Agricultura, Sociedad y Desarrollo

CHARACTERIZATION OF CHILE POBLANO PRODUCERS FROM THE SIERRA NEVADA DE PUEBLA BY MANAGEMENT OF CROP FERTILIZATION

Ana María **Tlelo-Cuautle**[1], Oswaldo Rey **Taboada-Gaytán**[1*], Higinio **López-Sánchez**[1], Javier **Cruz- Hernández**[1], Ignacio **Ocampo-Fletes**[1], Juan Carlos **Velázquez-Aradillas**[2]

[1]Programa en Estrategias para el Desarrollo Agrícola Regional. Colegio de Postgraduados, Campus Puebla. Boulevard Forjadores de Puebla Núm. 205, Santiago Momoxpan, Municipio de San Pedro Cholula. 72760, Puebla, México.
[2]Universidad Politécnica de Puebla. Tercer Carril del Ejido "Serrano" s/n, San Mateo Cuanalá, Juan C. Bonilla, Puebla.
*Corresponding author: toswaldo@colpos.mx

ABSTRACT

Historically, farmers have generated knowledge about agriculture from their experiences. However, it is not known whether the farmers of the Sierra Nevada de Puebla implement adequate fertilization management for the cultivation of Chile Poblano, due to lack of information on this subject. The aim of this research was to document the knowledge that farmers have about fertilization management for Chile Poblano, through the application of a questionnaire that makes it possible to obtain information in this regard, and will serve as a basis to improve current practices. 50 producers were interviewed, selected from a regional register of 200 farmers, with a qualitative-quantitative sampling of maximum variance, in 14 localities, distributed among nine municipalities of the Sierra Nevada. The information was analyzed using descriptive statistics and cluster analysis. Three groups of producers were identified, taking as a classification criterion, the way in which they use local manure, commercial organic fertilizers and chemical fertilizers in terms of the management of nutrients for the crop. It was concluded that farmers have generated empirical knowledge about the use of manure and chemical fertilizers for the cultivation of Chile Poblano, but they do not know how to appropriately combine these sources to increase fruit yield.

Keywords: Commercial organic fertilizers, peasant knowledge, chemical fertilization, use of local manure.

Citation: Tlelo-Cuautle AM, Taboada-Gaytán OR, López-Sánchez H, Cruz- Hernández J, Ocampo-Fletes I, Velázquez-Aradillas JC. 2022. Characterization of chile poblano producers from the Sierra Nevada de Puebla by management of crop fertilization. Agricultura, Sociedad y Desarrollo https://doi.org/10.22231/asyd.v19i2.771

ASyD 19(2): 112-125

Editor in Chief:
Dr. Benito Ramírez Valverde

Received: May 28, 2018.
Approved: January 27, 2021.

Estimated publication date:
October 17, 2022.

INTRODUCTION

Modern agriculture has multiple purposes, particularly those of agronomic, economic, social and environmental nature, so implementing an appropriate crop fertilization management program is extremely relevant, because its implementation will in some way affect at least one of these objectives. A clear example is increase in yield as a result of apt fertilization, which results in economic and social benefits for farmers.

Both organic and chemical fertilizers represent basic inputs in agricultural activity that are used to improve the nutritional status of plants, promote vegetative growth and as a consequence increase the production of food such as cereals, oilseeds, fruit trees and vegetables, aiming not only to maximize yields, but also to optimize the quality of the product of commercial interest. It is considered that a nutrient management program should consider the use of organic matter sources such as manure, compost and vegetable residues, among others, together with the use of chemical fertilizers (Santiago and Reynoso, 2009; Ortega, 2013; Santa-María *et al.*, 2015). Farmers, through the constant handling of these products, generate a set of empirical observations based on experiences with their own crops, but, sometimes, also through

experimentation and individual or collective invention; this knowledge is transmitted from generation to generation, which enriches a particular aspect of the production process, especially when it is handled locally (Williams *et al.*, 2003; Landini, 2011). Being knowledgeable about adequate management of plant fertilization, especially in small scale family-oriented agriculture, provides several benefits, such as an increase in the content of organic matter, a greater tolerance to damage from pests and diseases by having plants that are well nourished and vigorous, and an increase in food sources as the result of increasing yields (Pretty *et al.*, 2003; Florentín *et al.*, 2011; Bunch, 2012). A traditional practice by farmers to improve the quantity and quality of their crops, in addition to the physical and chemical properties of the soil, has been the application of organic matter in the form of manure, either fresh or in a state of decomposition (Ortega, 2013). Likewise, the use of chemical fertilizers is also an important factor for improving the productivity of agriculture, as these not only improve yield, but also provide an increase in crop by-products (Kumar *et al.*, 2015).

In the case of family-oriented agriculture, on many occasions agricultural and livestock activities are complementary, so in order not to discard animal waste, the intention is to use it for agriculture and that its use contribute to improving the economy of these production units (Cole *et al.*, 2016). Good fertilization and crop management enhance the agronomic performance of the plant and thereby generate additional income for the farmer (Flores *et al.*, 2004; Ugarte *et al.*, 2007). Crop nourishment programs, including those directed at fruit trees and vegetables, include abundant application of fertilizers, particularly those containing nitrogen. However, often there is no fertilizer management program that makes it possible to control the amount applied to the crop; also, on many occasions, the nutrients contained in the soil are not determined, resulting in nutritional imbalance, which is reflected in physiological problems for the entire plant.

