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Full Length Research Paper

Small farmer practices for production improvement of the kidney-type tomato landrace: A case study in Oaxaca

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In order to describe the crop management of the kidney-type tomato landrace in four communities in Oaxaca, Mexico, and determine the productive potential of four accessions (seed lots) under three management systems, 25% of the tomato producers in the communities of Santa Cruz Xitla, La Soledad, Santa Ines del Monte and Santa Maria Vigallo were interviewed, and a factorial experiment on crop management practices was established under a randomized block design with three replications. Results of the interviews revealed that, the kidney-type tomato landrace is produced under a system that combines traditional technology, sowing or transplanting in 'cajetes' (a hole or pit in which to place the seed or seedling), and introduced technologies such as drip irrigation, use of Agribon row cover, plastic mulch and chemical control of pests and diseases. In the statistical analysis of the factorial experiment, significant differences ($P \leq 0.05$) were found among the accessions for all yield characteristics evaluated. The seed lot from Ejutla, Oaxaca generated the highest average fruit weight and equatorial and distal fruit diameter. The seed lots from Ejutla and Zimatlán interacted favorably with the traditional management and biospace systems in relation to higher expressions in fruit weight and distal and equatorial diameter.

Key words: Biospaces, local knowledge, native tomato, small farmers.

INTRODUCTION

Modern industrial agriculture is dependent on synthetic fertilizers and pesticides to obtain the highest productivity possible and involves high expenditures. As a counterpart, organic and low-input farming systems have emerged. Although these systems are still under debate, their aim is to maximize yields and benefit-cost ratios, reduce environmental pollution, provide a wise use of natural resources and reduce risks to human health (Clark et al., 1999). Alternative systems are based on traditional knowledge and practices, ecological principles, and are also the product of the integration of modern scientific and traditional knowledge (Altieri et al., 1991).

The adoption of technological innovations in agriculture is presented as an opportunity to increase production and income in less-developed rural communities. However, in these systems, several technologies are only partially successful or are not adopted because they involve factors such as credit access, information, risk aversion, inadequate or non-existent production incentives, land

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tenure, insufficient human capital, chaotic input supply and lack of infrastructure, among others. Even with all these difficulties, the small farmers depend on agriculture for their survival (Feder et al., 1985).

The lack of bridges of communication, outreach and dissemination of appropriate technologies for small farmers result in them partially or wholly copying the practices carried out by commercial farmers that normally involve high inputs or considerable infrastructure access (Altieri et al., 1991). An example of this are the public policies implemented in the State of Oaxaca, Mexico related to the financing granted for the construction of greenhouses for tomato production (OEIDRUS, 2007), under which farmers stop being producers of staple crops and become tomato producers with a consequent lack of training and high production costs. In Mexico, given its socio-cultural richness, only a few projects have been aimed at melding traditional and scientific knowledge or technology to help design alternatives for the technical management of agricultural production problems and reduce costs.

Despite their reduced capacity to invest in production technologies, traditional farmers are gradually increasing the number of technological adoptions and adaptations to their production systems (Orozco-Cirilo et al., 2008). However, the technological innovations applied to their traditional farming systems are scant. The innovations are a combination of technologies and technical components that help to streamline the production process; however, most innovations are targeted at mono-cropping, with its use of a large amount of inputs, machinery or equipment, without taking into account the production systems into which they are or will be adopted (Röling, 2004). Although the decision to adopt an innovation is individual and autonomous, it is always influenced by the diffusion of the technologies and innovations (Rogers, 2003; Siles-Gonzales, 2004).

In Oaxaca, Mexico, 775 ha are sown with tomato (*Solanum lycopersicum* L.) and of this sown area, 40 to 50% is planted on the field by small farmers (SIAP, 2010). Although there are no state statistics on the use of native and commercial varieties, there is documentary evidence that the kidney-type tomato (flattened-round fruits with shoulders) is grown in the Center and South of the State (Carrillo-Rodriguez et al., 2009), in a very similar manner that reported in Granada and Aragon, Spain (Berenguer, 2005; Carravedo-Fontana, 2006).

In Oaxaca and other states of Mexico, small farmers adapt production technologies and practices that help them increase their economic benefits in the management of native genetic resources they possess. The native tomato has high genotypic diversity in Oaxaca (Carrillo-Rodriguez et al., 2009) and has high regional demand (Ramos-Pastor et al., 2009). The aim of this work was to describe the management of the kidney-type tomato landrace in four communities in the State of Oaxaca and evaluate the productive potential of the traditional management system under experimental conditions.

