The 'Poblano' chili production system: characteristics and stratification of farmers

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Abstract

Although the 'Poblano' chili production system in Puebla has not been described, it has been reported that its yields are low; however, its causes have not been documented. This study aimed to describe and analyze the 'Poblano' chili production system and formulate a proposal for the stratification of farmers of this crop. To this end, in 2018, a questionnaire was applied to 54 farmers from 13 localities in the Sierra Nevada of Puebla. The results indicated that 94.4% of farmers cultivated no more than one hectare of 'Poblano' chili, 100% sowed landrace seeds, 74.07% produced seedlings in 'canoa' or seedbeds, the 'Secadera' disease was the main phytosanitary problem and the average yield was 1.07 t ha^{-1} of dried fruit. The main differences between the farmers were family nature, tenure of land on lease, years growing 'Poblano' chili, and some technical-productive variables such as yield, fruit drying time, weeding interval, and phosphate fertilization in seedlings. The cultivation of 'Poblano' chili in Puebla is carried out in an agricultural system in transition, from traditional to conventional, which allowed differentiating groups of farmers.

Keywords:

Capsicum annuum, conventional, Puebla Valley, traditional.

In Mexican agriculture, the chili is the second most important vegetable. At the national level, the average yield of green and dried chili is 17.2 and 1.8 t ha^{-1}, respectively. It is worth mentioning that in Peru an average yield of dried chili of more than 10 t ha^{-1} is reported (FAOSTAT, 2013). Chihuahua, Sinaloa, and Zacatecas stand out as the states with the highest production of green chili, since together they represent 59.8% of national production; while, in dried chili, Zacatecas and San Luis Potosí are the largest producers, since together they contribute 70.9% of national production (SIAP, 2015).

In Puebla, the 'Poblano' or 'Mulato' chili stands out for its culinary and cultural importance and for being an important source of economic income for many families (Toledo-Aguilar et al., 2016). Despite this, there has been a decrease in yield per hectare in recent years. In this regard, Rodríguez et al. (2007) mention that yields of almost 25 t ha^{-1} were reached in past decades. Contreras et al. (2011) and Toledo-Aguilar et al. (2011) point out that the decline of this indicator is associated with the lack of improved varieties and phytosanitary problems. Nevertheless, it is unknown what other factors in the production system may be influencing the decline in yields.

The characterization of production systems is a widely used means to have a clearer idea of all the factors influencing their development, information that allows them to be classified as traditional, conventional, or in transition and thus be able to influence more effectively in their improvement.

Another utility of the characterization of the system is that it allows the grouping of farmers that operate similarly or differently (Vilaboa and Díaz, 2009). In Mexico, there are studies of the characterization and typification of agricultural production systems in vanilla (Barrera-Rodríguez et al., 2009), common walnut (Luna-Méndez et al., 2013), tomato (Cih-Dzul et al., 2011), avocado (Sangerman-Jarquín et al., 2014) and corn (Uzcanga et al., 2015). These explain the socioeconomic and technological dynamics in which each crop develops.

Nonetheless, there is a lack of this type of study in the cultivation of chili, especially in conditions where low-scale production agriculture prevails, as is the case of the 'Poblano' chili in Puebla. The characterization of the production system of this crop will allow the establishment of guidelines for possible intervention strategies that help solve the problems associated with low production. Therefore, the objectives of this research were (i) to describe and analyze the 'Poblano' chili production system; and (ii) to formulate a proposal for the stratification of farmers of such crop.

The study was conducted in 2018 in the Sierra Nevada of Puebla, a region that concentrates the state's largest production of 'Poblano' chili. To select the municipalities and the number of farmers to be interviewed, a list of 60 farmers participating in the 'Poblano' Chili Product System of the state of Puebla was considered as a sampling frame, based on that list, a questionnaire was applied to 54 farmers from nine municipalities (San Andrés Calpan, San Luis Chiautzingo, Domingo Arenas, San Miguel Huejotzingo, San Felipe Teotlalcingo, San Martín Texmelucan, San Matías Tlalancaleca, San Pedro Cholula and San Salvador el Verde) and 13 representative localities of the 'Poblano' chili producing region along the Sierra Nevada of Puebla.