Studies have been carried out to determine knowledge concerning the use of organic and chemical fertilizers in fertilization practices (Nesme *et al.*, 2005) and for crops such as the local variety known as "chile de agua" (Aparicio-del-Moral *et al.*, 2013) and rice (Guo *et al.*, 2015). Recently, a project was undertaken in the study area confirming that local manure or commercial organic fertilizers may be used as substrate components for the production of good quality Chile Poblano seedlings (Acevedo *et al.*, 2020). However, in the Sierra Nevada region of Puebla, there is a lack of knowledge about how producers manage fertilization in the cultivation of Chile Poblano, because they do not know the exact amount of nutrients that should be applied to a certain surface area (Herrera, 2016). This negatively impacts farmers in terms of production achieved and corresponding economic income, without the extent of this effect having been quantified.

In the case of the Chile Poblano, the way in which producers handle fertilization of the crop is unknown, so it is necessary to identify and systematize the knowledge that farmers have regarding plant nutrition, by recording the way in which chemical and organic fertilizers are applied in the study area. We expect that results obtained will be useful for assessing

the type of Chile Poblano producer found in the study area, based on the knowledge they manifest regarding the use of organic and chemical fertilizers, thus making it possible to promote programs that focus on the design and implementation of fertilizer management for the crop, according to the needs presented by producers.

MATERIALS AND METHODS

Study area and sample size

The research was carried out in nine municipalities of the Sierra Nevada de Puebla (Figure 1), which is the most important chile poblano producing region in the state, where family-oriented agriculture is one of the main activities. The municipalities of the study region were: Domingo Arenas, San Miguel Huejotzingo, Juan C. Bonilla, San Andrés Calpan, San Lorenzo Chiautzingo, San Martin Texmelucan, San Matías Tlalancaleca, San Salvador el Verde and Santa Rita Tlahuapan. 14 localities were selected from the nine municipalities where Chile Poblano is produced (Table 1).

The number of Chile Poblano producers to be interviewed was defined by qualitative-quantitative sampling with maximum variance. The sample size was based on a register of approximately 200 producers located in the Sierra Nevada de Puebla. The equation used to determine the sample size was:

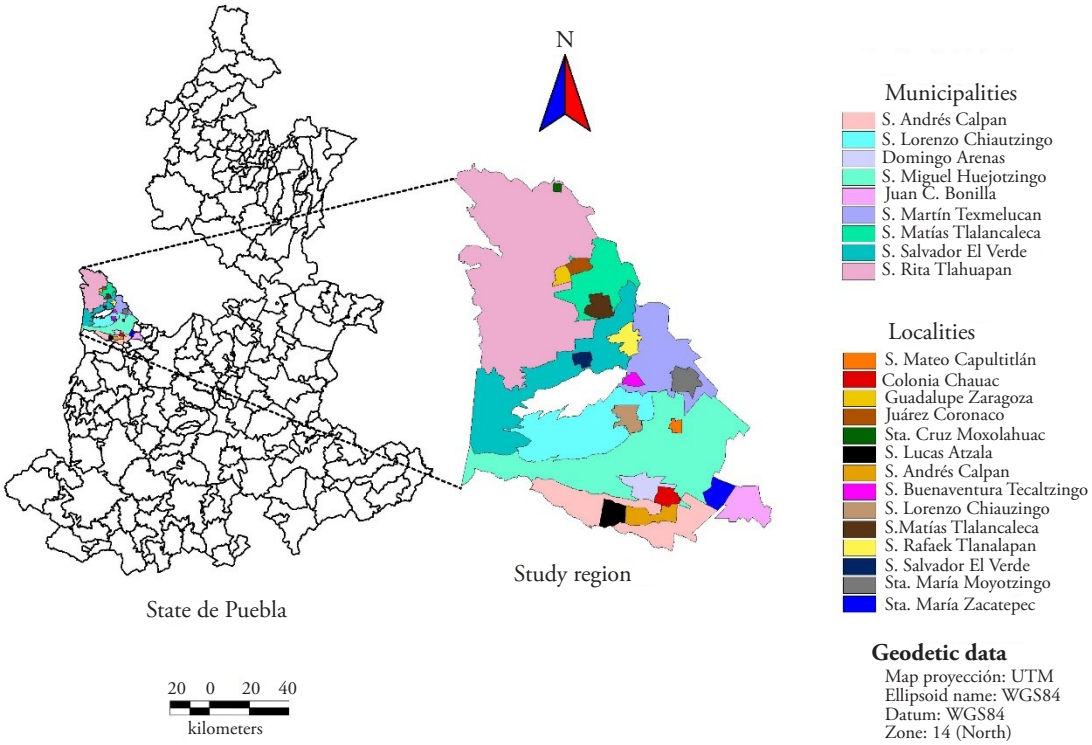

Figure 1. Position of municipalities and study localities in the Sierra Nevada de Puebla.

Table 1. Distribution of surveys by municipalities and localities in the Sierra Nevada de Puebla region.

