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Maintenance of squash (*Cucurbita* spp.) landrace diversity by farmers' activities in Mexico

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Abstract

Squash (*Cucurbita* spp.) is a common component in traditional cropping systems in Mexico, mainly in the agroecosystem known as the "milpa", in which squash is cultivated in association with maize (*Zea mays*), the main crop. Using a questionnaire, 80 farmers were interviewed about crop production and selection practices in order to understand how these factors affect genetic diversity of local squash populations. We found that the most of the farmers who cultivate squash were elderly 59.8 ± 14.5 (mean ± SD; $n = 78$) years old. Squash varieties in the area were exclusively locally adapted landraces, and had not been replaced by modern squash cultivars. Two cultivated squash species, *C. argyrosperma* ssp. *argyrosperma* and *C. moschata*, had been grown intercropped with maize by 97.5% of the interviewed farmers, but only 50.0% were still producing squash at the time of the study. Farmers recognize typical characteristics of particular varieties within each of the local cultivated squash species, and selection is directed to maintain their identity. Nearly two thirds of the farmers (62.0%) had exchanged seeds of squash for planting, a practice that serves to increase genetic variability in the populations. All of the interviewed farmers were conscious of the possible hybridization between the wild gourd (*C. argyrosperma* ssp. *sororia*) and their cultivated squash. Despite various natural and human managed factors identified as contributing to enhancement of genetic diversity in these populations, results of the study show that genetic erosion of *Cucurbita* is likely in the region in the near future.

Introduction

Squash (*Cucurbita* spp.) is one of the major crops domesticated in Americas and spread throughout the world (Whitaker and Bohn 1950; Cruces 1987; Harlan 1992; Merrick 1995). It is cultivated for production of fresh vegetables (e.g., vegetable marrow, zucchini types) and mature fruit (e.g., cushaw, pumpkin types). In Mexico, this crop plays an important role as an integral component of a traditional cropping system known as the "milpa", which consists of the association of maize–bean–squash or maize–squash (Lira 1995). Both immature and mature fruits and seeds of *Cucurbita* species provide inexpensive sources of proteins and vitamins for the diet of rural and urban families (Esquinas-Alcazar and Gulick 1983). In addition, flowers and tender vegetative parts are also consumed (Cruces 1987; Lira 1995).

In Mexico, four of the five domesticated species of *Cucurbita* are commonly cultivated: *C. argyrosperma* Huber ssp. *argyrosperma*, *C. moschata* Duch., *C. pepo* L. and *C. ficifolia* Bouché. The first three species stand out in the economy and diet of the Mexican population. Landraces are common in both in production for market and for home consumption (Lira 1995; Lira and Montes 1992). Due to differences in ecological adaptation, a general vertical stratification correlated with altitude occurs, with landraces of *C. argyrosperma* and *C. moschata* tending to be distributed at low to intermediate elevations, and those of *C. pepo* and *C. ficifolia* produced at intermediate to high elevation (Whitaker 1968; Lira 1995; Merrick 1995). More recently in the NW of Mexico, improved squash varieties of the fifth domesticated *Cucurbita* species, *C. maxima* Duch. ex Lam., have been introduced for production directed mainly towards export markets (Merrick 1995).

Phenotypic diversity within landrace populations of *Cucurbita* is high, and includes variation in shape, size and color of fruits; number and size of seeds; quality, color and thickness of the fruit flesh; tolerance to pests; and precocity in fruit production, among other traits (Whitaker and Davis 1962; Garzón et al. 1993; Lira 1995). In *Cucurbita* as well as in other crops for which farmers save seed, this variation is favored and maintained by deliberate selection for specific traits by farmers (Clawson 1985; Altieri and Merrick 1987). The same type of local selection regime has been noted for clonally propagated crops, whereby with potatoes, for example, Brush et al. (1981) mention that rural cultures in Peru classify and select their landraces according to a range of criteria, including agronomic, culinary, medicinal or ritual aspects. These criteria generate primarily two types of selection pressures: (1) selection to improve crop yield by choice of conspicuous traits, and (2) selection aimed at maintaining landraces and characteristics within those populations that are important to the farmer for reasons other than productivity itself (Louette and Smale 2000). Cultivation of these landraces perpetuates local knowledge about crops and crop production, and this knowledge has served as an important resource for breeders and agricultural scientists in the formal sector (Brush and Meng 1998).