MATERIALS AND METHODS

Study area

The descriptive work of the tomato cultivation system was conducted in the communities of Santa Cruz Xitla (municipal seat); La Soledad and Santa Ines del Monte, municipality of Santa Ines del Monte; and Santa Maria Vigallo, Zimatlan Alvarez. All of the communities are located in the Central Valleys region of Oaxaca. The sites are 16° 19' to 16º 56' NL and 96º 40' to 96º 48' WL, between 1500 and 2400 m.a.s.l. (INEGI, 2010). In the first phase of the study, information was collected from farmers and their families through interviews with an ethnographic approach. The questions were designed to describe the activities undertaken by farmers in the cultivation of native kidney-type tomato (landrace), a flattened-shape fruit with shoulders. In each community, the interview was conducted to a random sample of 20 tomato producers (25% of the total). The semi-structured questionnaire designed to support the interview contained general and specific socio-demographic questions to describe technological characteristics or components and farming practices, including: land preparation, transplanting or direct sowing, soil preparation, management of biotic and abiotic factors, origin of seed used, estimated average yield and production destination. Additionally, a general description was made, based on the technique of participant observation in relation to crop management.

Experimental evaluation of traditional management

From the farmers surveyed, a random sample of kidney-type tomato seed by community was obtained and labeled by origin. Each sample was sown and then transplanted under a factorial design (4×3) with distribution in randomized complete blocks with three replications. The factor A was made up of four origin seed lots (accessions) and factor B by three management systems: (a) The traditional farmer method under an open sky and without pruning; (b) Pruning to two stems; and (c) Pruning to four stems, with the latter two in biospaces with anti-aphid netting. In each experimental plot, the following characteristics were evaluated: Yield per plant, average fruit weight, fruit number per plant, and polar and equatorial diameter of the fruit.

Statistical analysis

For the first phase, a descriptive analysis based on the responses of the farmers interviewed was made. The data from the experimental phase were subjected to an analysis of variance by means of the lineal model of randomized complete blocks with three replications for each variable evaluated. When there was a difference between factors and in the interaction, a comparison of means was carried out using the Tukey method ($P \leq 0.05$). All statistical analyses were performed using the SAS program (1999).

RESULTS AND DISCUSSION

Farmers interviewed in Santa Cruz Xitla, La Soledad, Santa Ines del Monte and Santa Maria Vigallo, Oaxaca had a broad age range, with 55% being from 35 to 55 years old, 27% aged 55 years and above, and 18% from 15 to 35 years old. This indicates a proportional pyramid among age ranges, combining experience and youth. Farmers commented that they hope the four-decade-old tradition of planting native tomatoes will not be lost, although there is little interest among young people to continue planting tomato landraces and some who have greenhouses have already begun planting commercial or improved tomato varieties.

The study communities form part of the Zapotec indigenous group in the Central Valleys of Oaxaca. Among the families, it was estimated that 73% of the farmers interviewed had at least one child working in the United States. This fact is reflected, to some extent, in the ability of the families to confront risks in the production of tomato landraces, since in cases of partial or total loss, they would have the financial backing of their children who would send them remittances as has been documented in other regions of Oaxaca (Reyes-Morales and Gijon-Cruz, 2007).

Traditional crop management

In the four communities studied, all family members, both men and women, provide the labor necessary to carry out the agricultural practices required by the tomato crop (73%), and only on certain occasions (9%) are the practices undertaken exclusively by the male children. Due to the highly labor-intensive nature of the crop, people are sometimes hired (18% of the time), primarily for harvesting, weeding or pruning of the crop.

The three communities use traditional methods for obtaining seed. Although there are slight variations among them, the core method can be summarized as follows: "The finest tomatoes are chosen and crushed and squeezed by hand; the seeds and pulp are placed in a 'sieve' (homemade screen) where they are sometimes rinsed with water. The seed and pulp waste are then deposited on paper to dry. Once dry and prior to sowing, they are broken down to separate the seed". As for the movement of seed between and within communities, it was determined that 27% of producers have their own seed, 45% 'borrow' seed from a relative and later return the same amount, and 28% get the seed in other communities, in the regional market of Miahuatlan de Porfirio Diaz or in the city of Oaxaca. This local seed supply system is a peasant strategy that promotes conservation of local genetic material (landraces or native varieties) in place of diversification, eliminates the costs that would otherwise be borne by buying seed from distribution companies, and increases the adaptability of landraces to specific agro-ecological micro-niches, as has been documented for maize in Oaxaca (Badstue et al., 2006).