Municipality	Locality	NCLoc	NCMun
Domingo Arenas	Colonia Chahuac	1	1
Juan C. Bonilla	Santa María Zacatepec	2	2
San Andrés Calpan	San Andrés Calpan	2	
	San Lucas Atzala	3	5
San Lorenzo Chiautzingo	San Lorenzo Chiautzingo	7	7
San Martín Texmelucan	San Rafael Tlanalapa	4	
	Santa María Moyotzingo	5	
	San Buenaventura Tecaltzingo	7	16
San Matías Tlalancaleca	San Matías Tlalancaleca	5	
	Juárez Coronaco	4	9
San Miguel Huejotzingo	San Mateo Capultitlán	4	4
San Salvador el Verde	San Salvador el Verde	2	2
Santa Rita Tlahuapan	Guadalupe Zaragoza	3	
	Santa Cruz Moxoláhuac	1	4
Total		50	50

NCLoc: number of questionnaires per locality and NCMun: number of questionnaires per municipality.

$$n = \frac{NZ_{\alpha/2}^2(0.25)}{Nd^2 + Z_{\alpha/2}^2(0.25)}$$

where n: sample size; N: number of producers in the register; d: accuracy; $Z_{\alpha/2}$: Reliability. Z value (standard normal distribution).

The sample size was 33, but for purposes of attaining more reliable information, it was decided to consider a final sample of 50 farmers to be interviewed.

$$n = \frac{(200)(2.5)_{\alpha/2}^2(0.25)}{(200)(0.2)^2 + (2.5)_{\alpha/2}^2(0.25)} = 33$$

Design of questionnaire

Gathering of information was carried out during field trips and direct visits to the private homes of the farmers. A questionnaire consisting of 55 questions was applied to Chile Poblano producers; this questionnaire was divided into four categories: 1. General characteristics of farmers and management practices of Chile Poblano crop, 2. Crop fertilization management through the use of organic fertilizers (manure and commercial fertilizers) and chemical fertilizers, 3. Institutional support received by farmers to encourage the cultivation of Chile Poblano and 4. Traditional knowledge that has been generated, maintained and transmitted to farmers concerning the agronomic management of the crop.

Statistical analysis

A descriptive analysis was carried out where characteristics of Chile Poblano cultivation were considered, such as obtaining the seed and type of fertilization, among others. A cluster analysis was performed based on the Euclidean distance matrix grouping, using Ward's method, to define groups of producers who shared common characteristics in terms of fertilization management for the Chile Poblano crop. The statistical program used for information analysis constituted the SAS program, version 9.4 (Statistic Analysis System Institute, 2013).

RESULTS AND DISCUSSION

Characteristics of farmers and management of the Chile Poblano crop

Chile Poblano farmers from the Sierra Nevada de Puebla have dedicated an average of 17 years to cultivating this crop. Figure 2 shows educational level and age of farmers. 78% finished primary and secondary and 20% finished high school or undergraduate level; only 2% of farmers have no academic education. The age of the Chile Poblano farmers ranges between 24 and 79 years, averaging 55 years old. Results indicate that level of education influences management of the Chile Poblano crop, thus Galindo (2007) ascertains that age and level of schooling determines the level of acceptance and adoption of new technologies for growing the crop, as it is apparent that the youngest producers with highest level of schooling are the ones who are most willing to implement technological recommendations that have not yet been put into practice.

Farmers have an average of 1.0 ha for Chile Poblano cultivation, although 44% have less than 0.5 ha and 14% have more than 2 ha. 58% have a private property, while

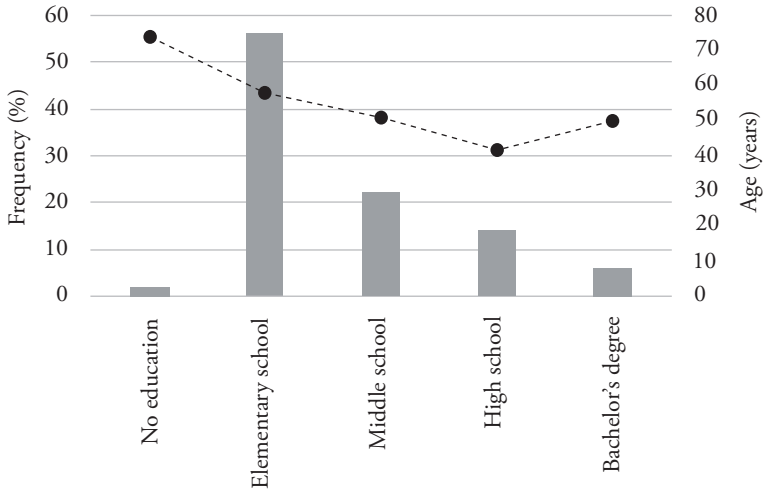

Figure 2. Educational level and age of Chile Poblano farmers in the Sierra Nevada de Puebla.

20% own communal land. Notably, despite the fact that some have their own land for cultivation, 62% tend to rent land and on average they rent 1.4 ha. Those who rent mentioned that the method used for fertilizing the crop on rented land was based on chemical fertilization, whereas those who owned their land fertilized it with manure and chemical fertilizers.