Implementation of modern strategies to increase crop productivity (e.g. use of herbicides and replacement of local traditional crops by introduced crops or varieties) has caused reduction of genetic diversity of crops in areas with traditional agriculture (Altieri 1991; Oldfield and Alcorn 1987). Loss of genetic diversity may be more significant in those areas where the crop originated and was domesticated, because levels of genetic variation within landrace populations in those regions commonly are high (Brush 1991; Bellon and Taylor 1993). In such areas, both wild relatives of cultivated plants and landraces may be important sources of genetic diversity for crop gene pools and can be the basis for current or future crop improvement programs (Doebley 1990, 1992; Wilson 1990).

In western Mexico the ancestors of maize (*Zea mays* ssp. *parviglumis* Iltis & Doebley) and common beans (*Phaseolus vulgaris* L. ssp. *sylvestris*) have survived until the present, and they occur usually in small populations, grow in sympatry with the domesticated forms (Miranda 2000). In this same region two cultivated squash species, *C. argyrosperma* ssp. *argyrosperma* and *C. moschata*, and the wild type *C. argyrosperma* ssp. *sororia* (L.H. Bailey) Merrick and Bates grow in sympatry. There is experimental evidence of compatibility among these *Cucurbita* taxa (Merrick 1990), and they are closely related phylogenetically (Wilson et al. 1992). High levels of gene flow among the wild gourd and cultivated squash taxa have been detected in this region (Montes-Hernández and Eguiarte 2002). Since species of *Cucurbita* are monoecious, they require the visits of pollinators in order to set fruit (Hurd et al. 1971; Bautista-Anaya 1997; Canto-Aguilar and Parra-Tabla 2000). In Mexico, squash is pollinated mainly by *Cucurbita*-specialist bees of the genera *Peponapis* Robertson and *Xenoglossa* Smith, the honey bee, *Apis mellifera* L., or other generalist species of bees (Hurd et al. 1971; Canto-Aguilar and Parra-Tabla 2000).

In order to understand the practices carried out by farmers to maintain genetic diversity of cultivated squash, we conducted this study with two objectives: (1) evaluating the cultural practices relevant to maintaining genetic diversity, and (2) determining how farmers perceive and maintain distinct varieties despite the presence of gene flow. We test the hypothesis that the farmers' activities maintain the genetic diversity of cultivated squash.

Materials and methods

This study was conducted in three municipalities of the southwestern area of the state of Jalisco,

Table 1. Municipalities, localities, geographic coordinates and elevation (*m*) of sites in Jalisco, Mexico, and numbers of interviewees (*n*) where the survey was conducted.

Municipality	Locality	N/W	*m*	*n*
Autlán	El Chante	19° 43′ 09″/104° 12′ 24″	919	31
El Limón	San Miguel Hidalgo	19° 51′ 07″ /104° 04′ 54″	804	19
El Limón	San Juan de Amula	19° 49′ 59″ /104° 04′ 42″	797	10
Ejutla	Ejutla	19° 53′ 56″ /104° 09′ 27″	1140	13
Ejutla	Los Naranjos	19° 54′ 59″ /104° 07′ 36″	1102	7

Geographic names that will be used throughout the text are the municipalities – Autlán, El Limón, and Ejutla – rather than the village localities.

Table 2. Environmental and production aspects of the municipalities studied.

Attribute	Autlán	El Limón	Ejutla
Area of arable land (%)	61.5	73.4	20.6
Area under irrigation (%)	21.5	11.3	3.5
Annual mean temperature	23.5	24.8	22.8
Annual mean rain (mm)	997.5	887.3	878.7

Mexico (Table 1), during the summer of 2000. In two municipalities – El Limón and Ejutla – we studied two localities, and in the third one – Autlán – a single locality. The municipalities were selected based on differences in environmental characteristics, including arable area, crop production systems, water resources for agricultural production, topography, and crops planted in addition to maize (Martínez-Reding 1992; INEGI 2001) (Table 2). In the three municipalities, a detailed survey was conducted to characterize the farmers' activities and criteria for maintaining squash diversity. Through the use of a questionnaire during individual interviews, farmers were asked questions and responses recorded. Farmers were randomly selected for interviews in each municipality from a list of the Mexican government program called PROCAMPO (Programa de Apoyo al Campo), which is directed to support the rural economy. The unique prerequisite for inclusion of farmers in this study was that they had been engaged in maize production – rather than necessarily squash production – since PROCAMPO program provides assistance to maize producers. The total of interviews was 80 : 31 in Autlán, 29 in El Limón and 20 in Ejutla (Table 1). Before the formal survey, the questionnaire was tested with a sample of five randomly chosen farmers cultivating squash from El Chante in the municipality of Autlán. Questions were clustered into four themes: (1) seed selection practices for subsequent planting seasons, (2) seed exchange practices among farmers, (3) reasons why farmers have ceased squash production, and (4) farmers' beliefs regarding gene flow.