The variables studied were: a) socioeconomic variables such as the age of the farmer, educational level, number of members per family, number of family members who help with the activities of growing 'Poblano' chili, time spent on agriculture, land tenure, destination of production and years growing 'Poblano' chili; b) technical-productive variables such as type of seed used, way of obtaining seedling, fertilization, interval of days between weedings, drying time of ripe fruits, moisture conditions during the crop cycle, most common phytosanitary problems, pesticides used and dried fruit yield; and c) days of work in transplantation, weeding, fertilization, pesticide application, irrigation, and harvesting.

The statistical analysis was performed using descriptive statistics to explain the most important generalities of the system. A principal components analysis was performed to stratify the farmers, and the variables that explained the greatest proportion of the variation were selected, with which a cluster analysis was carried out based on the Euclidean distance matrix and grouping with the

Ward method. Univariate and multivariate analyses of variance and mean tests (Tukey, 0.05) were applied to the groups defined by the cluster analysis. The same analysis was performed on the variables chemical fertilization and the amount of pesticides used to complement the description of the groups. The SAS version 9.4 (SAS Institute Inc., 2013) program was used to perform these analyses.

The results of the most important generalities indicate that the system is represented by small farmers who have, on average, 2.3 ha of their own land, although only a small part of them allocated it to chili production. The farmers are elderly, because, although their age range fluctuated from 25 to 82 years, their average was 55 years. Most farmers (83.3%) have low schooling, since 62.9% completed primary education, 20.4% junior high education, 3.7% high school, 3.7% technical studies, and 5.6% bachelor's degree, the rest (3.7%) had no school level. Considering the above, the 'Poblano' chili production system in this region can be considered as a transition between the traditional and the conventional.

The family unit is small since it is made up of five members on average, which influences the production of chili. In small production units, it is necessary that more members are involved to achieve higher levels of production and lower costs for hired labor. The pluriactivity was low, 88.9% are full-time farmers. It is important to know the level of this characteristic because it influences the dynamics of crop production (Osorio-García *et al.*, 2015), as it generates income for the family (Martínez and Vallejo, 2019).

Ninety-eight point one percent considered that their agricultural activity is for family consumption and sale purposes. The area allocated to the cultivation of 'Poblano' chili is small since 94.4% of farmers used less than one hectare. The precise data are as follows: 18.5% cultivated less than half a hectare, 40.7% from 0.5 to 0.75 ha, 35.2% cultivated 1 ha, and 5.6% cultivated from 2 to 2.5 ha.

The use of seeds and the production of seedlings are typical of a traditional system: 100% of farmers sowed landrace seeds, although 1.8% of them, in addition to landraces, also sowed improved seeds. Seventy-four point zero seven percent of farmers carried out seedling production in 'canoa' or seedbed. The production of seedlings in "canoa" is not exclusive to traditional systems, because in other areas, such as Zacatecas, the seedling is also produced in 'canoa' (Galindo, 2007). The transplantation season was generally between the first days of March and early April. Also characteristic of traditional systems is the very low yield of dried fruit. In this system, the average yield was 1.07 t ha^{-1}, lower than the national average of 1.8 t ha^{-1} (FAOSTAT, 2013).

In addition to the above, fertilization is not adequate. Ninety-eight point one five percent used nitrogen (urea), 77.8% applied phosphorus (diammonium phosphate), and 44.5% applied potassium (potassium chloride), but in low quantities (98N, 78P, and 15K kg ha^{-1}). Toledo-Aguilar *et al.* (2011), when studying populations of 'Poblano' chili in the Sierra Nevada region of Puebla, applied doses of 140N-80K-60P kg ha^{-1} and obtained yields from 1.6 to 9.6 t ha^{-1} of dried fruit. In the 'Poblano' chili production system in Puebla, the main nutritional deficiency is potassium.

Even though 94.4% of farmers grow under rainfed conditions, water was not a limitation, since on average four supplemental irrigations were used during the crop cycle, with gravity irrigation being the most used (92.5%). Irrigation water was used more in the municipalities of Domingo Arenas, San Andrés Calpan, and San Andrés Cholula, as six to 12 irrigations were applied, mainly due to the type of sandy soil that exists in these municipalities.

