, and Hidalgo (Ayala Garay *et al.*, 2016), which shows that the older producers are those from Mexico City. Of the total people interviewed, 5% were women and the rest men; regarding education, it was found that 22% of the producers have concluded higher level studies, another 22% middle level, and 56% basic level; and small-scale land ownership of 1.5 ha predominates.

Amaranth production process in Tulyehualco, Xochimilco

Land preparation is mechanized. During sowing, the seed that is used is the one collected from previous cycles, which producers store in sacks in their homes. Ramírez Meza *et al.*

(2010) found that the producers safeguarded the Teuhtli Ecological Conservation Zone through transmission of their traditions, identity and knowledge of their environment from generation to generation, and, at the same time, the cultivation of amaranth and its genetic diversity. Moreno Velázquez *et al.* (2005) mention that it is a common practice among producers to select in the field the panicles with adequate phenological characteristics for their common use as seed, and based on this practice, more than 50% of the surface cultivated in Mexico with amaranth is sown with seed from the previous harvest, without taking into consideration its physical, physiological, and sanitary quality. On average, six kilograms of seed are used to sow a hectare. Only 5.6% of the producers use selected seed. The topological arrangement is furrows with width of 0.40 m, at 0.60 m and 0.30 m of between each sowing hole, in which a variable number of seeds is deposited with the purpose of ensuring that several plants germinate and grow in each hole. This is so that clearing is done 30 days after sowing, which consists in uprooting the smallest plants and leaving three, four or five plants, depending on the productive logic of each producer. Of the interview respondents, 76.7% mix the seed with soil or dry livestock manure before sowing, with the aim of seeds not being eaten by birds or removed from the furrow as a result of rain or wind; this is because the seeds are placed in the sowing hole without being covered, since from their experience if the seed is covered the number of plants that emerge is very low, with which they run the risk of needing to replant. Regarding fertilization, the producers carry out two applications of fertilizer; the first is at the time of sowing and the other 45 days after emergence.

Concerning technical assistance, 56% mention that the lack of advice against pests is the main problem that they face, since they ignore how to combat them. Pérez Torres *et al.* (2011) reported that *Hypolixus truncatulus* (Fabricius) (Curculionidae) was identified in Tulyehualco, and they mentioned that the larvae causes damages in the stem, by making a series of galleries along it and therefore the necessary nutrients are not absorbed, since they do not reach the apical tissues which are weakened until they break; and this happens between the months of September and November, when the plant is undergoing the beginning of anthesis (pollen release) and its maturation begins.

Forms of amaranth production in Tulyehualco, Xochimilco

Ramírez Meza *et al.* (2017) mention that presently two types of amaranth sowing are known:

1. Indirect sowing, which is characterized by generating first the seedbeds (called chapines) where the seed is sown and germinated, to later perform the transplant (72% of the producers). Espitia Rangel *et al.* (2010) mention that in Tulyehualco, Mexico City, the crop is rainfed, it is grown on the skirts of nearby hills and goes through two stages: seedbed and transplant. The seedbed is prepared from the end of April to the beginning of May, to carry out the transplant at the beginning of the rainy season, which habitually takes place since June. The seedbed preparation is done through the chinampa system and for that purpose the beds are established in plots near the canal, with size of 5 to 10 m width and 100 m length. The next day, when the bed is slightly

dry, it is cut into small squares (chapines) and it is sown. In sowing with chapin, inputs are used such as bokashi (organic fertilizer that is obtained from the fermentation of dry materials that are conveniently mixed; the nutrients obtained from the fermentation of the materials contain higher and lower elements, which form a complete fertilizer superior to the chemical fertilizer formulas) and sulfo-calcic soup, where the active ingredient is calcium sulfide (The Food and Agriculture Organization, 2011), which serves to control pests while in direct sowing it is only the manual application of cattle manure as fertilizer.

2. Direct seed drilling with high population density (28% of the producers), where the seed is dropped without leaving any space, covered lightly and the plants grow together, the distance between furrows is 60 cm and 4 to 6 kg of seed per hectare are required (Ramírez Meza *et al*., 2017).

When it comes to fertilization, 6.6% of the producers do not apply any type of fertilizer; 15.6% apply only chemical fertilizers, generally 50 kg ha^{-1} of diammonium phosphate (18-46-0) 20 days after sowing and 50 kg ha^{-1} of urea (46-0-0) 60 days after sowing; 77.8% of the survey respondents combine chemical and organic fertilization which consists in average applications of one ton of livestock excretes per hectare before sowing, 50 kg ha^{-1} of diammonium phosphate and 50 kg ha^{-1} of urea following the same calendar of farmers that only conduct chemical fertilization. The organic fertilizer most frequently used is livestock defecation, primarily from cattle.