The Chile Poblano seed used by farmers is Creole and is mostly their own, only 18% was obtained in other localities, mainly in San Miguel Huejotzingo, Juárez Coronaco, San Matías Tlalancaleca, San Rafael Tlanalapa and San Gregorio Zacapechpan. 86% of the Chile Poblano cultivation area is irrigated, while the rest is cultivated under season rain-fed conditions.

The yield obtained for green fruit is 1.4 t ha^{-1}, whereas for dried fruit it is 0.76 t ha^{-1}. 62% of the farmers tend to use additional labor apart from the production unit, hiring an average of 13 daily workers per crop cycle; apart from this, extra labor comes only from family members, who help with cultivation work. The product in the form of dried fruit is used more for commercial purposes, as 78% of the farmers sell this dehydrated, whereas the rest market both green and dried fruit. Not knowing the adequate amount of fertilizer for crops, leads to low yields in the study area; lower than the national average of 21.5 t h^{-1} of green fruit and 1.9 t ha^{-1} of dried fruit (FAOSTAT, 2018).

Compost and fertilization

Figure 3 shows the amount of fertilizers and chemical fertilizers used in Chile Poblano cultivation. Farmers manage three types of fertilization sources: manure, commercial organic fertilizers and chemical fertilizers. For example, 98% of respondents use chemical fertilizers more frequently, 48% apply manure in combination with chemical fertilizers,

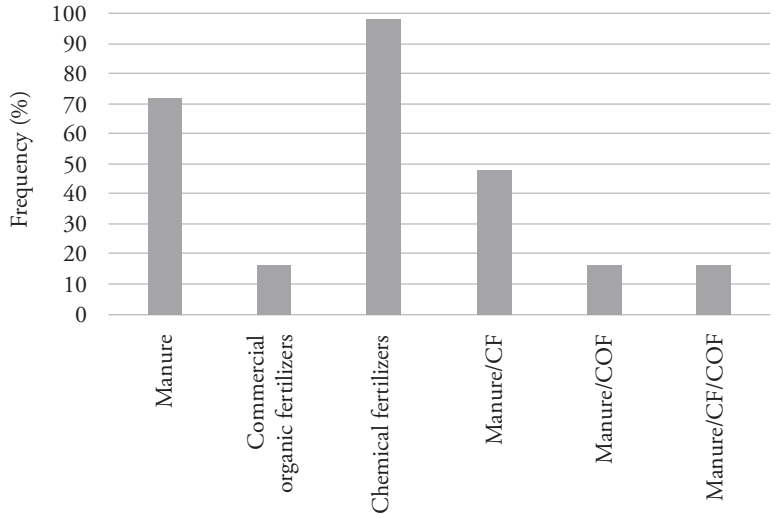

Figure 3. Combination of organic compost and chemical fertilizers used for growing Chile Poblano in the Sierra Nevada de Puebla.

and only 16% apply the combination of manure-commercial organic fertilizer-chemical fertilizers. Results indicate that the majority of farmers prefer to use chemical fertilizers and a minority a combination of these. The theory about the knowledge of farmers, when combining the use of chemical fertilizers and organic fertilizers to crops, indicates that a deficit exists in terms of the amount applied and the optimal amount recommended for the development of the plant (Barra, 1999; Aparicio-del-Moral *et al.*, 2013). These results concur with the theory indicating a lack of knowledge about the adequate amount of fertilizers to apply for the cultivation of Chile Poblano, when manure, commercial organic fertilizers and chemical fertilizers are used as nutrient sources.

Production of manure for use as organic fertilizer

58% of farmers own some type of livestock, among which cattle, sheep and pigs are predominant. The production of manure depends on the species of cattle they have; generally, in the study area, based on the register of 200 Chile Poblano producers, 292 t of cattle manure, 200 t per year of sheep manure and 40 t per year of pig manure are produced annually, which means that the local availability of this source of nutrients is not a limitation to its use. 76% of farmers simply stockpile manure until it is moved to the field for application, and 76% are willing to procure manure for application on their farms, as long as it is available either in their own locality or in a neighboring locality. Based on the compiled information, it is apparent that farmers tend to use manure to fertilize their crops, asserting that 72% of them employ some type of manure in the cultivation of Chile Poblano; the most commonly used is cattle manure, followed by sheep.

As mentioned before, most farmers in the study area own a number of animal species that generate variable amounts of manure per year. Having this type of nutrient source for plants can be taken advantage of by farmers, who apply it directly to their farmland, creating the impression of reduced use of chemical fertilizers and thus in the overall expense per crop. Additionally, they mention that manure as a source of nutritional elements in cultivated areas, lasts for 5 years after its application, a fact corroborated by Schröder (2005).