Results

Data obtained show that the vast majority (97.5%, or 78 out of the 80) of the maize growers interviewed have grown squash, and in every case squash was grown as an intercrop with maize. However, 100% of the squash producers considered it as secondary or tertiary in priority, after maize and other crops such as chili pepper (*Capsicum annuum* L.), tomato (*Solanum lycopersicum* L. (syn. *Lycopersicon esculentum* Miller)), watermelon (*Citrullus lanatus* L.), and certain forage grasses ("Jaragua", *Hyparrhenia rufa* (Nees) Stapf., Bermuda (*Cynodon dactylon* (L.) Pers., Guinea (*Panicum maximum* Jacq.), among others, in spite of the widespread use of squash seeds and immature or mature squash fruits for human consumption.

Landrace varieties of two species of *Cucurbita* – *C. argyrosperma* and *C. moschata* – rather than any improved, modern squash varieties were cultivated by farmers interviewed in the study (Table 3). Across the study sites, *C. argyrosperma* ssp. *argyrosperma* was grown by 57.5% of the farmers. The local names for this species are "rayada", "buchona", "patipona" or "puerquera". We did not find any correlation between the folk taxonomic names and selection for specific uses (data not shown). In contrast, *C. moschata* – whose local name is "calabaza de castilla" or "tamalayota" – was more popular than *C. argyrosperma*, and it is

Table 3. Percentage of farmers that had cultivated *Cucurbita* species in the municipalities studied.

Taxa	All farmers ($n = 80$)	Autlán ($n = 31$)	El Limón ($n = 29$)	Ejutla ($n = 20$)
Only *C. argyrosperma* ssp. *argyrosperma*	33.7	3.2	37.9	75.0
Only *C. moschata*	40.0	64.6	34.5	10.0
Both *Cucurbita* species	23.8	29.0	24.1	15.0
Never produced squash	2.5	3.2	3.5	0

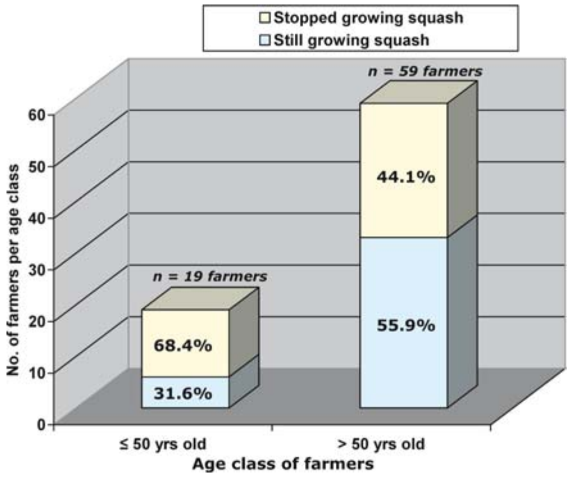

Figure 1. Farmer's age group relative to engagement in squash production.

sown by 63.8% of the farmers. Significant differences, however, were detected among municipalities in terms of species preferences (Table 3). In Autlán *C. moschata* was produced by 93.6% of the farmers, but *C. argyrosperma* only by 32.2%. In Ejutla an opposite pattern was observed, *C. argyrosperma* grown by 90.0% and *C. moschata* only by 25.0%. In El Limon, the two species were equally popular, both cultivated by 58.6–62.0% of the farmers. Differences in target commodity can explain patterns of species distribution. In general *C. argyrosperma* is the preferred species when the end-use is seed consumption; in contrast, *C. moschata* is favored when the end product is mature fruit flesh.