When the producers were asked about the future prospects for growing tomatoes in their community, 45% said that it was going to disappear, 27% said that it would first decrease in scale, but disappear in the long term, 18% did not know what would happen, and a low proportion (9.2%) argued that it would not disappear but that there should be a program to encourage or support the production of kidney-type tomato. Altieri (2002) noted that these traditional production systems are fragile because they depend on local markets and external inputs; as a result, he proposes ecological management of resources and production processes to avoid external dependencies and promote the rate of return for the producer, a strategy that appears to correspond to the tomato management system described herein.

Combining modern and traditional technologies

Ground preparation is carried out with a tractor (plowing, harrowing and furrowing), with a yoke of oxen (three plowing and furrowing passes) and sometimes the two together. Later 'cajetes' (a hollow or hole in the ground for planting) are made in the furrow and bovine or goat manure is placed in them. In this work, modern technology refers to all crop management practices not generated in the study communities. Afterwards, the 'cajete' is watered and the seed deposited in it; alternatively, two to three seedlings produced at home are transplanted into the 'cajete'. This traditional sowing system in 'cajetes' is still common for corn (*Zea mays* L.) in the Mixteca Oaxaqueña region (Volke-Holler et al., 1998). Among communities, some variation or combination of traditional and modern tomato cultivation systems was shown (Table 1, with the most frequent values). For example, transplanting is used in all four communities, while direct sowing in the 'cajete' and flood irrigation is also used in the communities of La Soledad and Santa Cruz Xitla. In recent years, drip irrigation has been introduced in Santa Ines del Monte and Santa Maria del Monte Vigallo, and plastic mulch in the first. Agribon® row cover use is only reported in Santa Cruz Xitla. All this indicates a combination of traditional management and a low number of modern technologies, from two to four, and underscores the use of labor to perform certain common agricultural practices such as hoeing and weeding.

The low use of modern technologies in tomato landraces cultivation, as recorded in the four communities studied, reflects, in part, the fact that in the state of Oaxaca no technology transfers are being made by regional and national agricultural research institutions, including, for example, the technologies developed in the experimental station in Etla, Oaxaca, operated by the Instituto Nacional de Investigaciones Forestales, Agricolas y Pecuarias (National Research Institute of Forestry, Agriculture and Livestock, known by the acronym INIFAP in Mexico). Although there may be little or no dissemination of these technologies, this situation

Table 1. General characteristics of the main agricultural practices for the tomato landraces cultivation in four communities of Oaxaca, Mexico.

Agricultural practice	Santa Ines del Monte	La Soledad	Santa Maria Vigallo	Santa Cruz Xitla
Plowing	With yoke	With yoke	Yoke	Yoke
Harrowing	With yoke	With yoke	No	Tractor[1]
Furrowing	Seedbed	With yoke	Seedbed	Yoke
Seed origin	Own	Own	Own	Own
Sowing	Transplant	Transplant and direct	Transplant	Transplant and direct
Irrigation system	Drip irrigation[1]	Flood irrigation	Drip irrigation[1]	Flood and by cajetes
Plastic mulch use	Yes[1]	No	No	No
Agribon[2] row cover use	No	No	No	Yes[1]
Number of hoeings	None	Two	Two	One
Fertilization	Organic and chemical[1]	Organic and chemical[1]	Fertigation[1]	Organic and chemical[1]
Training (management)	Horizontal	Horizontal	Vertical	Horizontal
Weeding	Once	Yes	Three times	Twice
Chemical pest control	Yes[1]	Yes[1]	Yes[1]	Yes[1]
Number of modern technologies introduced	Four	Two	Three	Four

[1]Modern technologies introduced or adapted by small farmers.

Table 2. Statistical significance of the mean square at analysis of variance for five agronomic variables studied.

Sources of variation	DF[1]	Yield (kg plant^{-1})	Fruit weight	Fruits per plant	Equatorial diameter	Polar diameter
Origin of the seed (S)[2]	3	3.895*	4132.22**	2167.58*	3.881**	2.185**
Management systems (M)	2	2.157^{NS}	633.24^{NS}	958.02*	2.485**	0.078^{NS}
S×M interaction	6	1.862^{NS}	1229.75*	835.36*	1.245*	0.607*
Mean		3.636	62.06	65.86	5.42	3.54
CV (%)		29.42	26.65	23.43	7.97	10.39

[1]DF, degree free; [2]seed lots of kidney-type tomato of Ejutla, Zimatlan, Miahuatlan and San Antonino, Oaxaca; ^{NS}non-significant at $P > 0.05$; *significant at $P < 0.05$; **significant at $P < 0.01$; CV, coefficient of variation.

may also be because few technologies and innovations have been generated for small farmers who grow their crops in agroecosystems with limited fertility and water, and shallow soils. However, the adoption of technologies or innovations depends on the dissemination of information (Rogers, 2003; Siles-Gonzales, 2004). In these case studies, it was observed that agrochemical and fertilization system company representatives are the ones who have put on demonstrations in communities, and their products have been the main components added to the production system.