Use of commercial fertilizers

The use of commercial organic fertilizers is low, because 80% of farmers have no interest in using it and only a small percentage (20%) do use this type of fertilizer; among the reasons mentioned, to explain their low use, is that they are very expensive, they do not know where to get them or they simply do not like to use them. Farmers who apply commercial fertilizers see results in the form of increased crop productivity as the result of adding organic matter, as the use of commercial fertilizers that include organic matter such as earthworm humus and farmyard manure is efficient for chili production. (Ribeiro *et al.*, 2000)

Application of chemical fertilizers

98% of farmers use chemical fertilizers. These include predominantly diammonium phosphate (DAP) 18-46-0 (72%) and urea (48%), and to a lesser extent potassium chloride (12%). Importantly, macronutrients (N, P and K) are required by crops in considerable amounts to maintain commercially acceptable yields. These nutrients have received most attention in fertilization practices and applying them in optimal quantities has caused increases in the product of commercial interest. However, it should also be taken into account that the nutritional needs of plants are defined by the species, so that it is necessary to consider quantity, quality, form and moment of application (Betrán *et al*., 2006). The management of chemical fertilization by Chile Poblano producers in the study area indicates a lack of knowledge in this regard, particularly if the low percentage of producers who apply potassium is considered, as this element is fundamental for the production of enzymes during stages of development and to maintain water balance in plant tissues. However, if potassium is not provided in optimal amounts, plants do not reach their fruit yield potential, which is reflected in a decrease in the expected harvest (Kuangfei *et al*., 1999).

The farmers interviewed, mentioned that they do not know the adequate amounts for each fertilizer that should be applied and therefore, they make applications similar to those they carry out for the maize crop, without making an accurate record of the total amount applied. For Galindo (2007), the two crop management practices that producers carry out inadequately, due to ignorance, are disease control and fertilization, resulting in low yields and poor fruit quality. Salazar-Jara and Juárez-López, (2013) mention that the nutritional requirement of chili as a basis for calculating the fertilization dose in kg t^{-1}, indicates a requirement of 2.4 to 4.0 N, 0.4 to 1.0 P_2O_5 and 3.4 to 5.29 K_2O with the purpose of reducing the cost of production and optimizing the supply of fertilizers, while reducing negative impact on the environment, and thus promoting optimum quality and quantity of harvested products.

The cluster analysis based on the variables of the use of manure, organic fertilizers and chemical fertilizers for management of the fertilization of the Chile Poblano crop divided the farmers into three groups (Figure 4). Each group is integrated according to the similarity in which the producers use these nutrient sources, alone or in combination, for the fertilization of the crop. The integration of these groups was determined by the following characteristics:

Group I is made up of 14% of farmers with an average age of 46.2 years, who use cattle manure, because the cattle they own generate an average of 63 tons of manure per year. The amount of manure applied to the farmland is 15 t to an average area of 1.5 ha, which is applied prior to transplanting. In this group, the producers also apply compost, of up to a ton to this surface area, which they apply during the first work on the crop. The chemical fertilizers most used by farmers are the application of 316 kg of urea and 59 kg of 18-46-0 to an average crop area of 1.5 ha, which represents the greatest cost in terms of acquiring

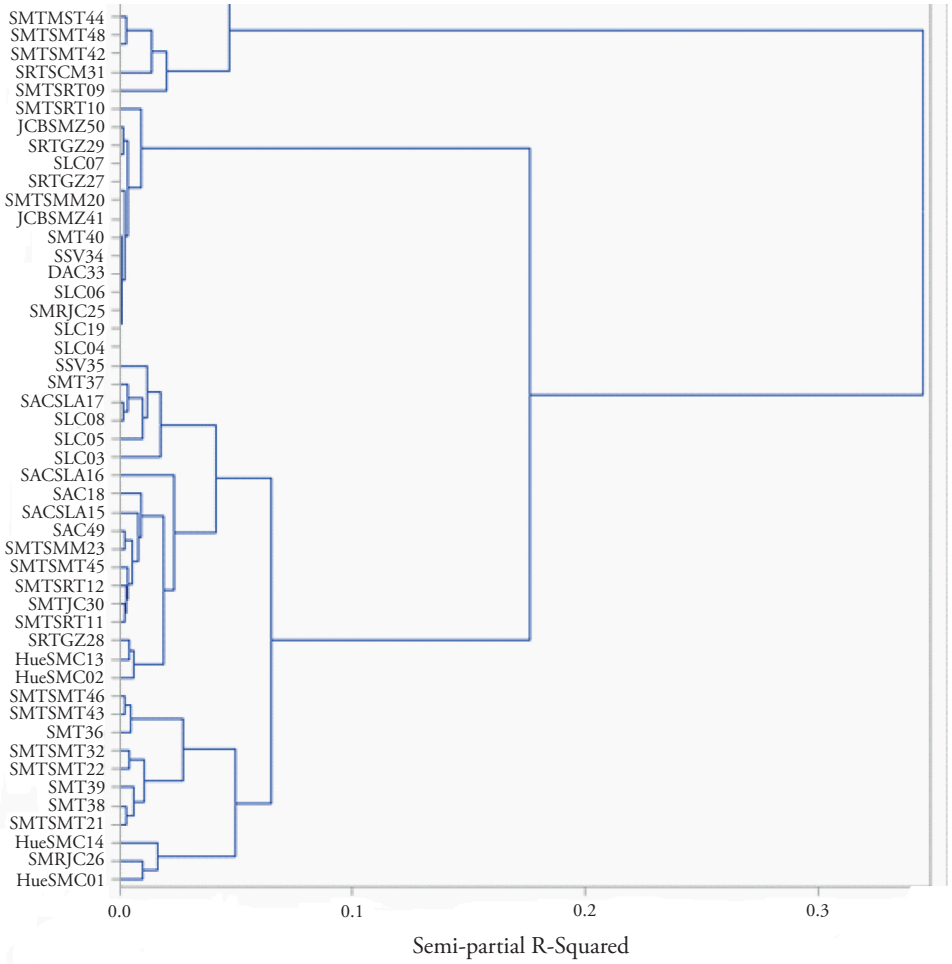

Figure 4. Groups of farmers based on fertilization management for the Chile Poblano crop in the Sierra Nevada de Puebla.

both types of fertilizer during crop nutrition management. This group of farmers does undertake to combine manure, commercial fertilizers and chemical fertilizers, as they have observed plants generate better roots, greater strength during development and have obtained greater yields.