Differences were also observed in terms of whether or not individual farmers were growing one squash species or both, and these distribution patterns appeared to be correlated to some extent with differences in topography and irrigation. Ejutla is characterized by steep slopes, and no irrigation (Table 2). In that municipality seed is the major market-oriented commodity for squash and therefore *C. argyrosperma* is the dominant species. That species was more commonly grown without *C. moschata* (75.0% of the farmers) than with it (15.0%). Only 10.0% of the farmers in Ejutla were growing *C. moschata* without *C. argyrosperma* (Table 3). On the other hand, in Autlán there exists large areas of flat, arable terrain – a fifth of which is irrigated (Table 2) – that facilitate the commercial production of high-quality mature squash fruits that are sold in regional and local markets. Mature fruit is the most valued squash commodity in Autlán, and *C. moschata* is the dominant squash species. In Autlán, more than twice (64.6%) of the number of squash producers reported that they grew *C. moschata* without *C. argyrosperma* as those growing both squash species (29.0%); a single farmer in Autlán was growing only *C. argyrosperma* (Table 3). The production pattern in El Limón – where land is arable and flat, but less commonly irrigated than in Autlán – was different, with some preference exhibited for production of just one species of squash (37.9% of the farmers grew *C. argyrosperma* alone; 34.5% grew *C. moschata* alone) instead of two (24.1% grew both species), but there was no strong preference for one species over the other in that municipality (Table 3).

Only two maize producers had never planted squash (Table 3). However, 50.0% of the interviewed farmers had discontinued cultivation of squash prior to the time of the study (Figure 1). Out of those who had cultivated squash in the past but were no longer growing it, nearly two thirds (64.1%) had stopped producing squash more than 3 years ago, and one third (35.9%) had stopped in the last 1 or 2 years (Figure 2). The age of farmers interviewed ranged from 28 to 86 years old, and averaged 59.8 ± 14.5 (mean ± SD; $n = 78$) years old. For purposes of analysis, we divided the farmers into two age classes – the "younger" age = 38.4 ± 6.6 (mean ± SD; $n = 19$) years were defined as those 50 years old or younger, and the "older" age = 66.3 ± 8.9 (mean ± SD; $n = 59$) years defined as those over 50 years old. Younger farmers who had grown squash were much more likely to have abandoned squash production than older farmers. One third (31.6%) of the younger farmers were still

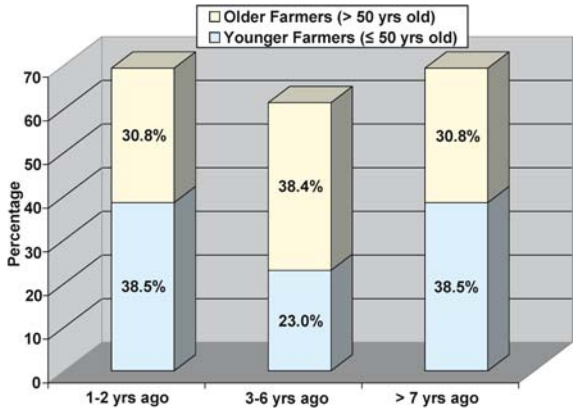

Figure 2. Time period when squash production was discontinued relative to age of farmer.

Table 4. Relation between percentage of farmers still involved in squash production and farmer's age.

Age class of farmers	All farmers ($n = 78$)	Autlán ($n = 30$)	El Limón ($n = 28$)	Ejutla ($n = 20$)
≤50 years old	7.7	10.0	3.6	10.0
>50 years old	42.3	43.3	35.7	50.0

Table 5. Reasons why farmers have stopped growing squash (number of individuals).

	Autlán ($n = 14$)	El Limón ($n = 17$)	Ejutla ($n = 8$)
Shift to herbicide use for maize production	3	3	4
Low price of squash commodities	2	4	1
Squash in milpa system increases costs production	1	3	1
Shift to mechanized maize production	1	2	1
Shift to non-milpa (e.g. non-maize based) system of crop production	4	3	0
Low prices of maize	3	2	1

involved in squash production. In contrast, 55.9% of the older farmers were still producing squash (Figure 1). There were some differences in these patterns among municipalities. A slight majority (53.3–60.0%) of farmers of all ages in both Autlán and Ejutla were still engaged in squash production at the time of the study, whereas in El Limón it was less prevalent (39.3%) (Table 4). When this practice was related to the farmers age, similar patterns were found among regions. In Ejutla and Autlán, older farmers were four times more likely to be growing squash than younger ones, and most older farmers were still doing so. In El Limón, few of the younger farmers were still growing squash, whereas almost one third of the older farmers were doing so (Table 4).