The markets in Miahuatlan de Porfirio Díaz and the wholesale food market in the city of Oaxaca are the main destinations for the tomatoes produced in the four communities. At certain times of the year, the kidney-type tomato sells for a higher price (about 15% more) than the saladette tomato in the city of Oaxaca. In these markets, it is common to see reed (*Phragmites australis*) baskets of between 15 and 20 kg. This slight price markup seems to encourage tomato landraces cultivation, but more specific marketing studies are required to determine the future outlook of the crop in the region and whether this factor can help in the conservation of this local genetic resource.

Experimental response of the traditional management system

In the experimental evaluation were detected significant differences between the origin of each seed lot for yield per plant, average fruit weight, fruits per plant, and equatorial and polar diameter of the fruits by analysis of variance. For the management factor (traditional vs modern), significant difference was only detected for fruits per plant and fruit equatorial diameter. In the case of the interaction (S×M), only yield showed no significant differences (Table 2). All this indicates that both seed lots origin and management without pruning, to two or four stems influence the quality of size fruit at harvest.

In comparing the agronomic behavior averages between collections or seed lots, it was noted that the one from Miahuatlan presented the lowest values in fruit

Table 3. Mean values of five morphological variables of kidney-type tomato seeds from four communities.

Origin of seed lots	Yield (kg plant^{-1})	Fruit weight (g)	Fruits per plant	Equatorial diameter (cm)	Polar diameter (cm)
Ejutla	3.712a^{b1}	91.61^{a}	44.7^{b}	6.28^{a}	4.19^{a}
Zimatlan	4.536^{a}	63.15^{b}	71.7^{a}	5.55^{b}	3.63^{b}
Miahuatlán	3.204^{ab}	42.63^{c}	81.4^{a}	4.74^{c}	3.13^{c}
San Antonino	3.092^{b}	50.85b^{c}	65.4^{a}	5.13^{bc}	3.19^{bc}

[1]Means with the same letter are not significantly different (Tukey, P ≤ 0.05).

Table 4. Average response to management systems based on five agronomic variables.

Crop management system	Yield (kg plant^{-1})	Fruit weight (g)	Fruits/ plant	Equatorial diameter (cm)	Polar diameter (cm)
Traditional management	4.072^{a1}	69.4^{a}	58.8^{b}	5.9^{a}	3.6^{a}
Biospace and 4 stems[2]	3.610^{a}	54.9^{a}	75.9^{a}	5.1^{b}	3.5^{a}
Biospace and 2 stems[2]	3.226^{a}	61.8^{a}	62.8^{ab}	5.2^{b}	3.5^{a}

[1]Means with the same letter are not significantly different (Tukey, P ≤ 0.05); [2]Modern management.

yield, weight and diameter, while the Ejutla seed was the most outstanding as it had the greatest diameter (6.3 to 4.2 cm) and average fruit weight (91.6 g) (Table 3). This diameter obtained was similar to the tomato variety Paulo, with an equatorial diameter greater than 6 cm and average fruit weight of 97 g obtained in a field production system with a planting density of 1.1 plants m^{-2}, up to 66% higher than other planting densities (Villegas-Cota et al., 2004).

The results show that variants of kidney-type tomatoes produced regionally are adapted to the farmer's management conditions. This evidence contributes relevant elements and supports the observations of Moreno-Ramirez and Ramirez-Vallejo (2009), who reported that Oaxaca tomatoes come in a wide variety of shapes and sizes compared to those of Yucatan, Campeche and Guerrero; for example, they estimated a potential yield of 2.71 kg plant^{-1} and high healthiness in the collection OX-1. In another study of organic fertilizer in the production of kidney-type tomatoes, average yield was 1.39 kg plant^{-1} (Ramos-Pastor et al., 2009). Comparing the yields per plant obtained in this work for the collections evaluated with those reported by the aforementioned studies, a greater potential in the collections for variation was identified, ranging from 3.09 to 4.5 kg per plant with the highest value in the collection from Zimatlan.

In the comparison of traditional tomato crop management without pruning versus biospace management with pruning to two and four stems (modern), no statistically significant differences (P> 0.05) were detected for yield per plant, average fruit weight and polar diameter, and traditional management was even superior in polar diameter. In general, the traditional management system presented the lower quantity of fruits, but they were bigger (Table 4).