Group II is made up of 28% of farmers, who have an average age of 57.3 years, making them the oldest group of producers. In this group, the application of chemical fertilizers predominates, in the form of 75 kg of urea, 120 kg of 18-46-0 and 30 kg of potassium chloride (KCl) for an average area of 1.2 ha. These fertilizers are applied during the first cultivation work for the Poblano pepper crop. According to the producers, they prefer to use this type of fertilizer to provide their crops with nutrients because they are fast-acting and favor the development of the plant, which results in an increased yield of chili fruit.

Farmer is group III comprise 58% with an average age of 55.8 years; they have sheep,

which generate an average of 40 t of manure per year. In this scenario, producers apply the manure after it has been stored for three to six months, applying an average of 15 t to 1 ha prior to transplanting. They also apply chemical fertilizers: 65 kg of urea, 100 kg of 18-46-0, and 25 kg of potassium chloride (KCl) per unit area. This type of producer incorporates the application of manure, mainly sheep manure, to their farmland, plus the application of chemical fertilizers, as this results in better fertilization of the Chile Poblano plants, and an increase in yield of both green and dried product. It is apparent, in the same study area, that the application of sheep manure at a high level (15 t ha^{-1}), in combination with chemical fertilization at a medium level (80N-40P-80K) contributes to significantly increasing yields of green Chile Poblano (Tlelo-Cuautle *et al*., 2020).

Ren *et al*. (2011), mentions that the grouping of producers in terms of fertilization management serves as an information system, where each farmer has specific knowledge regarding how he fertilizes his crop. Based on this knowledge, it should be possible to improve recommendations concerning the fertilization of the Chile Poblano crop. However, it is necessary to discover exactly how producers are managing their crops in terms of nutrients; unfortunately, this is information that producers often do not record and systematize, or that they do not easily share.

The fundamental factor that enabled the grouping of farmers as presented in Figure 4 entailed the management of fertilization for the Chile Poblano crop. The differentiation of the producers into three groups was made based on the following: the first undertook combined fertilization employing manure, compost and chemical fertilizers, the second based theirs only on the use of chemical fertilizers and the third used manure plus chemical fertilizers. The means of providing nutrients for plants, characteristic of group three, is the most widespread and occurs more frequently in seven municipalities, where the manure resource, generated by the different species of livestock they own is used, but this is complemented by the purchase of chemical fertilizers.

Here, we should return to what Galindo (2007) asserts, in the sense that to increase chili production, it is necessary to carry out an integrated control of pests and diseases, use better varieties and fertilize with the appropriate doses, among other aspects. The same author points out that a limitation to achieving the above refers to the fact that producers apply low doses of fertilizer, compared to the optimal recommended dose. In this case, for the Sierra Nevada de Puebla area, Huerta *et al*. (2007) mentions that the fertilization formula 120-80-100 is appropriate for managing Chile Poblano nutrients.

If this recommendation is taken as a parameter, the producers from the three groups described previously manifest poor crop fertilization management, as the producers in Groups I, II and III use the fertilization formulas 156-27-00, 55 -55-18 and 48-46-15, respectively, resulting in them achieving product yields of the order of 1006, 598 and 2050 kg ha^{-1}. There is an apparent inverse relationship between the adoption of technological recommendations in the cultivation of chili, and the age and educational level of the producers (Galindo 2007).

Results indicate that something similar occurs in the study area, as the producers in Group I are the youngest with an average of 46.2 years of age, are those who have shown a greater willingness to innovate in the nutritional management of the crop by resorting to both the use of chemical fertilizers and local manure, as well as the use of commercial organic fertilizers; the producers of Groups II and III, with a more advanced age of 57.3 and 55.8 years, respectively, maintain more traditional fertilization management, using only local manures and chemical fertilizers. It is worth mentioning that the nutrition of the crop in sustainable family agriculture cannot be based only on the use of chemical fertilizers, it is best to accompany these with applications of manure to help improve soil fertility, because as this is slow release, the nutrients they contain are available to be used by plants for a longer period of time (Calatayud and Mateu, 1995; Latournerie *et al*., 2002; Dopico *et al*., 2009).

Institutional support and traditional knowledge

90% of the farmers mentioned that they do not receive any institutional support and only 10% of them receive economic support from agencies such as SAGARPA and the municipal presidency, for the purchase of fertilizers that they apply for the cultivation of Chile Poblano.