The most common reason given for discontinuation of squash production was use of herbicides against weeds associated with maize, an incompatible practice with production of squash, which tends to be susceptible to maize-specific herbicides (Table 5). Some farmers stated that labor costs tend to be higher when squash is produced in association with maize because of the presence of the squash vines which limit the use of mechanical cultivation; manual cultivation was perceived as more costly. Farmers who were not growing squash said that the growth habit of squash vines causes the maize plants to lodge and, consequently, it would be necessary to continually remove squash vines from maize stalks, thus increasing costs. Another common reason for discontinuing squash production was that low prices of squash seeds and fruits discourage its production (Table 5).

In some cases farmers had left squash production to concentrate only on maize production. In contrast, other farmers stopped milpa-based production entirely, that is cultivation of maize and all milpa-associated crops – including squash (Table 6). Low prices and low maize productivity and the high cost of inputs such as herbicides, labor, and fertilizers (Table 5) are the main reasons which explain the situation in the studied region. The number of farmers who stopped planting both maize and squash was higher in El Limón (60.8%) than in the other two municipalities (40.0–46.6%) (Table 6). Almost one third of the farmers in El Limón produce maize in monoculture, and 10% of them grow a variety of maize selected for ear husks used to prepare "tamales", which garners a high price. Additionally, one third of farmers in that municipality were sowing high value crops, such as muskmelon (*Cucumis melo* L.), chili pepper, or tomato. In Autlán half of the farmers had shifted from the traditional milpa cropping system to commercial production of sugar cane (*Saccharum officinarum* L.) or mescal (*Agave angustifolia* Haw.). In contrast, in Ejutla only one

Table 6. Percentage of farmers that had stopped planting squash and, among those growers, the percentage that still cultivate maize.

	Autlán ($n = 30$)		El Limón ($n = 28$)		Ejutla ($n = 20$)	
	Had stopped growing squash	Continued maize	Had stopped growing squash	Continued maize	Had stopped growing squash	Continued maize
Farmers	46.6	50.0	60.8	64.7	40.0	87.5

Table 7. Percentage of farmers that select different number of fruits for planting.

	Autlán ($n = 30$)	El Limón ($n = 28$)	Ejutla ($n = 20$)
Mixed from many fruits	6.6	10.7	20.0
2–5 fruits	10.0	17.8	55.0
6–10 fruits	33.3	28.6	10.0
11–15 fruits	16.7	14.3	5.0
16–20 fruits	16.7	14.3	10.0
>21 fruits	16.7	14.3	0

Table 8. Frequency of the traits (%) used by farmers to select fruits and seed for sowing.

Trait	CAA as fruit	CMO as fruit	Seeds (both species)
Size	30.8	61.7	68.8
Shape	8.3	10.2	
Weight	11.7	36.7	59.2
Skin color	11.2	63.4	
Health	70.6	77.8	52.6
Skin hard texture		67.3	
Skin soft texture		76.8	
Pulp thickness		66.9	
Maturation stage	73.1	77.7	
Pulp		75.6	
Uniformity			74.8
Full size			73.7
Plump embryos			78.2

CAA – *C. argyrosperma* ssp. *argyrosperma*, CMO – *C. moschata*.

farmer had ceased growing the milpa and started planting grass for fodder.

The fruits selected for planting by each farmer varied from 2 to 30 or more, with an average of 8.9 (Table 7). This variation can be explained in part by the area destined for milpa production per household, which varied from one to seven hectares. The quantity of seeds used to plant *Cucurbita* is on average 0.5 kg/ha. The area for milpa production and number of fruits selected are not necessarily correlated (data not shown), since some farmers use a low number of seeds because their milpa plot is small (1 to 2 ha), but they select a small number of seeds from different squash fruits, rather than selecting many seeds from one or a few fruits. Only nine farmers (11.4%) did not use fruits as the units of selection; instead, these farmers take a portion of the bulked seed that would otherwise be used for consumption or sale (Table 7).

Seed selection is based exclusively on fruits previously selected. Farmers do not select seeds from plants in the field during the cropping season, but instead choose the best fruits post-harvest. Before consumption of mature fruits, as either food or fodder, farmers select seeds from the best phenotypes according to criteria concerned with quantity and quality of the product. First they consider the typical characters of each species. Seventy five percent of farmers mentioned the following suite of traits for planting purposes: fruit size, shape, weight and health (Table 8). These criteria vary on a species-specific basis since both species are selected for different purposes, *C. argyrosperma* is used mostly for seed consumption, and *C. moschata* is used for fruit flesh consumption. Most of the farmers (77.9%) considered large size, full, plump embryos, and uniformity as primary seed traits (Table 8). Almost all the farmers interviewed (97.5%) select both fruits and seeds by themselves, rather than by involving other members of their households.