In clayey soils, excess water leads to the presence of phytosanitary problems related mainly to soil fungi. Damping off was the main problem at the seedling stage, while the disease known as 'secadera' (wilting) (*Phytophthora capsici* Leo., *Fusarium oxysporum* Schlechtend.:Fr. and *Rhizoctonia solani* Kühn.) was after transplantation and during the development stage. During this stage, the incidence of the grasshopper pest (*Sphenarium purpurascens* Ch.) and the watery fruit rot were also reported.

Of the 121 days of work used to carry out the main activities of the cultivation of 'Poblano' chili, most of them were used for weeding (44 days of work) and harvesting (30 days of work). The preparation of the land required two days of work, the production of seedlings six, transplanting 12, the application of fertilizers seven, the application of pesticides 13, and irrigation seven days. In Zacatecas, chili cultivation requires an average of 150 wages ha^{-1} year^{-1} (Aguilar and Esparza, 2010).

Regarding the stratification of farmers, the principal component (PC) analysis showed that in the 'Poblano' chili production system, the main differences between farmers are due to socioeconomic and technical-productive characteristics. In this regard, Luna-Méndez *et al.* (2013) mention that the differences between groups of farmers within an agricultural system are generally socioeconomic and technical-productive. The formation of five groups of farmers and three subgroups within Group I is shown in (Figure 1). There was no grouping pattern between farmers from the same locality; however, some groups include at least two farmers from the same locality.

Figure 1. Grouping of 'Poblano' chili farmers in Puebla. The x-axis shows the key of the 54 farmers interviewed. Roman numerals indicate groups and subgroups of farmers.

The first three PCs explained 48.04% of the total existing variation. The first PC explained 18.54% of the total variation, mainly through the variables interval of days between weedings, time spent on agriculture, and the destination of production. The second PC explained 15.28%of the total variation, with a greater influence of the variables land area on lease, number of family members who help with the activities of the cultivation of 'Poblano' chili and the yield of dried fruit, while the third PC explained 14.23% of the total variation, which includes the variables

years growing 'Poblano' chili, drying time of ripe fruits and amount of phosphorus applied during seedling production (g m^{-2}).

The drying time differs because the landrace populations of 'Poblano' chili used by farmers present variability in pericarp thickness (Toledo-Aguilar *et al.*, 2016); therefore, fruits with greater thickness will require more drying time.

The univariate and multivariate analysis of variance of the farmer groups showed statistical differences for almost all the variables considered. The means of the variables used for the formation of the groups are shown in Table 1. The difference between the groups exhibits the heterogeneity that exists between the groups of farmers of the 'Poblano' chili production system in Puebla.

Table 1. Means of variables that influence the largest variation of the groups of farmers of the 'Poblano' chili production system in Puebla.

G	Socioeconomic variables (P1-P5)															Technical-productive variables (P6-P9)							
	P1		**P2**		**P3**		**P4**		**P5**		**P6**		**P7**		**P8**		**P9**	
Ia	1	b	2.3	b	0.5	a	51	a	3	a	12.1	b	20.7	b	17.3	b	995.4	a
Ib	1	b	2.4	b	1.2	a	19.5	b	3	a	2.8	b	24.1	a	24.1	a	1 781.3	a
Ic	1	b	1.9	b	1.1	a	17.4	b	3	a	3	b	28.5	a	21.6	a	715	b
II	1	b	7	a	5	a	13.3	c	3	a	1.6	b	30	a	36.7	a	807.3	a
III	1.7	a	2.3	b	6	a	16.7	c	3	a	7.5	b	21.4	b	14.7	b	1 166	a
IV	1.5	a	3	b	0	a	40	a	3	a	315	a	22.5	a	25	a	1 504.5	a
V	1	b	3.5	b	1	a	14.5	c	2	b	0	b	37.5	a	15	b	1 156	a

G= group or subgroup; P1= time spent on agriculture; P2= number of family members who help with 'Poblano' chili cultivation activities; P3= area on lease (ha); P4= years growing 'Poblano' chili; P5= destination of production; P6= dose of phosphate fertilization in seedlings (g m^{-2}); P7= interval of days between weedings; P8= drying time of ripe fruits (days); and P9= dried fruit yield (kg ha^{-1}). Means with the same letter in the same column are statistically equal (Tukey, 0.05).