Even when the technology concerning aspects of nutrients for plants is constantly advancing, the management of the fertilization of the Chile Poblano crop among the producers of the Sierra Nevada de Puebla is characteristic of a production system typical of traditional agriculture. Farmers in the area mention that the transmission of knowledge about the production of Chile Poblano is declining, because new generations often seek other types of work or tend to emigrate and are not interested in the countryside, especially concerning the cultivation of Chile Poblano and particularly in the study area.

76% of producers associate the lunar phases with the agronomic management of the Chile Poblano crop, as this is rooted in traditional knowledge that has been transmitted from generation to generation; in this sense, Méndez (2003) mentions that traditional practices, decisions and beliefs offer a possibility for expanding the frontier of scientific knowledge. 32% of producers rely on the first quarter lunar phase for establishing plants in the field, as producers associate this with a low presence of pests and a better vegetative development of the crop. Lunar phases have great influence on agriculture, as according to ancient knowledge, each lunar phase is relevant in terms of particular aspects such as soil, harvest, pruning, planting, pests; with the new moon and crescent moon being those considered most useful for ensuring greater crop productivity (Andrade *et al*., 2017).

87.7% of producers consider it important to transmit the knowledge they have about the management of the Chile Poblano crop to the new generations, so that they will continue to conserve the seed of these local populations, as they consider this to be a way of also conserving their particular identity. In this sense, García (2007) points

out that given its character and collective utility, among the peoples and communities that maintain traditional knowledge, it has a greater use value than exchange value, as this type of knowledge is part of the natural heritage and culture of these groups, which reinforces and defines their identity. Based on this, it is important to recognize that initiatives and efforts are necessary in order to understand, systematize, conserve, protect, take advantage of and innovate on the traditional knowledge that is still maintained as part of the culture of both indigenous and non-indigenous groups, who practice agriculture in the particular environmental conditions of our country.

This research contributes to understanding how the farmers of the Sierra Nevada de Puebla manage fertilization for the cultivation of Chile Poblano, with a perspective on the use of manure and chemical fertilizers, while aiming to provide information that serves as a basis to improve current practices, thus allowing more efficient use of organic fertilizers, by considering them as a low-cost local resource.

CONCLUSION

The farmers of the Sierra Nevada de Puebla have generated and maintained a certain level of knowledge about the use of manure, commercial organic fertilizers and chemical fertilizers for the management of fertilization in the cultivation of Chile Poblano, but they do not know precisely how to implement a combination of these resources to increase product yield, as even when the three groups of producers identified resort to the use of local manure and commercial organic fertilizers, they maintain the application of chemical fertilization doses well below the technological recommendations for the study area, reflected in the low product yields obtained.

Acknowledgments

To each of the Chile Poblano farmers pertaining to the localities of the municipalities that make up the Sierra Nevada of the State of Puebla, who kindly answered the questionnaire for the purposes of this investigation. Also, thanks to Dr. Nicolás Pérez Ramírez for elaborating Figure 1.

REFERENCES

Acevedo-Alcalá P, Cruz-Hernández J, Taboada-Gaytán OR. 2020. Abonos orgánicos comerciales, estiércoles locales y fertilización química en la producción de plántula de chile poblano. Revista Fitotecnia Mexicana. 43(1):35-44.

Andrade RIM, Rojas JA, Espinoza MM, Viamonte KR. 2017. Influencia lunar en cultivos, animales y ser humano. Revista de Ciencia, Tecnología e Innovación. 4:37-47.

Aparicio-del-Moral JO, Tornero-Campante MA, Sandoval-Castro E, Villarreal-Manzo LA, de los Ángeles, Rodríguez-Mendoza M. 2013. Factores Sociales y Económicos del Cultivo de Chile de Agua (*Capsicum annum* L.) en tres Municipios de los Valles Centrales de Oaxaca. Ra Ximhai. 1(9):17–24.

Barra JDE. 1999. Técnicas de diagnóstico útiles en la medición de la fertilidad del suelo y el estado nutrimental de los cultivos. Terra Latinoamericana. 3(17):209–219.

Bunch R. 2012. Restoring the soil: a guide for using green manure/cover crops to improve the food security for smallholder farmers. *Canadian Foodgrains Bank*, Winnipeg. 94 p.

Calatayud-Giner S, Mateu-Tortosa E. 1995. Tecnología y conocimientos prácticos en la agricultura valenciana. Noticiario de Historia Agraria. 9:43-67 pp.

Cole JC, Smith MW, Penn CJ, Cheary BS, Conaghan KJ. 2016. Nitrogen, phosphorus, calcium, and magnesium applied individually or as a slow release or controlled release fertilizer increase growth and yield and affect macronutrient and micronutrient concentration and content of field-grown tomato plants. Scientia Horticulturae. 211:420–430.

Dopico E, Linde AR, Garcia-Vazquez E. 2009. Traditional and Modern Practices of Soil Fertilization: Effects on Cadmium Pollution of River Ecosystems in Spain. Hum Ecol. 2(37):235–240.

FAOSTAT (Food and Agriculture Organization of the United Nations, Statistics Division). 2018. Estadísticos de la producción mundial de chile. http://www.fao.org/faostat/es/#data/QC (Marzo de 2021).

Florentín MA, McDonald MJ. 2011. Green manure, cover crops and crop rotation in conservation agriculture on small farms, Integrated Crop Management. Food and Agriculture Organization of the United Nations. Rome. 95 p.