The amount of seed that farmers use for planting squash per hectare was dependent in part on the distribution of squash plants within the maize plots (Table 9). When squash seeds are mixed with maize seeds, and both crops are sown at the same time, squash seed distribution is at random within the maize rows, but with higher quantity (≈50%) of squash seeds per hectare on average. In contrast, the quantity of squash seeds was lower when squash was sown separately between a subset of the maize furrows. Under the latter planting

Table 9. Percentage of farmers using different methods for squash planting.

	Autlán ($n = 30$)	El Limón ($n = 28$)	Ejutla ($n = 20$)
Sown in mixture with maize seed	43.3	64.3	90.0
Sown in mixture in rows	53.3	35.7	10.0
Sown alone in strips	3.3	0	0

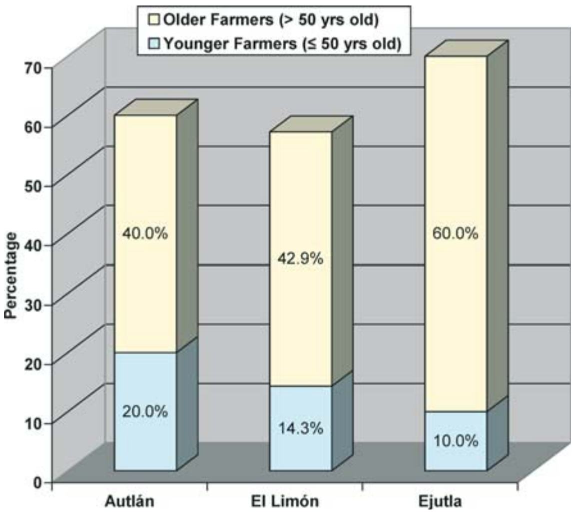

Figure 3. Farmers that have exchanged squash seeds for planting.

design, squash seeds are typically sown between rows (generally from 5 to 10) of maize, 8 or 10 days after maize sowing, when maize seedlings are present. Overall, nearly two thirds of the farmers (62.8%) mixed squash seeds with maize seeds before sowing (Table 9). However, this practice was observed to be especially common in Ejutla, where 90.0% of farmers engage in it. In contrast, about one third to about half of farmers in Autlán and El Limón preferred to intersperse squash plants in only a subset of maize rows (Table 9). These differences in planting practices could be correlated with differences in topography. Most of the interviewees in Ejutla cultivated hillsides (Table 2), using the traditional method of slash and burn, in a cropping system called "huamil", "coamil" or "cuamil". Under this system planting is generally manual, with aid of a "coa", which is an iron rod attached to a piece of wood, used to open a hole in the ground where seeds of maize and squash are deposited. On other hand, in Autlán and El

Table 10. Percentage of farmers that have exchanged squash seeds.

	Autlán ($n = 18$)	El Limón ($n = 16$)	Ejutla ($n = 14$)
Each year	22.2	18.7	14.3
From 2 to 3 years	16.7	12.6	14.3
Occasionally	61.1	68.7	71.4

Limón most of cultivated terrain is flat (Table 2), and farmers often use tractors for planting maize and then subsequently sow manually a subset of their maize furrows with squash seeds.

In relation to the exchange of seed stock among households, about one third (35.9%) of the farmers said that they have never exchanged seeds for sowing, whereas about half that number (14.1%) of farmers stated that it is a necessity that seeds be exchanged. The reason provided to explain why seed exchange is perceived as necessary was that if the same seed source population is used over time, yields would decline. We did not observe differences among communities in these beliefs. Differences were observed between both age classes of squash producers, whereby the "older" farmers exchanged more squash seeds for planting, and this pattern appeared to be part of the culture of squash production (Figure 3). Time interval for seed exchange was variable: 18.0% of the total number of farmers that exchanged seeds performed this practice every year, while 66.0% exchange seeds only occasionally (Table 10). Among those farmers who have exchanged seed stock of squash sporadically, the reason for the exchange was reported as principally due to two reasons: (1) to replenish seed supplies when the previous harvest netted low seed yield (19.8% of the farmers that have exchanged seed), and (2) to obtain sources of novel germplasm (39.7%). Out of the total number of farmers interviewed, 17.9% sowed seeds from a source that differed from their own seed stock during their last planting cycle involving squash production. Most of the seeds are exchanged among neighbors of the same town (86.4%), and the rest among other family members within the same village (12.3%). For each species, the squash types that were recognized as present in those communities have always been the same ones, since none of the interviewees reported loss of a particular variety, nor did any of them report introduction of especially novel squash germplasm.