Group I, made up of full-time farmers engaged in agriculture, was divided into three subgroups. Subgroup I-a, which was made up of seven farmers (13% of the total), is distinguished mainly by grouping farmers who have been growing 'Poblano' chili for the longest time (51 years) and who obtain an average yield of 995.4 kg ha^{-1}. Subgroup I-b, which represents 20.4% of farmers, is distinguished mainly by averaging the highest yield of all groups (1 781.3 kg ha^{-1}). Subgroup I-c, which represents 40.7% of farmers, averaged the lowest yield (715 kg ha^{-1}).

Group II, made up of 5.5% of full-time farmers engaged in agriculture, is distinguished from the others by averaging the largest number of family members (seven members) who help with the activities related to the cultivation of 'Poblano' chili, by having the lowest average number of years growing 'Poblano' chili (13.3 years) and by having a higher average number of days for drying ripe fruits (36.7 days). The average yield in this group was 807.3 kg ha^{-1}. Group III, which represents 13% of farmers, is distinguished mainly by grouping farmers who rent the largest area of land (6 ha) and by using the least number of days for drying ripe fruits (14.7 days). The average yield in this group was 1 166 kg ha^{-1}.

Group IV, which groups 3.7% of farmers, is distinguished mainly because farmers did not rent land to carry out their agricultural activities and because they were the ones who applied the

largest amount of phosphorus in the seedling production stage (315 g m^{-2}). The average yield in this group was 1 504.5 kg ha^{-1}. Group V, which clustered 3.7% of full-time farmers engaged in agriculture, is characterized because they do not apply phosphorus in the form of fertilizer during seedling production, because they have the longest intervals of days between each weeding of the crop (37.5 days), because the drying time of ripe fruit was 15 days on average, and because the main destination of production was the sale. The average yield in this group was 1 156 kg ha^{-1}.

Another aspect to consider is nutrition and pesticide use (Table 2). The synthetic fertilization that was applied in each group indicates that it was less than what the crop demands. Farmers in group IV applied the highest dose of nitrogen (182 kg ha^{-1}) and phosphorus (177 kg ha^{-1}) and those in group V did not apply potassium. Also, the number of foliar fertilizers used was low. Soil fertilization should be complemented with the application of foliar fertilizers since these allow correcting deficiencies and nutritional requirements that cannot be covered with soil fertilization (Trinidad and Aguilar, 2010). Pesticides are mainly used to deal with disease problems. On average, five products were applied, with a minimum of two times during the cultivation cycle.

Table 2. Synthetic fertilization applied in the field and number of pesticides used by the groups of farmers of the 'Poblano' chili production system in Puebla.

Variables	Groups and subgroups							Overall a verage
	Ia	Ib	Ic	II	III	IV	V	
N (kg ha^{-1})	117	93	81	72	73	182	71	98
P (kg ha^{-1})	43	71	70	45	42	177	69	74
K (kg ha^{-1})	10	21	13	25	17	22	0	15
Foliar fertilizers applied (units)	1	1	1	1	2	0	2	1
Pesticides applied (units)	4	5	5	5	9	5	3	5

N= nitrogen; P= phosphorus; K= potassium.

Conclusions

The cultivation of 'Poblano' chili in Puebla is carried out in an agricultural system in transition, from traditional to conventional. The characteristics associated with the traditional system were its cultivation in less than one hectare, with family and contracted labor, with landrace seeds, and with an inappropriate fertilization and disease control plan, so they obtain low yields of dried fruit, whose production is mainly intended for family consumption and sale in local markets. The characteristics associated with the conventional technified system were the use of synthetic fertilizers and pesticides and gravity irrigation predominantly. The stratification of 'Poblano' chili farmers suggests the possibility of serving small groups of farmers at the regional level in a differentiated way.

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