The families that do not own livestock (43.7%) purchase the fertilizer in other neighboring municipalities. Weed control is conducted manually and periodically during the entire cultivation cycle. From the middle of October to the end of November, once 90% of the plants reach maturity, the panicle is cut, and it is left for eight days in the open. The cut is done with a sickle or machete and left to dry so that now of seed threshing the seed is detached more easily. During the time when the panicles are in contact with the ground there is a risk that a certain amount of grain is lost whether from detaching or from rotting caused by fungi of the *Thecaphora* genus. Threshing is carried out generally in December, although some producers do not thresh until the beginning of January. Of the interview respondents, 22.6% thresh with the traditional method, which is done manually or with the use of load animals. This method consists in stepping on or whipping the dry panicles with rods, on cloths or canvases, for the seed to detach; then the seed is sifted to remove the dust and hay known as chaff. With the traditional method, threshing a hectare is done approximately in one week, although it depends on the number of workdays and the climate conditions, since in cloudy days and with high relative moisture the seed detaches with more difficulty. In contrast, 77.4% of producers use harvesting machines, destined for other crops such as sorghum (*Sorghum* spp.) from other municipalities or even from other states, to save time and work, since with this machinery a hectare sown with amaranth is threshed in one hour and less workdays are used. On average, five workers per hectare are employed to introduce the dry panicle manually into the harvester and to pack the grain. Since the harvesting machines are not designed for the amaranth grain, a certain amount of grain from the production is lost when it falls to the ground while the harvester advances. The average yield in the zone under usual agroclimatic conditions is 1.2 t ha^{-1}, under direct production and 1.35 t ha^{-1} of production through chapin, while the national average was 1.66 t ha^{-1} during 2016-2019 (SIAP, 2020).

Amaranth production costs in Tulyehualco, Xochimilco

For both types of sowing, the amaranth production costs were obtained (Table 1).

For the producers who cultivate with the help of chapines (seedbeds), they represent 13.7% of the total expenditure; the usefulness of employing chapin is to achieve the germination of amaranth under better conditions, without competition from weeds for nutrients, and when it reaches a height of 10 cm it is transplanted into the plot. In both cultivation methods there is an expenditure in workdays that represents on average 34.7% of the total costs, which reflects the great use of labor to carry out the activities that include chapin, weeding, sowing, fertilization, and harvest. Similarly, Ayala Garay *et al.* (2014) point out that in the sates of Puebla, Tlaxcala and Morelos, the cost structure per hectare of amaranth has expenses in manual labor as the most important segment, which represented 37% of the total cost on average, followed using inputs (21%) and mechanized tasks (19%). The cultivation of amaranth demands labors greatly, which makes its production process more expensive, and this is reflected in the cost structure.

Commercialization of amaranth

Regarding commercialization, 40% is carried out with stockpilers, and 60% of the products in the zone transform amaranth into various byproducts such as brittle, cookies, wafers and breads, which are traded directly in shops set up in their households or in semi-permanent stands on the streets. The producers who trade their harvest with local transformers sell at a low price, with the argument that it is a native seed. However, the

Table 1. Production costs of direct sowing and sowing with chapin, cycle 2019 (USD).

Concept	Planting con chapin	Direct planting
Land preparation ($/ha)	90.51	115.65
Chapin preparation ($/ha)	150.85	0.00
Inputs ($/ha)	176.50	278.58
Wages ($/ha)	394.73	289.14
Harvest($/ha)	291.65	173.48
Total Cost ($/ha)	1104.24	856.85
Yield t/ha	1.35	1.20
Price ($/t)	930.26	930.26
Income ($/ha)	1255.85	1116.31
Utility ($/ha)	151.61	259.47
Cost ($/t)	817.96	714.04
Profit per t	112.30	216.22
Benefit/Cost	0.06	0.07

Source: Prepared by the authors with information gathered in the field during October-November 2019. Prices from 2019.

transformers stockpile the production from Puebla and Morelos where they buy it at a higher price than in Tulyehualco, although the seed pops on average in 80%. However, there is a transformer who gives extra payment of 15% over the price to local producers since he does it with the intention of giving value to the native seed of the zone and supporting the producer to recover his investment.

Problems with amaranth in Tulyehualco

Regarding its cultivation, it is done under rainfed conditions, which is why it is necessary to understand water capture techniques and, with these, to have water available for auxiliary irrigation; in addition, the producer faces low yields per hectare, since lacking a production technology appropriate to the agroclimatic zone, sometimes producers ignore what to use to combat pests and diseases. Ayala Garay *et al.* (2014) mention that technical problems which prevail in amaranth cultivation make it necessary to elaborate a program for technology transfer and continuous training that detects the needs of the producer with the aim of improving production and yields, as well as minimizing risks to the crop. Something else that threatens the cultivation zone is the growth of the urban sprawl, invading cultivation lands since it is attractive for the producer to sell his plot for housing due to the income it generates, resulting partly from ageing of the people who are devoted to the farmland, who are over 55 years and because few young people are involved in farming, with amaranth plots being left without generational replacement. Ayala Garay *et al.* (2020) mention as part of their conclusions that an institutional transversal strategy is required to promote the cultivation and consumption of amaranth in Mexico, highlighting that, just as it is tolerant to droughts for cultivation and production, it is also a functional food that in addition to nourishing can prevent certain diseases due to its high content of essential amino acids and its content of bioactive peptides.

CONCLUSIONS

Amaranth production in the locality of Tulyehualco ought to be recognized because of its traditional form of production, where it stands out that its process follows ancestral techniques such as chapin. In the present scenario, primary production has a high demand for labor, particularly in sowing and harvesting, which generates employment in the region and rootedness of families in the region; however, mechanization is required. It is necessary to design new institutional channels to perform the transference of the existing production technology to the amaranth cultivation areas, with the objective of improving production, controlling phytosanitary problems, increasing yields, and diversifying its use and consumption.

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