In relation to farmers' perceptions of the potential genetic interchange between *C. argyrosperma* and *C. moschata*, 42.3% of the farmers believed that the two species are not able to hybridize spontaneously mainly because flowering phenology of the two species differs, with *C. argyrosperma* ssp. *argyrosperma* characteristically initiating its flowering earlier than *C. moschata*. Nevertheless, 18.0% of the farmers believe that is possible that this phenomenon occurs, because they indicated that there exists a period when staminate and pistillate flowers of both species occur simultaneously ("*hechan flores al mismo tiempo*"), and the same bee species visit both types of flowers ("*los mismos mayatitos las visitan*"). In addition, 18.0% of farmers noted another factor that would enhance opportunity for interspecific hybridization. They stated that variation in the planting date for squash occurs among farmers, and this variation makes possible the coincidence in flowering phenology of the two species. Some fruits show morphological characters intermediate between species or with characteristics of the other species and there was a perception by certain farmers that these fruits could be the product of interspecific hybridization. Nevertheless, those farmers report that "intermediate" type fruits are not desirable for selection of seed stock for subsequent planting.

All of the farmers were aware of the presence of the wild or weedy squash *C. argyrosperma* ssp. *sororia* in the region. Half of them (50.0%) have experimented with the use of its fruit and seeds as medicine, and its seeds for food (Merrick 1990). El Limón and Ejutla were the villages with greater involvement (55.0–60.7%) in the use of these wild gourds. Almost all of the farmers (93.6%) pointed out that is possible for *C. argyrosperma* ssp. *sororia* to cross with the cultivated squash in the field. All of the interviewed farmers answered that the bitter flavor of some immature squash fruits – which they indicated occurred occasionally – is evidence of possible "mixture" among both cultivated and wild types. Bitter flavor is a characteristic of the wild types. All farmers interviewed reported that their wives taste the immature squash before using them in food preparation. The farmers indicated that past experience has shown that only one bitter squash would render food inedible. This behavioral practice of testing squash fruits is carried out with less frequency for mature fruits. The explanation is that typically only one or two mature fruits would be used for cooking at any one time, and the probability of finding a bitter type is low, as opposed to the great number of immature fruit used for cooking. For controlling this weedy plant in the field it was reported that as soon as they recognize a wild plant within their squash plots they would remove it; also, farmers would eliminate such plants close to the milpas (mainly by cutting branches). But they recognize that is difficult to eliminate all weedy plants in and around the milpa, because field maintenance practices are infrequent.

Discussion

Most of farmers interviewed were elderly. This skewed age distribution implies a risk concerning the continuity of the traditional knowledge (Pulido and Bocco 2003). For all the families included in the survey, relatively few members remain in the villages and hence there are few people still involved in the agricultural activities. In the study area in the state of Jalisco in western Mexico, most young people migrate to the United States, or larger cities within Mexico (Velásquez and Papail 1997). We are deeply concerned about the high risk of loss of the traditional knowledge about cultivation practice associated with squash landraces, because younger males are not working anymore in agricultural activities locally, as was previously described in the region of this study (Benz et al. 2000).

In spite of the contribution of squash to local diets – and more generally, in Mexican popular culture – these plants occupy a relatively low place in the economy of the households. Squash was reported to occupy the third or fourth place on average among agricultural commodities, after maize and other crops or cattle-raising, and for the majority of farmers interviewed it is not a local cash crop. Several reasons are important in explaining why people in these communities discontinue growing squash, including herbicide use, abandonment of the maize-based milpa cropping system accompanied by a shift from maize to other crops, mechanization of farming, among other causes. But the most important reason is the low price of maize, and an uncertain market for squash seeds and fruits. However, some farmers still continue producing local squash because of cultural preference ("*las calabazas se comen desde tiernitas, hasta las semillas y nos dan algunos centavos"*, *which translates as* "*squash are eaten from time they are immature until the time they form seeds, and therefore it is as though they give us 'money in the bank*'"). The milpa system is an important element of the culture of SW region of Jalisco's traditional producers. With respect to this cultural significance Brush and Meng (1998) said that cultivation of landraces perpetuates local knowledge about crops and crop production, for that reason there exists an urgent requirement to conserve *Cucurbita* genetic resources in this region.