There was a statistically significant interaction between origin of seed lots and management systems. In this sense, the seed from Ejutla consistently presented the highest values for average fruit weight and equatorial and polar diameter in the three management systems. Next in order of importance was the genetic material from Zimatlan (Table 5). The results indicate a high genetic potential in the local genepools, independent of the management system used, and it is, moreover, important to mention that there are no registered improved varieties of kidney-type tomato fruits (flattened-round with shoulders), meaning they are only produced in these traditional regional cultivation systems. Traditional production systems are very close to the principles of organic farming in that they feature low-input use and seeds produced by the farmers themselves. In this sense, Garcia-Lopez et al. (2004) postulate that local or regional markets can encourage semi-commercial and agro-ecological production of native tomato varieties.

The farmers surveyed stated that the sale of kidney-type tomatoes is one of their main sources of income and that in times of higher demand in the Miahuatlan regional market or in the wholesale food market in Oaxaca City, they receive a higher price than that paid for the saladette tomato. This micro-niche market is important to preserve the genetic pool of this tomato landrace. In addition, the results presented in Table 5 show that: (a) The kidney-type tomato has been adapted to traditional management since statistically it obtains a similar yield per plant; (b) It also presented a favorable response to the implementation of technological improvements in crop management (e.g. biospaces and pruning); and (c) There were differences among the seed collections or sources with the management practices, with the Ejutla collection tending to produce less fruit per plant, but of greater size and weight. Although there is some prospect of improving

Table 5. Average response to the interaction between management system and seed origin in five agronomic variables.

Management system	Origin of seed lot	Yield (kg plant^{-1})	Fruit weight	Fruits/ plant	Equatorial diameter	Polar diameter
Traditional management system without cover	Antonino	2.671^{a1}	45.9^{b}	57.7^{b}	4.8^{b}	3.1^{b}
	Miahuatlan	2.583^{a}	29.1^{b}	89.7^{a}	4.1^{b}	2.7^{b}
	Zimatlan	3.273^{a}	56.5^{b}	58.3^{b}	5.2^{ab}	3.6^{ab}
	Ejutla	4.375^{a}	115.7^{a}	45.7^{b}	6.8^{ab}	4.6^{a}
Biospace and 2 stems[2]	Antonino	3.094^{a}	68.5^{ab}	47.0^{b}	6.0^{a}	3.4^{b}
	Miahuatlan	4.207^{a}	68.5^{ab}	61.3^{ab}	5.9^{a}	3.6^{ab}
	Zimatlán	5.299^{a}	74.0^{a}	71.7^{ab}	6.1^{a}	3.9^{ab}
	Ejutla	3.689^{a}	66.8^{ab}	55.3^{ab}	5.8^{a}	3.6^{ab}
Biospace and 4 stems[2]	Antonino	3.510^{a}	38.1^{b}	91.7^{a}	4.5^{b}	3.0^{b}
	Miahuatlan	2.821^{a}	30.3^{b}	93.3^{a}	4.2^{b}	3.1^{b}
	Zimatlan	5.035^{a}	59.0^{ab}	85.3^{a}	5.3^{ab}	3.5^{b}
	Ejutla	3.074^{a}	92.3^{a}	33.3^{b}	6.2^{a}	4.4^{a}

[1]Means with the same letter are not significantly different (Tukey, $P \leq 0.05$); [2]Modern management.

traditional practices, farmers were skeptical because they think the local production system is threatened and is bound to disappear, and with, the genetic resources found there. The crop supports food security and provides some income for the family, but it does not maximize it. This situation, with similar characteristics, was documented by Pulido and Bocco (2003) in another traditional production system in Michoacán, Mexico.

Conclusions

Despite the investment difficulties involved in improving and incorporating innovations into their production practices, small farmers in the communities of Santa Cruz Xitla, La Soledad, Santa Ines del Monte and Santa María Vigallo, Oaxaca, are still producing kidney-type tomatoes (flattened-round shape with shoulders) under a system that combines traditional technology (sowing or transplanting in 'cajetes') and introduced technologies such as drip irrigation, use of agribon, mulch and chemical control of pests and diseases. The seed lot from Ejutla, Oaxaca produced the highest average fruit weight and equatorial and distal diameter. There were no significant differences between traditional management without cover and the biospace system with pruning to two and four stems, in terms of yield per plant, fruit weight and polar diameter. The seed lots originating from Ejutla and Zimatlan, Oaxaca, interacted favorably with the traditional management and biospace systems in relation to higher expressions of weight and fruit distal and equatorial diameter. Moreover, a certain degree of adaptation of the kidney-type tomato gene pools under traditional management conditions and low use of technologies was found.

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