Flores P, Navarro JM, Garrido C, Rubio JS, Martínez V. 2004. Influence of Ca2+, K+ and NO3− fertilization on nutritional quality of pepper. J. Sci. Food Agric. 6(84):569–574.

Galindo G. 2007. El servicio de asistencia técnica a los productores de chile seco en Zacatecas. Convergencia. 43(14):137-165.

García AMA. 2007. Conocimiento Tradicional de los pueblos indígenas de México y Recursos Genéticos. Comisión Nacional para el desarrollo de los pueblos indígenas (CDI). Unidad de Planeación y Consulta. Dirección General del Desarrollo y Cultura de los Pueblos Indígenas. Dirección Ejecutiva de Investigación. México.

Guo M, Jia X, Huang J, Kumar KB, Burger NE. 2015. Farmer field school and farmer knowledge acquisition in rice production: Experimental evaluation in China. Agriculture, Ecosystems & Environment. (209):100–107.

Herrera FE. 2016. El sistema de producción de chile "Poblano": características y fitomejoramiento de germoplasma local sobresaliente. Tesis de Maestría. Postgrado en Estrategias para el Desarrollo Agrícola Regional. Colegio de Postgraduados Campus Puebla. 73 p.

Huerta de la PA, Fernández RS, Ocampo FI. 2007. Manual de chile poblano. Importancia Económica y Sociocultural. Colegio de Postgraduados, Campus Puebla. Fundación Produce Puebla A.C. 80 p.

Kuangfei L, Yaling X, Xuefeng L, Pastore G. 1999. Loss of nitrogen, phosphorus, and potassium through crop harvests in agroecosystems of Qianjiang, Hubei Province, PR China. Critical Reviews in Plant Sciences. 3(18):393–401.

Kumar A, Pathak AK, Guria C. 2015. NPK-10:26:26 complex fertilizer assisted optimal cultivation of Dunaliella tertiolecta using response surface methodology and genetic algorithm. Bioresource Technology. 194:117–129.

Landini F. 2011. La dinámica de los saberes locales y el proceso de localización del saber científico. Aportes desde un estudio de caso. Cuadernos de Desarrollo Rural. 65(7):21-43.

Latournerie L, Chávez JL, Pérez M, Castañón G, Rodríguez SA, Arias LM, Ramírez P. 2002. Valoración *In situ* de la diversidad morfológica de chiles (*Capsicum annuum* L. y *Capsicum chinense* Jacq.) en Yaxcabá, Yucatán. Revista Fitotecnia Mexicana. 25:25-33.

Méndez RM. 2003. Prácticas, decisiones y creencias agrícolas mágico-religiosas presentes en el sureste de México. Etnobiología. 3(13):66-78.

Nesme T, Bellon S, Lescourret F, Senoussi R, Habib R. 2005. Are agronomic models useful for studying farmers' fertilization practices?. Agricultural Systems. 3(83):297–314.

Ortega R. 2013. Integrated Nutrient Management in Conventional Intensive Horticulture Production Systems, in: II International Symposium on Organic Matter Management and Compost Use in Horticulture. Acta Hort. 1076:59–164.

Pretty JN, Morison JIL, Hine RE. 2003. Reducing food poverty by increasing agricultural sustainability in developing countries. Agriculture, Ecosystems & Environment. 1(95):217–234.

Ren Z, Chen J, Cheng J, Ma W, Lü X. 2011. Knowledge-based fertilization recommendation system and application. Transactions of the Chinese Society of Agricultural Engineering. 12(27):126–131.

Ribeiro LG, Lopes JC, Martins Filho S, Ramalho SS. 2000. Adubação orgânica na produção de pimentão. Horticultura Brasileira. 2(18):134–137.

Salazar-Jara FI, Juárez-López P. 2013. Requerimiento macronutrimental en plantas de chile (*Capsicum annuum* L.). Revista Bio Ciencias. 2(2):24-34.

Santa-María GE, Moriconi JI, Oliferuk S. 2015. Internal efficiency of nutrient utilization: what is it and how to measure it during vegetative plant growth?. J. Exp. Bot. 11(66):3011–3018.

Santiago MVG, Reynoso DSF. 2009. Seguridad alimentaria, saberes campesinos y agroecología. Revista Brasileira de Agroecología. 2(4):3995-3998.

Schröder J. 2005. Revisiting the agronomic benefits of manure: a correct assessment and exploitation of its fertilizer value spares the environment. Bioresource Technology. 2(96):253–261.

Tlelo-Cuautle AM, Taboada-Gaytán OR, Cruz-Hernández J, López-Sánchez H, López PA. 2020. Efecto de la fertilización orgánica y química en el rendimiento de fruto de chile Poblano. Revista Fitotecnia Mexicana. 43(3):283-289.

Ugarte MEB, Belmar CA, Holwerda HT. 2007. Guía de manejo de nutrición vegetal de especialidad pimiento. SQM the worldwide business formula. 100 p.

Williams DR, Potts BM, Smethurst PJ. 2003. Promotion of flowering in Eucalyptus nitens by paclobutrazol was enhanced by nitrogen fertilizer. Can J for res. 1(33):74–81.