One type of genetic resource conservation is *ex situ* – maintenance of crop genetic resources in gene banks, botanical gardens, and agricultural research stations (Plucknett et al. 1987). Another type is *in situ* – maintenance of genetic resources on-farm or in natural habitats (Brush 1991; Maxted et al. 1997). There are two distinct but associated activities that are currently both referred to as on-farm conservation. The difference between the two activities is based on whether the focus is the conservation of genetic diversity within a particular farming system or the conservation of the traditional farming system itself (Brush 1991, 2000; Maxted et al. 1997, 2002). To establish an on–farm project, long-term sustainability must be considered in the planning, establishment and ongoing management, where security of greater diversity results from the complementary application of *ex situ* and *in situ* techniques (Maxted et al. 2002).

Regarding the relatively low number of squash fruits that farmers select for sowing, and the relatively low amount of seeds that are sown per hectare, in spite of squash is outcrossing, the resultant population sizes of squash tend to be smaller than before. Local cultural practice for squash means that farmers select relatively low numbers of fruit for sowing, and sow relatively low numbers of seed per hectare. Thus, despite the existence of outcrossing, low population size over time could represent a bottleneck, which could result in a serious loss in heterozygosity (Hedrick 2000), and, therefore, a loss of the variability in *Cucurbita*. But certain other cultural practices, specifically the practice of exchanging seeds, and the different methods for squash planting that may promote crossing among plots, probably decreases this potential problem. It is important that farmers select a part of the total phenotypic diversity of fruits of each variety, without limiting themselves to just one single ideal fruit shape or size, or other traits. Similar processes have been described by Louette and Smale (2000) in maize in a nearby region, where farmers choose many maize ears within an ideotype of landraces, but with a range of morphological traits that identify this local landrace. There are important differences between this type of local seed selection and formal plant breeding methods, in the latter of which the variance of traits is required to be very limited (Louette and Smale 2000). A majority of farmers interviewed in this study, for example, considered uniformity as an important trait to selecting seeds, but did not mention either uniformity, shape, or weight as significant traits for selection of fruit types within their populations (Table 8). Selection and maintenance of landraces are more clearly defined in maize because of the number and definitions of landraces are very large compared to that for landraces of squash. In several regions of Mexico farmers sow some areas of their plots with improved maize varieties, which provokes obvious hybridization among landraces and improved maize varieties, but local farmers still persist in conserving their original maize local varieties (Aguirre et al. 2000; Louette et al. 1997; Perales 1998).

The exchange of seeds for planting among farmers could allow maintenance of the genetic diversity in these squash populations and consequently be useful as a method to increase the genetic basis of their squash germplasm. Use and benefits of increasing diversity by exchanging seeds for planting has been reported in maize by Aguirre (1999) and Louette et al. (1997) in Mexico, and in local varieties of cowpea in Africa by Uguru (1998). The belief that the same seed stock should not be planted over successive seasons, or that the landrace population must be "renewed" because its yield will decline, has been reported for others crops and regions (Wood and Lenné 1997; Louette and Smale 2000). But in the central part of Mexico in the states of Mexico, Morelos and Puebla in a similar study of cultural practice associated with local squash production, only 7% of the interviewed farmers had exchanged squash seeds for planting (Bautista-Anaya 2003).

Conclusion

The continuous contact between the two cultivated *Cucurbita* species and the wild relative, the presence of common pollinators, the actions that are carried out by local farmers may be useful to maintain the phenotypic diversity of squash landraces (Lira 1995; Lira and Montes 1992). However, we believe that because of the relatively large number of farmers that have stopped cultivation of squash, the elderly age of the squash farmers and the small amount of seeds sown, there exists the risk of loss of the diversity of these species. We predict a scenario of dramatic genetic erosion in the near future in *Cucurbita* at the region of this study. For these reasons we consider that it is very important to promote a program of on-farm conservation of *Cucurbita* genetic resources, where *ex situ* and *in situ* techniques will be applied in a complementary form.

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